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EUROPEAN EEL IN THE MEDITERRANEAN SEA

Outcomes of the GFCM Research programme

PREPARATION OF THIS DOCUMENT

This publication was prepared in the context of the GFCM Research programme on European eel: towards coordination of European eel stock management and recovery in the Mediterranean Sea funded by the European Union.

It reports the results of the research programme, which was carried out as a concerted action by project partners (research institutes or universities and relevant administrations of nine participating countries in the GFCM area of application) under the overall coordination of the GFCM Secretariat.

The publication consists of an introduction, 15 chapters and a conclusion. The introduction presents the general background and structure of the GFCM research programme. Chapters 1 through 7 present results related to eel habitat, eel recruitment and eel stocks in the Mediterranean. Chapters 8 through 11 cover results related to the analysis of European eel exploitation in the Mediterranean. Chapters 12 and 13 offer a review and analysis of management measures and frameworks in place in the Mediterranean and an assessment of alternative existing or potential measures under different management scenarios. Results related to the analysis of monitoring frameworks for European eel in place in the Mediterranean are given in Chapter 14, while the results of the revision of GFCM Data Collection Reference Framework (DCRF) Task VII-Eel are presented in Chapter 15. The conclusion chapter summarizes the the research programme’s main outcomes towards identifying possible management scenarios in the Mediterranean Sea according to the best data available

ABSTRACT

In line with the provisions of Recommendation GFCM/42/2018/1 on a multiannual management plan for European eel in the Mediterranean Sea and on the basis of the discussions held at the 2018 Working Group on the management of European eel, a GFCM research programme on European eel (*Anguilla anguilla*) was carried out from 2020 to 2022. Divided into five work packages, it was executed as a concerted action, joining the forces of ongoing research activities conducted by nine partners (Algeria, Albania, Egypt, France, Greece, Italy, Spain, Tunisia and Türkiye), including research institutes, universities and relevant administrations of interested countries. The main aim of the research programme was to devise a coordinated framework for the collection and analysis of data, as well as for the assessment and management of the resource, with a view to laying the groundwork for a long-term, multiannual management plan for European eel in the Mediterranean. The research programme enabled the collection of data and information on management and protection measures for stock recovery at both the national and local levels, as well as on eel fisheries and eel habitats and the biological and ecological features of local eel stocks. Meanwhile, it also established a common framework for assessing European eel stocks at different scales in the Mediterranean. This publication compiles and presents the results of the analyses carried out, together with the data collected, within the framework of this research programme, and it provides the scientific basis for advice on fishery management measures towards the recovery of eel populations, using the evidence collected as a foundation for action tailored to the Mediterranean scenario.

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PREFACE

European eel (*Anguilla anguilla*, Linnaeus 1758) is a temperate, catadromous species with a wide distribution range that includes coastal, transitional and inland waters of Europe and the wider Mediterranean region. The species is migratory and displays a unique and still not fully understood life cycle, with spawning assumed to take place in the Sargasso Sea (Northwest Atlantic), after which oceanic larvae (*leptocephali*) are transported by currents across the Atlantic Ocean to the coasts of the species' distribution range, where they metamorphose into glass eels that recruit to continental waters. Here they remain during their growing phase (yellow eels) until they attain a pre-reproductive stage (silver eels) after several years. Despite an extreme plasticity in phenotypic traits, as well as physiological and ecological adaptations, European eel populations have been affected by numerous natural or human-induced pressures that have impacted their habitats. In recent decades, this species has undergone a dramatic decline in abundance throughout its global distribution range due to several causes, including fishing pressure. The severity of this decline has been formally recognized by the International Council for the Exploration of the Sea (ICES), which estimated in 2017 that glass eel recruitment had dropped to less than ten percent of its 1960–1979 average, intermittently dropping to lower than one percent in the North Sea.

This situation has been interpreted as resulting from the combined effects of a number of natural causes and anthropogenic pressures impacting European eel, including oceanic changes, overfishing, habitat degradation and habitat loss, as well as contamination from increased pollutant loads and widespread infection by the swim-bladder parasite *Anguilliculoides crassus* and other pathogens. All these threats are likely to have been acting synergistically on multiple life-history stages, causing a general decrease in the spawning stock, as well as influencing qualitative aspects of the escaping breeders, which may potentially affect the migratory and reproductive capacity of eel populations.

The International Union for Conservation of Nature (IUCN) classified European eel as critically endangered in 2008, further confirming this status in 2010 and 2014. Meanwhile, debate has long continued on the measures that need to be undertaken to protect the global eel stock and ensure its recovery. Within the European Union, this discussion has provided the grounds for the implementation of a specific regulatory and management framework (Regulation EC 1100/2007, Council of the European Union, 2007). However, the need to address the issue of European eel recovery across the Mediterranean basin has been clearly highlighted, mostly to ensure that efforts towards this objective are put forward by all riparian countries.

In this context, the GFCM has been a key player in ensuring that data gaps are filled and that harmonized actions towards stock recovery and the conservation of this species are made by all Mediterranean countries exploiting European eel. Since 2013, the GFCM has acted to establish a Mediterranean framework and eel expert network working in these directions. Joint efforts have led, *inter alia*, to the adoption of a first decision addressing the management of European eel fisheries in 2019 and to the establishment of an ad hoc research programme in 2020, which concluded in February 2022 with clear indications for the GFCM Scientific Advisory Committee on Fisheries (SAC) regarding potential ways to ensure the recovery of Mediterranean European eel local stocks with the aim of maintaining a sustainable fishery in the future.

European eel has significant ecological and cultural importance in the Mediterranean region, being strongly associated with artisanal fisheries and the traditional management of Mediterranean coastal lagoons. Therefore, its decline also risks the survival of these traditional activities and the cultural heritage connected to them. Since the decline is linked to environmental problems affecting the habitats where eels spend part of their life cycle, intervening with measures to protect eels will also mean contributing to the restoration and recovery of these habitats. Recent advances have been made on issues of key interest, such as spawning grounds, the genetic structure of the eel stock, the biology of the ocean larval phase and evidence of silver eels crossing the Gibraltar Strait into the Atlantic Ocean. These results confirmed and clarified some basic questions surrounding eel populations in the Mediterranean, including Atlantic reproduction in the Sargasso Sea, the genetic structure and panmixia, emigration of spawners from the Mediterranean and the transport of larvae from the Atlantic Ocean across the Mediterranean. Several studies have also focused on local stocks throughout the Mediterranean, contributing to knowledge on eel biology in its continental stages (e.g. growth, differentiation, reproductive biology, population structure, ecology), as well as papers on recruitment, spawner quality and assessment of local stocks. This progress has provided the foundations for the work presented in this publication, adding to the knowledge base on European eel in the Mediterranean area, as well as hopefully contributing to global knowledge of the species.

Indeed, advances are being made to ensure that this iconic species continues to inhabit Mediterranean marine, coastal and fresh waters, and the GFCM will remain committed to keeping this species on its agenda, at least until fisheries are no longer considered a threat to the conservation of European eel.

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DATA USE AND AUTHORIZATIONS

Data produced and used by the project and published in this document (including tables and annexes) are not useable by third parties without specific authorization. A period of data embargo of three years (2023–2026) has been established from the date of publication, in order to allow the scientific partners involved in the research programme to finalize publications using its data and results.

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ACRONYMS AND GLOSSARY

ACRONYMS

ACRONYM	DEFINITION
AA	Administrative Agreement, typically the recurring agreement between ICES and the EC
AC	Absolute correspondence to axis inertia of a variable (in a correspondence analysis)
ACFM (ICES)	Advisory Committee on Fisheries Management
ACOM (ICES)	Advisory Committee on Management
ADGEEL	Advice drafting group on eel, for ICES
AIC	Akaike Information Criterion
AngHV-1	Anguillid herpes virus 1
ANCOVA	Analysis of Covariance
ANOVA	Analysis of Variance
BERT	Bayesian Eel Recruitment Trend model
BIC	Bayesian Information Criterion
CCM	Catchment Characterisation and Modelling
CITES	Convention on International Trade in Endangered Species of Flora and Fauna
CMS	Convention on the Conservation of Migratory Species of Wild Animals
COMM	European Commission, also EC is used.
CPUE	Catch per unit of effort
CR	Country Report
C&R	Catch and release
CUSUM	Cumulative Sum Control Chart
DAERA	Department of Agriculture, Environment and Rural Affairs (N. Ireland)
DBEEL	Database on Eel (from EU POSE project)
DCF	Data Collection Framework of the European Union
DEMCAM	Demographic Camargue Model
DG-MARE	Directorate-General for Maritime Affairs and Fisheries, European Commission
DLS	Data-Limited Stocks
EC	European Commission, also COMM is used.
e-DNA	Environmental DNA
EDA	Eel Density Analysis (model, France)
EIFAAC	European Inland Fisheries & Aquaculture Advisory Commission
EIFAC	European Inland Fisheries Advisory Commission – became EIFAAC in 2008
EMP	Eel Managment Plan
EMU	Eel Management Unit
EFF	European Fisheries Fund
EQD	Eel Quality Database
EQI*cont*	ICES Eel Quality Index for Contaminants

ACRONYM	DEFINITION
EQI*dis*	ICES Eel Quality Index for Diseases
EQS	Environmental Quality Standard of the Directive 2008/105/EC on environmental quality standards in the field of water policy
EROD	Ethoxyresorufin-O-deethylase
ESAM	Eel Stock Assessment Model
EU	European Union
EU MAP	The European Multi-Annual Plan, previously the DCF
EVEX	Eel Virus European X
FAO	Food and Agriculture Organisation
FEAP	The Federation of European Aquaculture Producers
GAM	Generalised Additive Model
GEM	German Eel Model
GFCM	General Fisheries Commission of the Mediterranean
GIS	Geographic Information Systems
GLM	Generalised Linear Model
GlobAng	French Model of Eel Population Dynamics
GST	Glutathione-S-transferase
HPS	Hydropower Station
ICES	International Council for the Exploration of the Sea
IMESE	Irish model for estimating silver eel escapement
IUCN	International Union for the Conservation of Nature
IUU	Illegal, Unreported and Unregulated fisheries
LAM	Lifetime anthropogenic mortalities
LHT	Life History Trait
LVPA	Length-based Virtual Population Assessment
L50	L50 = the length (L) at which half (50%) of a fish species may be able to spawn
MS	Member State, typically used in reference to EU Member States but not only
MSY	Maximum Sustainable Yield
NAO	North Atlantic Oscillation
NA	Not applicable
NC	Not collected, code to explain an empty data value cell
ND	No data, code to explain an empty data value cell
NDF	Non-detriment Finding
NIS	Non-indigenous species
NP	Not pertinent, code to explain an empty data value cell
NR	Not recorded, code to explain an empty data value cell
POSE	Pilot projects to estimate potential and actual escapement of silver eel (EU project)
POP	Persistent Organic Pollutants
RBD	River Basin District, typically as defined according to the EU Water Framework Directive

ACRONYM	DEFINITION
RGMAREEL	Workshop on Fisheries Related Impacts on Silver eels 2017
RG-TEMPP	Review of the Trans-border management plan for European eel, *Anguilla anguilla*, in the Polish-Russian zone of the Pregola River basin and Vistula Lagoon
RS_EMP	Review Service – Evaluation of Eel management Plans 2010
SAC	The GFCM Scientific and Advisory Committee on Fisheries
SCICOM	The Science Committee of ICES
SDI	Swimbladder Degenerative Index
SGAESAW	Study Group on anguillid eels in saline waters 2009
SGIPEE	Study Group on International Post-Evaluation on Eels 2010, 2011
SLIME	Restoration the European Eel population; pilot studies for a scientific framework in support of sustainable management (EU project)
SMEP II	Scenario-based Model for Eel Populations, vII (model applied in England and Wales, UK)
SPR	Estimate of spawner production per recruiting individual.
SQL	Special purpose programming language for managing data
SRG	Scientific Review Group of the European Commission
SSB	Spawning–Stock Biomass
STECF	Scientific, Technical and Economic Committee for Fisheries, European Commission
ToR	Terms of Reference
VPA	Virtual Population Analysis
WG	Working Group
WFD	Water Framework Directive, European Directive
WGEEL	Joint EIFAAC/ICES/GFCM Working Group on Eels
WKBALTEEL	Workshop on Baltic Eel 2010
WKBECEEL	Working Group on Biological Effects of Contaminants in Eel 2016
WKEELCITES	Workshop on Eel and CITES 2015
WKEELDATA	Workshop on Designing an Eel Data Call 2017
WKEELDATA2	Second Workshop on designing an Eel Data Call 2019
WKEELMIGRATION	Workshop on the Temporal Migration patterns of European Eels 2020
WKEMP	Workshop on Evaluating Management Plans – 2018
WKEPEMP	The Workshop on Evaluating Progress with Eel Management Plans 2013
WKESDCF	Workshop on Eels and Salmon in the Data Collection Framework 2012
WKFEA	Workshop on the future of eel advice 2021
WKLIFE	Workshop on the Development of Assessments based on LIFE-history traits and Exploitation Characteristics
WKPGMEQ	Workshop of a Planning Group on the Monitoring of Eel Quality under the subject “Development of standardized and harmonized protocols for the estimation of eel quality”
WKSTOCKEEL	Workshop on Eel Stocking 2016
WKTEEL	Workshop on Tools for Eel 2018
WGRFS	Working Group on Recreational Fisheries Surveys
YFS1	Young Fish Survey: North Sea Survey location

ACRONYM	DEFINITION
IYFS	International Young Fish Survey

GLOSSARY

TERM	DEFINITION
Anthropogenic	Caused by humans.
Assisted migration	The practice of trapping and transporting juvenile eel within the same river catchment to assist their upstream migration at difficult or impassable barriers, without significantly altering the production potential (B_{best}) of the catchment
Bootlace, fingerling	Intermediate sized eels, approx. 10–25 cm in length. These terms are most often used in relation to restocking. The exact size of the eels may vary considerably. Thus, it is a confusing term.
Carrying Capacity	The average maximum biomass of eel that can be supported by a given habitat.
Catch	The WGEEL uses the term catch(es) to mean fish that are caught but not necessarily landed. See landings below
Depensation	The effect on a population when a decrease in spawners leads to a faster decline in the number of offspring than in the number of adults.
Eel River Basin or Eel Management Unit	"Member States shall identify and define the individual river basins lying within their national territory that constitute natural habitats for the European eel (eel river basins) which may include maritime waters. If appropriate justification is provided, a Member State may designate the whole of its national territory or an existing regional administrative unit as one eel river basin. In defining eel river basins, Member States shall have the maximum possible regard for the administrative arrangements referred to in Article 3 of Directive 2000/60/EC [i.e. River Basin Districts of the Water Framework Directive]." EC No. 1100/2007.
Elver	Young eel, in its first year following recruitment from the ocean. The elver stage is sometimes considered to exclude the glass eel stage, but not by everyone. To avoid confusion, pigmented 0+cohort age eel are included in the glass eel term.
Escapement	The amount of eel that leaves (escapes) a water body, after taking account of all natural and anthropogenic losses. Most commonly used with reference to silver eel – silver eel escapement.
Glass eel	Young, unpigmented eel, recruiting from the sea into continental waters. WGEEL consider the glass eel term to include all recruits of the 0+ cohort age group, including some pigmented eel.
Index river	To be defined
Landings	The WGEEL uses the term Landings to mean fish that are brought ashore.

TERM	DEFINITION
Leptocephalus	Flat and transparent marine larval stage of eel, on migration from spawning ground to continental waters, between pre-Leptocephalus and metamorphosis to glass eel
Lifestage	Defined stage in the lifecycle of eel, whether leptocephalus, glass eel, yellow eel, or silver eel.
Limit reference point	A Limit Reference Point indicates a state of a fishery and/or a resource which is considered to be undesirable and which management action should avoid.
Non-detriment finding (NDF)	In relation to CITES, the competent scientific authority has advised in writing that the capture or collection of the specimens in the wild or their export will not have a harmful effect on the conservation status of the species or on the extent of the territory occupied by the relevant population of the species.
Ongrown eels	Eels that are grown in culture facilities for some time before being restocked. Whether the time is to meet quarantine requirements, for the receiving environment conditions to be suitable, or as part of the culture and grading purpose.
Pre-leptocephalus	First larval stage of eel, between hatching from ovum and leptocephalus
Production	The amount of fish produced from a waterbody. Sometimes referred to for silver eel in terms as escapement + anthropogenic losses, or production – anthropogenic losses = escapement.
River Basin District (RBD)	The area of land and sea, made up of one or more neighbouring river basins together with their associated surface and groundwaters, transitional and coastal waters, which is identified under Article 3(1) of the Water Framework Directive as the main unit for management of river basins. The term is used in relation to the EU Water Framework Directive.
Restocking	The practice of adding fish [eels] to a waterbody from another source, to supplement existing populations or to create a population where none exists
Silver eel	Migratory phase following the yellow eel phase. Eel in this phase are characterized by darkened back, silvery belly with a clearly contrasting black lateral line, enlarged eyes. Silver eel undertake downstream migration towards the sea, and subsequently westwards. This phase mainly occurs in the second half of calendar years, although some are observed throughout winter and following spring.
Target reference point	A Target Reference Point indicates to a state of fishing and/or a resource which is considered to be desirable and at which management action, whether during development or stock rebuilding, should aim. FAO, 1995.
To silver (silvering)	Silvering is a requirement for downstream migration and reproduction. It marks the end of the growth phase and the onset of sexual maturation. This true metamorphosis involves a number of different physiological functions (osmoregulatory, reproductive), which prepare the eel for the long return trip to the Sargasso Sea. Unlike smoltification in salmonids, silvering of eels is largely unpredictable. It occurs at various ages (females: 4 – 20 years; males 2

TERM	DEFINITION
	– 15 years) and sizes (body length of females: 50 – 100 cm; males: 35 – 46 cm) (Tesch, 2003).
Trap and Transport	Capturing downstream migrating silver eel for transportation around hydropower turbines
Yellow eel	Life-stage resident in continental waters. Often defined as a sedentary phase, but migration within and between rivers, and to and from coastal waters occurs and therefore includes young pigmented eels (‘elvers’ and bootlace).

STOCK REFERENCE POINTS AND DATA CALL TERMS

TERM	DEFINITION
Age	The age of eel in years., with part years as plus growth (e.g, 0+, 1+), starting at recruitment to coastal waters. Glass eel are defined as 0+.
Aggregate habitat (AL)	Data Call term for aggregrated habitats where data is commined across habitat categories
A_{lim}	Limit anthropogenic mortality: Anthropogenic mortality, above which the capacity of self-renewal of the stock is considered to be endangered and conservation measures are requested (Cadima, 2003).
A_{pa}	Precautionary anthropogenic mortality: Anthropogenic mortality, above which the capacity of self-renewal of the stock is considered to be endangered, taking into consideration the uncertainty in the estimate of the current stock status.
Aquaculture production	The biomass of eel harvested in aquaculture during a time frame; e.g., a year.
Baltic region	The countries bordering the Baltic Sea; sometimes other countries in the catchment are also included.
bio_age	mean age
bio_g_in_gy	proportion (in %) of glass eel [100 for only glass eel ; 0 for only yellow eel ; the proportion if mix of glass and yellow eel]
bio_length	mean length in mm
bio_sex_ratio	sex ratio express as a proportion of female; between 0 (all males) and 100 (all females)
bio_year	year during which biological samples where collected
bio_weight	mean individual weight in g
$B_{current}$ or B_{curr}	The Current escapement biomass: The amount of silver eel biomass that currently escapes to the sea to spawn, corressponding to the assessment year.
B_{best}	The amount of silver eel biomass that would have existed if no anthropogenic influences had impacted the current stock, included re-stocking practices, hence only natural mortality operating on stock. The Best achievable escapement biomass under present conditions: escapement biomass corresponding to recent natural recruitment that would have survived if there was only natural mortality and no restocking, corresponding to the assessment year.

TERM	DEFINITION
B_0	The amount of silver eel biomass that would have existed if no anthropogenic influences had impacted the stock. Reference point for the theoretical maximum quantity of silver eel expressed as biomass that would have escaped from a defined eel producing area, in the absence of any anthropogenic impacts.
B_{lim}	Limit spawner escapement biomass, below which the capacity of self-renewal of the stock is considered to be endangered and conservation measures are requested (Cadima, 2003).
B_{MSY}	Spawning stock biomass (SSB) that is associated with the Maximum Sustainable Yield.
$B_{MSY\text{-}trigger}$	Value of spawning–stock biomass (SSB) which triggers a specific management action, in particular: triggering a lower limit for mortality to achieve recovery of the stock.
B_{pa}	Precautionary spawner escapement biomass: The spawner escapement biomass, below which the capacity of self-renewal of the stock is considered to be endangered, taking into consideration the uncertainty in the estimate of the current stock status.
Commercial Fisheries	Fisheries with sale of catch for commercial gain
Coastal waters	WFD coastal waters
das_comment	Comment (including comments about data quality for this year)
das_effort	Effort (if used)
das_value	Value
das_year	Year
Eel mannagement unit (EMU)	Eel management unit defined in an Eel Management plan under the Eel Regulation 1100/2007.
F	Fishing mortality rate
FAO areas	See http://www.fao.org/fishery/area/search/en
F_{lim}	F_{lim} is the fishing mortality which in the long term will result in an average stock size at B_{lim}.
F_{pa}	ICES applies a precautionary buffer F_{pa} to avoid that true fishing mortality is above F_{lim}.
F-rec	recreational fishing mortality, per reporting year, in kg
Fresh waters	Waters with zero salinity
F_{MSY}	F_{MSY} is estimated as the fishing mortality with a given fishing pattern and current environmental conditions that gives the long-term maximum yield.
G	Code in Data Call for data comprising Glass eel only as defined in Glossary
G+Y	Code in Data Call for data comprising a Glass eel with yellow eel mix
GEE-n	Glass eel equivalents in numbers – the quantity of eel expressed as equivalent number of glass eel. Method provided in ICES (2013) report p103.
Glass eel recruitment series	Time series enumerating glass eel recruiting from the sea into continental waters.

TERM	DEFINITION
GLM	Generalized linear model (used by ICES to predict and fill in gaps in the data)
Habitat	Waters occupied by eel, whether fresh, transitional, coastal or marine
ICES statistical rectangles	See http://gis.ices.dk/sf/index.html?widget=StatRec
Inland waters	Fresh waters, not under the jurisdiction of Marine fisheries management (i.e. the CFP).
Landings from fisheries	Commercial landings include any eel taken from the water and landed on the market. Recreational landings include any eel taken from the water by recreational fisheries. Other landings include eel caught for assisted migration, translocation,
Length in mm	Total length measured from tip of nose to tip of tail (TL)
Longitude	x (longitude) EPSG:4326. WGS 84 (Google it)
Latitude	y (latitude) EPSG:4326. WGS 84 (Google it)
M	Natural Mortality
North Sea	For the purposes of ICES eel management, taken as ICES sea areas IV $_a$, IV $_b$, IV $_c$ and inflowing fresh water systems
Marine waters	(Abbreviated MO) Open marine waters
q_aqua_kg	Aquaculture production (kg) in reporting year
q_aqua_n	Aquaculture production (number of eel) in reportng year
Fisheries - Recreational	Recreational (= non-commercial) fishing is the capture or attempted capture of living aquatic resources mainly for leisure and/or personal consumption.
Releases	Eel released to the wild after capture
R_{target}	The Geometric Mean of observed recruitment between 1960 and 1979, periods in which the stock was considered healthy.
R(s)	The amount of eel (<20 cm) restocked into national waters annually
S	Code in Data Call for data comprising Silver eel
Sea region (division)	ICES Sea area statisitical rectangle. Where required for freshwater eel habitats, is the sea area the River basin drains to.
SEE–n	Silver eel equivalents in numbers – the quantity of eel expressed as equivalent number of silver eel
SEE_com	Commercial fishery silver eel equivalents
SEE rec	Recreational fishery silver eel equivalents)
SEE_hydro	Mortility in hydropower, pumps and water intakes etc expressed as Silver eel equivalents
SEE_habitat	Silver eel equivalents relating to anthropogenic influences on habitat (quantity/quality)
SEE_release	Silver eel equivalents relating to release activity
SEE_other	Silver eel equivalents from `other` sources
Silver eel abundance series	Time series of abundance of silver eel determined by consistent regular count or survey (usually by capturing migrating silver eel)

TERM	DEFINITION
ser_nameshort	short name of the recruitment series, this must be 4 letters + stage name, e.g. VilG, LiffGY, FremS, the first letter is capitalised and the stage name too.
ser_namelong	long name of the recuitment series eg `Vilaine estuary` for the Vilaine;
ser_typ_id	type of series 1= recruitment series, 2 = yellow eel standing stock series, 3 silver eel series
ser_effort_uni_code	unit used for effort, it is different from the unit used in the series, for instance some of the Dutch series rely on the number hauls made to collect the glass eel to qualify the series, see units sheet.
ser_comment	This comment should at least include a short description of the methods, give an idea on the size of the eels and the proportion of glass eel, whether it is mixed (e.g. glass and yellow) or not, possible biases (e.g. by restocking) and a mention if the series is special in any way (e.g. very old/long) Note that this text will be displayed as a description of the series in the shiny app, thus consider the "readability".
ser_uni_code	Units used in the series, see tr_units_uni sheet
ser_lfs_code	Lifestage see tr_lifestage_lfs sheet
ser_hty_code	Habitat type see tr_habitattype_hty (F=Freshwater, MO=Marine Open,T=transitional, AL=aggregate...)
ser_locationdescription	This should provide a description of the site, e.g. if ist far inland, in the middle of a river, near a dam etc. Also please specify the adjectant marine region (Baltic, North Sea) etc. (e.g. "Bresle river trap 3 km from the sea" or IYFS/IBTS sampling in the Skagerrak-Kattegat" Note that this text will be displayed as a description of the site in the shiny app, thus consier the "readability".
ser_emu_nameshort	The codes of the emu (emu_nameshort) in sheet tr_emu_emu. In case you provide data for each EMU separately then you don't need to fill in for AL and vice versa
ser_cou_code	The cou_code in the tr_country_cou table
ser_area_division	Fao code of sea region (division level) see tr_fao_area (column division)(https://github.com/ices-eg/WGEEL/wiki). These codes are for use only in the case of Coastal and Marine Open waters – otherwise you can leave it blank. ICES statistical rectangles (http://gis.ices.dk/sf/index.html?widget=StatRec) and FAO areas map (http://www.fao.org/fishery/area/search/en)
ser_tblcodeid	This should refer to the id of the series once inserted in ICES station table, currently void : ignore
ser_x	x (longitude) EPSG:4326. WGS 84
ser_y	y (latitude) EPSG:4326. WGS 84
ser_sam_id	The sampling type corresponds to trap partial, trap total, see tr_samplingtype_sam (sam_id)
Silver eel abundance series	Time series of abundance of silver eel determined by consistent regular count or survey (usually by capturing migrating silver eel)

TERM	DEFINITION
Skagerrak-Kattegat	For the purposes of ICES eel management, taken as ICES Sea areas III_b , III_c and inflowing fresh water systems
SPR	Spawner per recruit: estimate of spawner production per recruiting individual.
%SPR	Ratio of SPR as currently observed to SPR of the pristine stock, expressed in percentage. %SPR is also known as Spawner Potential Ratio.
Standing stock	The total stock of eel present in a waterbody at a point in time, expressed as a number of individuals or total biomass
sumA	total Anthropogenic mortality, per reporting year , in kg
sumF	total Fishing Mortality per reporting year, in kg
sumH	total non fishing Anthropogenic mortality, per reporting year in kg
sumF_com	Mortality due to commercial fishery, summed over age groups in the stock.
SumF_rec	Mortality due to recreational fishery, summed over age groups in the stock .
SumH_hydro	Mortality due to hydropower (plus water intakes etc) summed over the age groups in the stock (rate)
SumH_habitat	Mortality due to anthropogenic influence on habitat (quality/qauntity) summed over the age groups in the stock (rate)
SumH_other	Mortality due to other anthropogenic influence summed over the age groups in the stock (rate)
SumH_release	Mortality due to release summed over the age groups in the stock (rate: negative rate indicates positive effect of release)
Transitional waters	WFD transitional waters, implies reduced salinity
Transport/relocation operations	When eels have been collected somewhere in traps and transported to other places where they appear as "release" for the purposes of data recording
ΣF	The fishing mortality rate, summed over the age-groups in the stock.
ΣH	The anthropogenic mortality rate outside the fishery, summed over the age-groups in the stock.
ΣA	The sum of anthropogenic mortalities, i.e. $\Sigma A = \Sigma F + \Sigma H$.
Y	Code in Data Call for data comprising yellow eel only
Yellow eel abundance series	Time series of abundance of yellow eel determined by consistent regular count or survey
Yellow eel recruitment series	Time series enumerating yellow eel where this life stage is first observed at a site or is the stage at which eel enter freshwaters
Yellow eel standing stock series	Time series of abundance of yellow eel determined by consistent regular count or survey
"3Bs & ΣA"	Refers to the 3 biomass indicators (B_0, B_{best} and $B_{current}$) and anthropogenic mortality rate (ΣA).

TERM	DEFINITION
40% EU Target	From the Eel regulation (1100/2007): "The objective of each Eel Management Plan shall be to reduce anthropogenic mortalities so as to permit with high probability the escapement to the sea of at least 40% of the silver eel biomass relative to the best estimate of escapement that **would have existed if no** anthropogenic influences had impacted the stock". The WGEEL takes the EU target to be equivalent to a reference limit, rather than a target.

INTRODUCTION

At a transversal workshop on European eel (Salammbô, Tunisia, 23–25 September 2010), the General Fisheries Commission for the Mediterranean (GFCM) recommended developing management plans for European eel covering all subregions of the Mediterranean, as well as engaging Mediterranean countries in a Joint Working Group on Eels. The creation of a Joint ICES/EIFAAC/GFCM Working Group on European Eel was subsequently approved at the fourteenth session of the Scientific Advisory Committee on Fisheries (SAC) and the thirty-sixth session of the GFCM in 2012. At its thirty-seventh session in 2013, the GFCM agreed to support a European eel pilot action to contribute towards the participation of Mediterranean countries in actions supporting European eel at a stock-wide level.

At the forty-first session of the GFCM in 2017, the status of European eel was recognized as critical and the need for the development of a regional management plan was underlined. In this context, in 2018 the European Union, jointly with Tunisia, expressed the intention of proposing a management plan for European eel based on the conclusions of a dedicated working group on European eel.

Following a GFCM workshop on the management of European eel in 2018, during which technical elements for the management of European eel in the Mediterranean Sea were drafted, the forty-second session of the GFCM adopted Recommendation GFCM/42/2018/1 on a multiannual management plan for European eel in the Mediterranean Sea, based on a joint proposal from Algeria, the European Union and Tunisia. The multiannual management plan, applicable to all habitats where fishing activities occur in the Mediterranean Sea (freshwater, marine and transitional waters), was designed in a stepwise manner to provide and maintain high, long-term yields and to guarantee a low risk of stock collapse while maintaining sustainable and relatively stable fisheries.

During this transitional period, efforts were to be made towards enhancing data collection, including the use of past data dating as far back as possible, in the areas where European eel is known or likely to occur in countries'espective waters. Importantly, the recommendation established the need to design and launch a research programme in 2019 on European eel in the Mediterranean Sea. Based on the results of the research programme and of a dedicated working group on the management of European eel, in 2023 the SAC will advise on appropriate measures to achieve its long-term objectives with the aim of adopting long-term management measures in the same year.

Structure of the Research Programme

Partners and goals

Against this background, the "Research programme on European eel: towards coordination of European eel stock management and recovery in the Mediterranean" was executed as a concerted action joining the forces of ongoing research activities and expertise sharing over a period of around two years, from 2020 to 2022.

The RP involved nine partners, including scientists and national administration focal points from Albania, Algeria, Egypt, France, Greece, Italy, Spain, Tunisia and Türkiye (Table 1), as well as an external advisory board, relevant FAO regional offices and the GFCM Secretariat.

The RP had four specific goals, corresponding to four main work packages, within which research teams shared methodologies, data and expertise, as follows:

- Identify and appraise management and protection measures for the recovery of the eel stock relevant to the Mediterranean.
- Establish a common framework for long-term monitoring of eel in the Mediterranean.
- Collect and update data concerning eel stock and eel habitats in the Mediterranean Region.

- Establish a common framework for European eel stock assessment and appraise potential management scenarios in the Mediterranean.

The workplan built upon a strong coordination framework, also relying on international and national networking, and was implemented as five work packages, covering training and capacity-building (Figure 1).

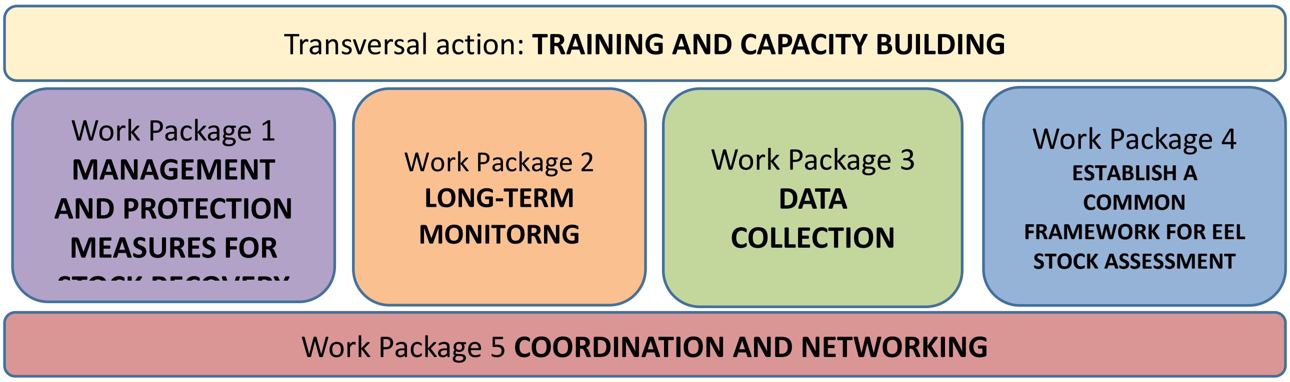

Figure 1. The five work packages included in the "Research programme on European eel: towards coordination of European eel stock management and recovery in the Mediterranean".

Table 1. Scientific partners and administration focal points and their roles in the GFCM "Research programme on European eel: towards coordination of European eel stock management and recovery in the Mediterranean".

No.	SCIENTIFIC PARTNERS			Country	Administration focal points	
	Institute	**Researcher(s)**	**Role**		**Administration**	**Person(s)**
1	Agricultural University of Tirana	Edmond HALA	• WP1: habitat management database (1.2.3) and mapping (1.2.4), data processing and drafting of relevant documents (1.3.2) • WP3: eel habitat database management (3.2.3) • All WPs: data provision to the greatest extent possible	Albania	Fisheries Directorate, Ministry of Agriculture and Rural Development	Arian PALLUQI Marco KULE
2	Centre national de recherche et de développement de la pêche et de l'aquaculture	Fateh CHEBEL Lamia BENDJEDID (Junior Researcher) Samir ROUIDI (Junior Researcher)	• WP2: database design and management (2.2.1, 2.2.2), data processing and drafting of documents (2.2.3) • All WPs: data provision to the greatest extent possible	Algeria	Direction Générale de la Pêche, Ministère de la Pêche et des Productions Halieutiques	Naciba LABIDI
3	National Institute of Oceanography and Fisheries	Azza EL GANAINY Tamer BITAR (Junior Researcher)	• WP3: eel local stocks database design and management (3.3.3) • WP5: coordination of transversal action on training and capacity building • All WPs: data provision to the greatest extent possible	Egypt	General Authority for Fish Resources Development	Atif SALAH MEGAHED OSMAN
4	Université de Perpignan	Elsa AMILHAT Noémie REGLI (Junior Researcher)	• WP2: WP Leader • WP2: database design and management (2.2.1, 2.2.2), data processing and drafting of documents (2.2.3) • All WPs: data provision to the greatest extent possible	France	Direction des pêches maritimes et de l'aquaculture, Ministère de l'agriculture et de l'alimentation	Marianna MONNEAU
5	Hellenic Fisheries Research Institute	Argyrios SAPOUNIDIS Eirini PAPANIKOLAOU	• Project: scientific coordinator • WP1: WP Leader	Greece	Ministry of Rural Development & Food, Directorate General of Fisheries,	Georgia PAPAIOANNOU

		(Junior Researcher)	• WP1: coordination of database management (1.3.1), data processing and drafting of relevant documents (1.3.2) • All WPs: data provision to the greatest extent possible		Directorate of Aquaculture	
6	Dipartimento di Biologia, Università degli Studi di Roma Tor Vergata	Chiara LEONE Irene PRISCO (Junior Researcher)	• WP3: WP Co-leader • WP3: management of database of eel fisheries (3.1.5), habitat (3.2.3), local stocks (3.3.3); support to design and management of databases (3.5.1); coordination of interactions between WPs (3.5.2) • All WPs: data provision to the greatest extent possible	Italy	Masaf, Directorate General of Maritime Fisheries and Aquaculture	Lorenzo Giovanni MAGNOLO
7	Universidad de Córdoba	Carlos FERNÁNDEZ DELGADO Mercedes HERRERA (Junior Researcher)	• WP3: WP Co-leader • WP3: design and management of habitat database (3.2.3); support to design and management of databases (3.5.1); coordination of interactions between WPs (3.5.2) • All WPs: data provision to the greatest extent possible	Spain	Direccion General de Pesca Sostenible, Secretaría General de Pesca – Ministerio de Agricultura, Pesca y Alimentación	Encarnacion BENITO REVUELTA
8	Institut National des Sciences et Technologies de la Mer	Rachid TOUJANI Marouene BDIOUI Emna DERIOUICHE (Junior Researcher)	• WP1: management database design and management (1.1.4), data processing and drafting of relevant documents (1.3.2) • WP3: eel trade database design and management (3.4.2) • All WPs: data provision to the greatest extent possible	Tunisia	Ministry of Agriculture, Fishing and Water resources instead of Ministry of Agriculture, Water resources and Fishing	Dorra BACCOUCHE Asma BNINA
9	Çanakkale Onsekiz Mart University	Şükran Yalçın ÖZDILEK Nurbanu PARTAL (Junior Researcher)	• WP1: help WP Leader to coordinate the design and management of databases (1.3.1) and the processing of data and drafting of preliminary documents (1.3.2)	Türkiye	Ministry of Agriculture and Forestry, DG of Fisheries and Aquaculture	Esra Fatma DENİZCİ ÇAKMAK Onur HASALTUNTAŞ

			• WP3: eel local stocks database management (3.3.3) • All WPs: data provision to the greatest extent possible			
Advisory Board (external advisers)		• Reinhold HANEL (Director of the Thünen Institute, Germany) • Giulio DE LEO (Hopkins Marine Station, Stanford University, USA)				
GFCM Secretariat		• Elisabetta Betulla MORELLO • Aurora NASTASI • Eleonora CICCOTTI • Fabrizio CAPOCCIONI				
FAO TUNISIA		Valerio CRESPI				

The following sections cover the aims and specific tasks of each WP, taking into account the final structure and definitive execution of the RP. The objectives of the WPs did not change substantially from the original project proposal and concept note, but the final configuration of the work, the specific tasks within each WP and their relative importance were progressively shaped and adapted for organizational purposes as the RP was implemented. This continual evolution also took into account operational limits imposed by the COVID-19 pandemic, including limited mobility in the initial, but fundamental, phase of data collection and opportunities for consultation between the competent offices and agencies on various topics.

***Work Package 1: Review of existing management and protection measures for European* eel stock recovery**

This work package (WP1) focused on listing and qualitatively analysing current and prospective management and protection measures, based on the feasibility of their application and effectiveness at different spatial scales within the Mediterranean region (such as sites, habitats and Management Units). This latter issue also took into account local management strategies (including fisheries measures, Ramsar sites and protected sites and the involvement of stakeholders), as well as local governance frameworks (management plans and legislation), to provide context for the potential role of any measure or set of measures that might be proposed to achieve European eel stock recovery in the Mediterranean area.

WP1 aimed to address:

- measures for commercial and recreational fisheries;
- measures on habitat loss or migration (upstream and downstream) impairment by damming;
- measures dealing with habitat restoration, improvement and protection; and
- measures to sustain local stocks (including restocking and assisted upstream migration, trap and transport) or to enhance escapement (silver eel release).

Against this background and with the aim of establishing a regional coordination framework for the implementation of management measures for eel stock recovery in the Mediterranean region, the specific aims of WP1 were as follows:

- List and critically examine measures within the different management and protection categories, as well as address their present modes of implementation and their relative effectiveness.
- Design, compile and manage databases containing all this information.
- Process all information, including through the use of mapping tools, towards drafting a document addressing the present and prospective framework for management, covering first, the feasibility and applicability of different measures in Mediterranean eel habitats, taking into account current management frameworks, eel habitat typologies and spatial application scales, and second, the preliminary definition of a set of priority measures to be implemented at a range of levels, from local (sites), to the level of specific Management Units and the regional scale.

WP1 was divided into several tasks and subtasks. It also relied on and interacted with WP3 (Table 2).

Table 2. WP1 tasks and subtasks.

WORK PACKAGE	TASK		Task description
WP1	Task 1.1 Eel management frameworks	Task 1.1.1	Design and management of databases
		Task 1.1.2	Listing of management frameworks currently in place or in preparation for eel management by country
		Task 1.1.3	Listing of management measures currently in place for eel by country
		Task 1.1.4	Listing of management measures envisaged for eel by country
	Task 1.2 Habitat management frameworks	Task 1.2.1	Design and management of databases
		Task 1.2.2	Listing of habitat protection and management frameworks currently in place by country
		Task 1.2.3	Listing of habitat protection and management measures currently in place by country
		Task 1.2.4	Mapping of protected sites within all habitat typologies (wetlands, lagoons, rivers, coastal areas) by country
	Task 1.3 Coordination	Task 1.3.1	Coordination of design and management of databases
		Task 1.3.2	Analysis

Work Package 2: Establishing the methodological basis and framework for long-term monitoring

This work package (WP2) aimed to establish a common structure for long-term monitoring eel stocks, as well as to provide elements for the determination of specific methodologies and sites, related to habitat typologies and eel stages.

This was carried out through the following activities:

- Investigation and census of all the monitoring frameworks already in place for eel in Mediterranean countries, addressing any issue, including fisheries, trade, features of local stocks, recruitment, escapement, stock indicators, quality and contamination, as well as eels for human consumption.
- Description and revision of the methods for collecting data on eel stocks (including sampling design, life stage identification and age reading), as well as monitoring of recruitment, yellow eel standing stocks and silver eel escapement, including based on recent findings and current methodological research.
- Agreement on a standardized protocol for eel data collection monitoring at the national level, harmonizing current existing national and international frameworks.

- Evaluation of the necessary characteristics for establishing key sites for long-term monitoring of those basic indicators of the status of the Mediterranean eel stock (including glass eel recruitment and silver eel escapement) that are representative of essential habitat typologies (lagoons, rivers and estuaries) or intra-regional differences (northern, southern and eastern Mediterranean), as well as the identification of such key sites.

This WP was divided into several tasks and subtasks (Table 3). The main deliverables were a framework for long-term monitoring and a monitoring framework database. The work performed in WP2 was a prerequisite for the WP5 deliverable revising the sections of the GFCM Data Collection Reference Framework (DCRF) related to European eel.

Table 3. WP2 tasks and subtasks.

WORK PACKAGE	**TASK**		**Task description**
WP2	**Task 2.1 Monitoring frameworks**	**Task 2.1.1**	Census of monitoring frameworks currently in place for eel by country
		Task 2.1.2	Mapping of sites for eel monitoring by country – recruitment, yellow eel, silver eel
		Task 2.1.3	Description of methods for eel monitoring by country (sampling design, life stage identification, age reading)
	Task 2.2 Coordination	**Task 2.2.1**	Design and filling of databases
		Task 2.2.2	Management of databases
		Task 2.2.3	Data analysis

Work package 3: Data collection

This work package (WP3) played a central role, as it involved the construction of databases both for specific descriptive analyses as well as to support and organize the results relating to all aspects of the programme. It focused on the collection and updating of data on three main issues over the European eel distribution range (including all coastal, transitional and inland waters) in the Mediterranean region:

- available habitats for European eel;
- biological and ecological features of local eel stocks, including data on recruitment; and
- European eel fisheries and the features of their exploitation (such as fishing effort and landings), including aquaculture.

The WP relied on thorough research and the sharing of existing documentation, using all potential sources of information, transformed and processed on a standardized basis, aiming towards the compilation of databases and thematic maps to be shared and used for further work within the RP.

Therefore, this WP provided standardized methods and protocols for collecting data, standardized data storage systems (e.g. databases, digital archives, maps) and a compilation of databases focused on the following topics:

- **European eel available habitats**, addressing the estimation of wetted areas for all habitat typologies relevant to eel (rivers, lakes, coastal lagoons and coastal areas), in order to collect and geo-reference information and edit such data. This task also addressed the collection of information on the environmental status of catchments and habitats, based on all available information (literature, internal reports, international frameworks for water monitoring and quality assessment and any other available sources).
- **European eel fisheries**, addressing the collection of all qualitative and quantitative information on eel fisheries and exploitation for all eel stages (glass eel, yellow eel and silver eel), including recreational fisheries and aquaculture. Priority information included sites where eel fisheries are present, descriptions of fisheries (methods, types of gear, number of fishers, seasonality and yields) and the collection of landings time series over time for any specific site or fishery that was available. Tentative information was also collected on illegal, unreported or unregulated fisheries that might be present. Data collection was carried out by involving all frameworks and administrations that were able to provide both historical and recent data.
- **European eel local stock biological and ecological features**, addressing the collection of all available qualitative and quantitative information on local eel stocks. Information on topics such as growth, differentiation, reproductive biology, population structure and ecology, concerning all continental stages of eel, including recruitment, was compiled by collecting available literature (published and grey, old and recent, local and international) that could contribute to the characterization of local eel stocks in the Mediterranean.

The WP was divided into several tasks and su-tasks and interacted with WP1 (Tasks 3.1.5, 3.2.3 and 3.4.2) and WP2 and fed into WP4 (Table 4). The main deliverables were a framework for data collection and several databases (on habitat, fisheries and local stocks).

Table 4. WP3 tasks and subtasks.

WORK PACKAGE	**TASK**		**Task description**
WP3	**Task 3.1 European eel fisheries and aquaculture**	**Task 3.1.1**	Design and management of databases
		Task 3.1.2	Collection of data on eel fisheries (sites, eel management units, water bodies, catchments), fishing typologies (including types of gear and methods, fishing effort), yields per year (by stage) and periods
		Task 3.1.3	Collection or revision of landing time series as available by country
		Task 3.1.4	Collection of information on recreational fisheries
		Task 3.1.5	Collection of information on stocking or restocking of European eel
		Task 3.1.6	Collection of information on European eel aquaculture
		Task 3.2.1	Design and management of databases

	Task 3.2 European eel habitat	**Task 3.2.2**	Collection of data on wetted areas for all habitat typologies (sites, eel management units, water bodies, catchments)
		Task 3.2.3	Collection of data on environmental quality status of wetted areas for all habitat typologies (sites, eel management units, water bodies, catchments)
	Task 3.3 European eel recruitment	**Task 3.3.1**	Design and management of databases
		Task 3.3.2	Collection of all available data on recruitment (sites, eel management units, water bodies, catchments), including from past and current monitoring and fisheries, and taking into account seasonality
	Task 3.4 European eel local stocks	**Task 3.4.1**	Design and management of databases
		Task 3.4.2	Collection of data on biological and ecological features of eel local stocks from research reports and national monitoring (sites, eel management units, water bodies, catchments), including eel quality and seasonality of eel life stages migration.
	Task 3.5 Coordination	**Task 3.5.1**	Providing support to the design and management of databases
		Task 3.5.2	Coordination of interactions between WPs

Work package 4: Appraisal of a common framework for stock assessment

This work package (WP4) was centred around establishing a common basis for assessing eel stocks at different scales in the Mediterranean (such as site, habitat, management unit, country or region), as well as contributing to the global assessment required for this species across its entire distribution area. It provided information on minimum requirements for data, methods and targets for assessment. It was designed to develop a model-based assessment for the appraisal of different existing or potential management measures, exploring management scenarios for sustainable eel exploitation in the Mediterranean and to contribute to eel stock recovery and conservation, with the aim of a common management plan involving all GFCM contracting parties and cooperating non-contracting parties (CPCs).

Therefore, this WP included the following:

- definition of the spatial scale(s) for assessment (also based on the results of WP3);
- revision of existing methods for assessment of stock indicators/reference points, both direct and model-based;
- identification of the best suitable models and methods and of the minimum requirements for their use, also considering their possible applications in data-poor and data-rich conditions; and
- model-based assessment for the appraisal of different existing or potential management measures.

The WP was divided into several tasks and subtasks and relied on data compiled in WP3 (Table 5). The main deliverables were a preliminary stock assessment and an appraisal of alternative management measures, as well as dedicated tools to perform these analyses.

Table 5. WP4 tasks and subtasks.

WORK PACKAGE	TASK		Task description
WP4	**Task 4.1 Existing assessments**	**Task 4.1.1**	Census of local stocks assessment case studies (sites, eel management units, water bodies, catchments)
		Task 4.1.2	Methods used for eel stock assessment by country
		Task 4.1.3	Collect data on reference points used in national eel stock assessments (sites, eel management units, water bodies, catchments)
	Task 4.2 Coordination	**Task 4.2.1**	Design of databases
		Task 4.2.2	Management of databases
		Task 4.2.3	Model-based assessment for the appraisal of different existing or potential management measures

Work package 5: Transversal work package on coordination and networking

This work package (WP5) aimed to identify the best management measures and frameworks for eel habitats in the Mediterranean region, as well as better coordination of management for eel stock recovery in the Mediterranean region. This objective required strong coordination frameworks, relying on international and national networking, and comprised the core activity of WP5, which was coordinated by the GFCM Secretariat with technical assistance from European eel experts.

The main task of WP5 was the revision of the DCRF Task VII-Eel. Transversal activity included training and capacity building through the involvement and capacity building of junior scientists in all participating countries.

The WP was divided into several tasks and subtasks (Table 6).

Table 6. WP5 tasks and subtasks.

WORK PACKAGE	TASK		Task description
WP5	**Task 5.1 Administrative support**	**Task 5.1.1**	Preparation of agreements with partners
		Task 5.1.2	Assistance to partners in financial reporting
	Task 5.2 Meetings and workshops	**Task 5.2.1**	Organization of project meetings
		Task 5.2.2	Organization of the GFCM Working Group on the management of eel (WGMEASURES-EEL)
	Task 5.3 Scientific	**Task 5.3.1**	Coordination of partners

	coordination and implementation	**Task 5.3.2**	Revision of the DCRF
		Task 5.3.3	Transversal action on training and capacity building
		Task 5.3.4	Preparation of reports and deliverables

Development and Features of the Research Programme

Role of Partners and chronology

Participants in the RP included nine scientific partners from nine CPCs, as well as national focal points, i.e. the appropriate contact point in each partner country's administration (see Table 1). The scientific partners included senior and junior scientists, with junior scientists recruited specifically for the needs of the RP. The initial division of roles foresaw that some partners with established experience in eel research and related issues would lead specific WPs to coordinate the scientific planning and launching of activities, with the involvement and support of other partners. However, once the activities were underway, the roles were reviewed and redistributed so that each partner assumed scientific responsibility for specific tasks. In addition, all the partners contributed as data providers for their respective countries. The role of national focal points was to liaise with scientific partners on any official country matter, as required, and to help scientific partners gain access to official data.

Over the course of the project, two external advisors were involved as members of the Advisory Board, participating in key project meetings, providing scientific advice regarding methodological choices and, in internal discussions, regarding the achievement and effective attainment of results.

The RP started with Phase 0, lasting from June 2020 to August 2020, during which the work schedule was hampered by the onset of the COVID-19 pandemic, meaning that effective and coordinated work commenced in September 2020 and ended in February 2022 (Table 7).

Table 7. Phases of the research programme, relative time periods, and activities.

Phase	Time period	Notes
Phase 0	June 2020–August 2020	Work was preliminary and exploratory in nature due to the prevailing COVID-19 situation
Phase 1	September 2020–April 2021	Work started, initially focused on preparing the structure of databases and collecting data. An interim meeting was held in April 2021, at which databases were examined and refined, specific tasks within each WP were identified and further steps and coordinated work were planned.

Phase 2	May 2021–June 2022	Data analysis and assessment were performed, along with drafting of the final report, preparation of final deliverables and organization of the final meeting, including a webinar to disseminate the RP and WGMEASURES-EEL-2022 results.

General methodology for data collection

While this section explains general methodological procedures for the RP, the specific methods of data collection and analysis for individual tasks are explained in detail in each chapter. During the initial phase, attention was given to the choice of temporal and spatial scales for data collection, the choice of eel habitat typologies, data sources and setting up the structure of databases.

Regarding the spatial scale for data collection, it was decided to collect data, to the greatest extent possible, at the level of single sites in order to work at the finest level of detail within the different tasks. Data available at the site level allowed for aggregation at any level – for example, by habitat, by eel management unit (if present), by country or by region. For the choice of the temporal scale, it was agreed to retrieve available data for the specific data type (including annual, seasonal or monthly), to be then aggregated or processed at various levels (total, average and frequency) as needed.

Five main habitat categories were identified based on the habitat types relevant for eel in the Mediterranean region (database code in parentheses): coastal marine waters (CMW); lagoons (LGN); river estuaries (RIE); rivers (RIV); and lakes (LAK).

The first category, CMW, was addressed in the initial phase of the habitat data collection by estimating the area of coastal areas that might be relevant to eel, but it was later excluded from further analyses because no significant information on local eel stocks was identified in most of these habitats. All the sites for which information on eel and its habitat was found were therefore assigned, based on environmental features, to four categories. These categories included transitional waters (LGN and RIE) and inland or continental waters (RIV and LAK) and were used for grouping and analysing information related to eel and its habitat in further steps.

In the preliminary and initial phases of the RP, consideration was given to the choice of variables to be included in the databases, to the design of databases and to reaching an agreement on the final database structure. Template Excel files were agreed upon and arranged, related to each specific issue, including README spreadsheets for each, with explanations and labels for each of the variables included in the specific database, as well as a sheet with the metadata information to be filled in by each partner, such as notes or sources.

Another methodological aspect considered during the preliminary phase was the methods for retrieving data and the data sources. Methods were agreed upon for the specific measurement of quantitative data (for example, wetted areas) and of qualitative data (for example, land use). Data sources were identified from all possible relevant resources, including official statistics and official reports (national and international), reports and websites of national environmental agencies, offices of national and local administrations, literature reviews (including past and recent papers), monitoring results and research project results. Details are given in the methodological sections of each chapter.

For specific tasks that required descriptive information gathering via interactions with national focal points and administrations (for example, WP1 “Collection of data on management measures”, WP2 “Collection of data and information on monitoring”, WP3 “Collection of information on fishing methodologies and fishing effort” and WP5 “Survey on eel fishery-related data collection for the revision of DCRF Task VII.6 Eel”), questionnaires were prepared and circulated to the national focal points and scientific partners and eventually to local offices. Upon submission of the completed questionnaires, all answers were archived for further analysis.

During all phases of the work, but specifically after the completion of the data collection in Phase 1, a quality check of all data was carried out to verify that the collected data satisfied the requirements for their intended use. The criteria used for this step were based on consistency, accuracy and relevance. Data not completely satisfying these criteria were eventually discarded from further analyses. As the aim of data collection was foremost to establish the methodology for data collection and then to use available data for a first descriptive analysis of eel-related issues, less importance was given to completeness and timeliness.

This phase of the work enabled the compilation of databases on:

- eel habitats (wetted areas, environmental features, habitat quality for eel);
- eel recruitment;
- eel local stocks (biological variables, eel quality);
- eel exploitation (fishing methodologies, fishing effort, landings);
- eel aquaculture;
- eel management measures; and,
- eel monitoring schemes (including eel fishery-related data collection).

The final databases, along with all intermediate versions and additional materials and documents (questionnaires, literature and reports, additional information and data, specific parts of the databases for analyses), were shared on the dedicated GFCM SharePoint for each WP, where they were stored for any further use by the GFCM Secretariat and partner countries. For WP1, WP2 and WP4, the databases combine the data for all countries, while WP3 databases were uploaded into separate country databases for each specific issue (habitat, recruitment, local stocks, fishery and landings, aquaculture).

Data use, analysis and deliverables

The data collected within each task were analysed to produce a first comprehensive, descriptive and quantitative knowledge base for European eel in the Mediterranean Region (Figure 2).

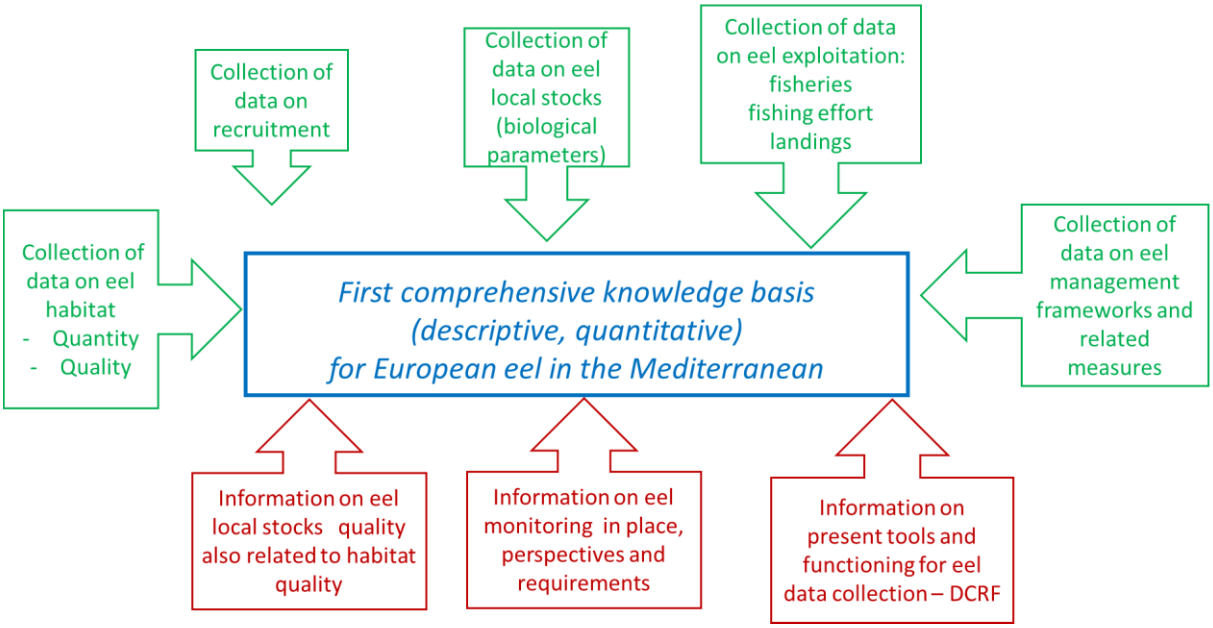

Figure 2. Methodological pathway for the research programme, from data collection to the preparation of the final report, which presents for the first time a comprehensive knowledge base related to the various aspects relevant to European eel in the Mediterranean area.

Specific methodologies for data analysis and results are presented in this report, in each chapter.

Data resulting from WP1 were used to make choices for potential management scenarios to be tested in WP4. This WP built its own dataset with data extrapolated from the WP1 and WP3 databases to provide data for a model to establish a common basis for assessing eel stocks in the Mediterranean. WP4 also included an assessment of the role of different existing or potential management measures and an appraisal of management options for the sustainable eel exploitation in the Mediterranean, contributing to eel stock recovery and conservation (Figure 3).

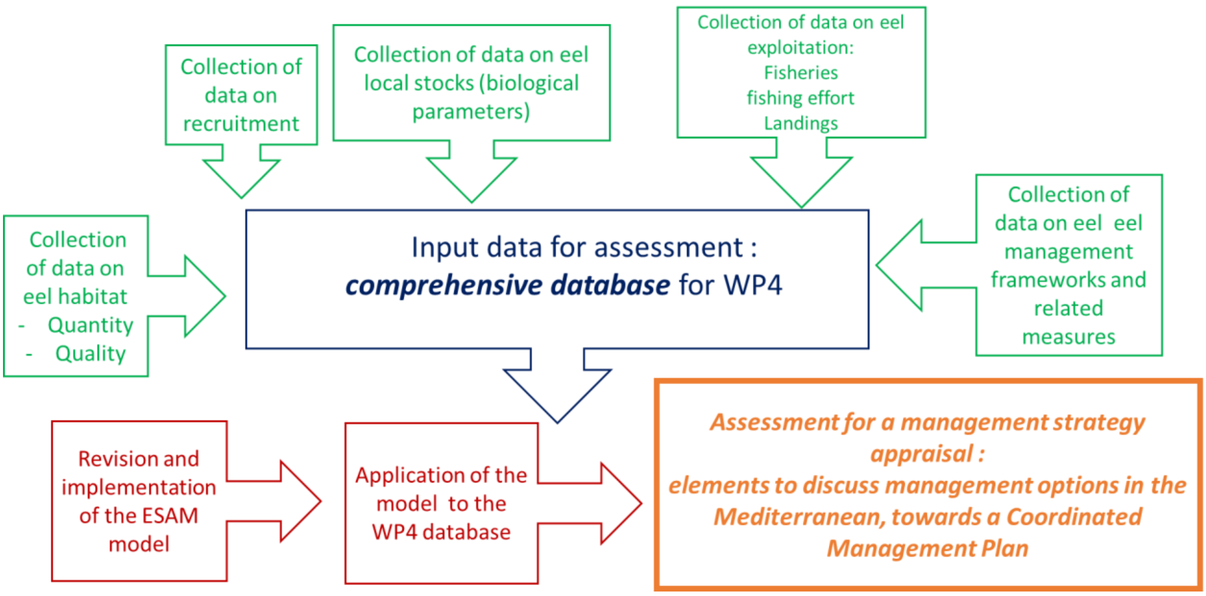

Figure 3. Methodological pathway, from data collection through to the assessment for an appraisal of different existing or potential management measures, in view of a coordinated management plan for the region.

CHAPTER 1. DEVELOPMENT OF A DATABASE FOR THE ANALYSIS OF EEL HABITATS IN THE MEDITERRANEAN

ABSTRACT

A database was designed within the WP3 on Data Collection to be filled in by the nine Mediterranean partner countries with the objectives of geo-referencing all eel habitat sites, and collecting data on the surface areas and environmental characteristics of these habitats. The database was designed to provide information for quantitative analysis of wetland areas, both current and lost, descriptive analysis and characterisation of each type of habitat and qualitative analysis with an estimation of the quality of the geo-referenced habitats.

It aimed to be as complete and exhaustive as possible to provide information for the other subtasks of the WP3 Task 3.2 Eel Habitat, and provide basic information for the relevant WPs including on the following aspects:

- Site description: habitat type (river, RIV; river estuary, RIE; lake, LAK; coastal lagoon, LGN), geo-references, wetted surface, migration routes and river discharge, if applicable.
- Main physico-chemical characteristics: temperature, trophic status, saline typology and annual average salinity.
- Environmental quality parameters: pollutants (persistent organic pollutants and heavy metals), percentage of land uses in the drainage area, conservation status of the riparian vegetation, presence of invasive alien species and percentage of protected surface.
- Natural mortality: presence and type of predators and parasites or pathogens.
- Anthropogenic mortality: fishery (legal, illegal; presence or absence of fishing barriers in lagoons) and existence of turbines and pumping stations.

HIGHLIGHTS

- A database was developed with a suitable structure to store all information relating to the characteristics of the habitat in the sites characterized by the presence of eels in the Mediterranean area.
- The data collected by the various countries varied in completeness, time scale, and in the source of the information. European Union countries already had available data collected as part of the actions for the preparation of National Eel Plans (EU Regulation 1100/2007), while others began collecting them as part of this research programme.
- In the future, it will be possible for all countries to improve the completeness of the data based on agreed methodologies.
- The habitat database provided a fairly complete overview of the eel habitat situation from a quantitative and qualitative point of view.
- The information collected at the site level enabled the provision of the information necessary to characterize the sites (WP4, Chapter 13).

1.1. INTRODUCTION

Eel stocks in the Mediterranean have their own peculiar characteristics as they are in the southernmost part of their distribution range while they are also far from the eel reproduction area in the Atlantic Ocean. Meanwhile, climatic conditions and especially higher temperatures also mean that Mediterranean eel stocks may have a life cycle with a shorter freshwater phase, because of faster growth rates compared to eels in cooler regions. Furthermore, Mediterranean stocks, which are largely confined to coastal lagoons and brackish water habitats, have lower glass eels recruitment levels, because migration dynamics of glass eels in lagoons are different to those in Atlantic estuaries (Aalto *et al*., 2015).

Early maturation means that the turnover rate, the time between arrival as glass eels and spawning migration as silver eels, is also faster than at higher latitudes, which has led to conjecture about the important role that southern European and north African populations may play in eel population recovery (Dekker, 2003; ICES, 2007; Kettle, Vøllestad and Wibig, 2011; Aalto *et al*., 2015).

Mediterranean aquatic habitats have distinctive characteristics with respect to two fundamental factors, the strongly seasonal climate and the influence of the Mediterranean Sea, with its particular tidal regime in coastal waters. The main characteristic of Mediterranean rivers is a highly seasonal rainfall pattern, which results in variable stream flows and marked drought periods during the summer months when flow ceases and rivers consist of isolated pools with high temperatures and low oxygen levels. These unstable habitats often lead to heavy fish mortality due to thermal and respiratory stress (Herrera and Fernández-Delgado, 1994; Fernández-Delgado and Herrera, 1995; Kondolf and Batalla, 2005; Datry, Larned and Tockner, 2014).

The Mediterranean climate together with the construction of dams, built to supply agricultural and human demand for water, as well as for flood prevention, has made Mediterranean rivers some of the most heavily regulated in the world (Kondolf and Batalla, 2005: Kettle Vøllestad and Wibig, 2011). The hydrological impacts lead to modifications in the structure and functionality of aquatic ecosystems, resulting in the disappearance of key species (Ekka *et al*., 2020) as well as substantial ecological alteration of river basins (Dudgeon *et al*, 2006, Navarro-Ortega *et al*., 2012; Dudgeon, 2013; Ekka *et al*., 2020) and makes variable water levels and degradation of water quality, major issues in the Mediterranean region (Navarro-Ortega *et al*., 2012).

Coastal lagoons are coastal water bodies separated from the sea by sand barriers, interrupted by one or more shallow channels that allow water exchange with the sea (Kjerfve, 1994). Mediterranean lagoon ecosystems are distinct from lagoons in true coastal waters, such as those on Atlantic coastlines that are affected by strong tides. (Cataudella, Crosetti and Massa, eds., 2015). The dynamics of the lagoons, including their water and salinity regimes, result from seasonal variations in precipitation, evaporation and temperature, the importance of which depends on lagoon size and latitude (Cataudella, Crosetti and Massa, eds., 2015). Due to high nutrient input levels, they are productive, highly biodiverse, brackish habitats (De Wit, 2011), playing an important role as breeding grounds and nursery areas for many invertebrate and fish species (Kapetsky, 1984; Ardizzone, Cataudella and Rossi, 1988). The most relevant problems for Mediterranean lagoons are anthropogenic impacts such as fishing, pollution, eutrophication, the introduction of exotic species and habitat loss. As a result, many Mediterranean coastal lagoons have recently disappeared, or are under threat of disappearance (Cataudella, Crosetti and Massa, eds., 2015; Soria, Pérez and Sòria-Pepinyà, 2022).

Anthropogenic impacts on aquatic habitats will also increase due to climate change. Increased frequency of prolonged droughts and floods, together with changes in land use and water demand for human consumption and irrigated agriculture, are likely to lead to an increase in hydraulic engineering works resulting in increased pressures and negative effects on habitat conditions and biota (Dudgeon *et al*., 2006; Datry, Larned and Tockner, 2014; Cataudella, Crosetti and Massa, eds., 2015).

In this context, and given that declines in Mediterranean eel populations have already been recorded (Ciccotti, 2005; Aalto *et al.*, 2005), an investigation into the availability, quality and crucial issues facing habitats, with specific reference to local and global eel stocks, is an important first step. With this aim, the research programme emphasised the characterization of eel habitats at as fine a level as possible, with specific tasks within the framework of the WP3-Data collection. The specific objectives of the habitat work were geo-referencing of all eel habitats present in the nine participating countries and data collection on the surface area and environmental characteristics of these habitats. This information was then analysed in three different ways: quantitative analysis of current and lost wetland areas; descriptive analysis and characterisation of each type of habitat; and, qualitative analysis with an estimation of the quality of the geo-referenced habitats.

This chapter lists and describes the information and variables collected to develop the habitat database, as a result of scientific partners from the nine participating countries filling in national databases. The specific methodologies for habitat data collection and further analysis, especially for the quantitative estimates and the qualitative assessment of sites, are given in Chapters 2–4. The habitat database was also used for other analyses within all Work Packages, to accomplish the different tasks of the research programme according to specific needs and objectives, whose results are described in Chapters 5–14.

1.2. MATERIALS AND METHODS

A database was designed to be filled in by each partner country containing the following information for each water body:

- Area description/habitat type:
    - River (RIV)
    - River Estuary (RIE)
    - Lake (LAK)
    - Coastal lagoon (LGN)
- Geo-reference: site name, coordinates, Country, EMU, etc.
    - Wetted surface areas: current and potential
    - Migration routes: free or obstructed to varying degrees
    - River discharge
- Physicochemical characteristics
    - Annual average water temperature
    - Trophic status
    - Saline typology and annual average salinity
- Environmental quality parameters
    - Pollutants: persistent organic pollutants (POPs), heavy metals
    - Percentage of land use in the drainage area
    - Conservation status of the riparian vegetation
    - Number and taxonomic position of invasive alien species present
    - Percentage of protected surface
- Natural mortality
    - Presence and type of predators
    - Parasites and pathogens
- Anthropogenic mortality
    - Fishery: legal, illegal and presence/absence of fishing, lagoons, barriers.
    - Presence of turbines and pumping stations

For a detailed explanation of each of the different sections, the characteristics and exact definition of each variable see *The Read Me Habitat Spreadsheet* of the WP3-Habitat Data Base **(Supplementary Material on the Methodology).**

To achieve the objectives, an intensive search for information and data was carried out considering all possible sources including scientific literature, official web sites and grey literature on each water body existing in the nine partner countries.

A database was designed to be filled in by each partner country containing the following information for each water body:

<u>Area description</u>

Habitat type:

- River (RIV): freshwater areas upstream the estuarine zones. Only those with seasonal/permanent waters were selected, rejecting temporary ones (wadis/ravines, etc.)
- River Estuary (RIE): transitional waters including deltas and marshlands.
- Lake (LAK): inland water bodies, generally freshwater, connected to the sea by a river.
- Coastal lagoon (LGN): water bodies with different degrees of salinity, close to the coastal areas and connected to them through a drainage channel.

Geo-reference:

- Coordinates; country, Eel Management Unit (EMU) code and site name

Wetted surface areas:

- Current: wet surface areas available for eels at the present time.
- Potential: wet surface areas not available for the eel at the present time.

Migration routes:

- For both migration phases (anadromous glass eels and catadromous silver eels), the degree of obstruction, from completely free connection to the sea to completely obstructed.

River discharge:

- If applicable, measured as annual river discharge or annual average discharge.

<u>Physicochemical characteristics</u>

Annual average water temperature

Trophic status:

- Measured through the concentrations of chlorophyll a, total nitrogen, total phosphorus and presence or absence of dystrophic crises.
- Categories were: "Oligotrophic", "Mesotrophic", "Eutrophic", "Hypereutrophic".

Saline typology and annual average salinity

- Categories were freshwater, oligohaline, mesohaline, polyhaline, euhaline and hyperhaline.

<u>Environmental Quality</u>

Pollutants:

- Concentrations of pollutants (indicating whether the sample was obtained in water, sediments, eels or other living organisms) selected according to eel health descriptors included in the European Eel Quality Database (Belpaire et al., 2011).
- Persistent organic pollutants (POPs), PCBs (polychlorine biphenyls), pesticides, brominated flame retardants, dioxins, PAH (polycyclic aromatic hydrocarbons), PFAs (perfluoroalkyl substances), heavy metals (Cd, Hg, Pb, Cr, Ni, Cu, Zn, As, Se, Mn, Co, V, Ba, Sr).

Percentage of land use in the drainage area.

Riparian vegetation:

- Conservation status of the river basin riparian vegetation.
- Number and taxonomic position of invasive alien species present in the area.

Protected surface area:

- Percentage of protected surface area and the type of specific network protection (such as Ramsar, Natura 2000).

<u>Natural Mortality</u>

Presence and type of predators:

- Piscivorous fish, birds and other animals.

Parasites and pathogens:

- Prevalence (percent) of *Anguillicola crassus*, other parasites, bacteria and viruses.
- Selected according to the eel health descriptors included in the European Eel Quality Database (Belpaire *et al*., 2011).

<u>Anthropogenic Mortality</u>

Fishing mortality:

- Legal and illegal fisheries with an indication of stage of maturity targeted: (G) glass eels, (Y) yellow eels, (S) silver eels, (G/Y) glass + yellow eels, (Y/S) yellow + silver eels or (G/Y/S) aggregation of all the life stages.
- Presence or absence of fishing in lagoons or at lagoon barriers.

Turbines and pump stations:

- Number of both, without specific eel passes, that exist in the migration route of the geographical point under consideration.

1.3. DEVELOPMENT OF A GEO-REFERENCED DATABASE

This subtask met two main objectives:

- Development of a database and GIS map with all eel habitats of the Mediterranean basin geo-referenced.
- Data supply to WP4 on stock assessment (Chapter 13)

The information for the elaboration of a GIS map will contain the following variables (under consideration).

A specific WP4 database was developed that contained information on the following variables referring to each of the eel habitats in the Mediterranean basin:

- Site name and coordinates of each river, estuary, coastal lagoon and lake.
- Extent in hectares of the current surface area.
- Annual average temperature.
- Degree of connection with the sea, measured through the existence of free (anadromous and catadromous) or hindered (partially or totally) migrations.
- Presence of parasites and pathogens and prevalence in the stock (percent).
- Predators: presence and number of cormorants, presence of otters and presence and species name of piscivorous fish.

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Read Me Habitat Spreadsheet of the WP3-Habitat Data Base

MISSING DATA		
Short definition	Code	Definition
not reported	NR	data or activity exist but numbers are not reported to authorities (for example for commercial confidentiality reasons).
no data	ND	activity / habitat exists but data are not collected by authorities (for example where a fishery exists but the catch data are not collected at the relevant level or at all).
not collected	NC	where there are insufficient data to estimate a derived parameter (for example where there are insufficient data to estimate the stock indicators (biomass and/or mortality).
not pertinent	NP	where the question asked does not apply to the individual case (for example where catch data are absent as there is no fishery or where a habitat type does not exist in an EMU).

WP3_HABITAT VARIABLES	Code	EXPLANATION	Units	Types of Units
Country	Country_fullname	Full name		Character
Year of evaluation	Year	Four digits (include successive rows for different years if necessary)		Number
Site name	Site_name	Just put the name you give to your station (include successive rows for different sites if necessary)		Character
Scale	Scale	Please indicate the geographical scale to which the data refer, e.g., sub-basin, lagoon basin, river segment, point sampling, etc.		Character
Area/River basin	Area_basin	Indicate the geographical area or drainage basin to which the station (Site_name) belongs		Character
EMU code	EMU_name short	See EMU codes in the general *Read Me* spreadsheet of WP3 database		Character
Site coordinates:		Should be in decimal degrees with wgs84-epsg4326 or other coordinate system with complete information to allow us to reproject your data. If it is the entire area of a water body take the centre.		

Longitude	Long		Decimal Degrees (DD)	Number
Latitude	Lat		Decimal Degrees (DD)	Number
AREA DESCRIPTION				
Habitat type		For rivers, select only those with seasonal/permanent waters, eliminating temporary ones (wadis/ravines, etc.)		
	OMW	Open Marine water (open sea)		Character
	CMW	Costal Marine Water: surface waters on the land side of a line that is located at a distance of one nautical mile from the coast or the mouth of rivers. In the special case of areas where surface waters extend beyond one nautical mile, they should be considered as Coastal Marine Waters (CMW) and not as Open Marine Waters (OMW)		Character
	LGN	Coastal Lagoons (several saline typologies)		Character
	RIE	River Estuary (transitional waters including deltas, marshlands, etc.) measured from the mouth of the river until 30 km upstream of the main channel (if there are more accurate measurements use instead, e.g., length of the permanent saline wedge, etc)		Character
	RIV	Freshwater area from the end of the estuary zone (measured as above) to the first unsurpassable obstacle.		Character
	LAK	Lake (freshwater)		Character
Potential surface	Pot_sur	Refers to wetted surface (ha) above the first unsurpassable barrier (without eel-pass) until a high of 1000 m a.s.l. Counting a representative average channel width each 5 km and multiply these by the length of each representative channels (5 km). If there is another more accurate measurement, please use instead	ha	Number
	Lak_psur	The potential surface area for habitats available to eel at a time prior to the land use modification (extraction, drainage, etc.). Consider all the changes that have occurred after about 1850 to the present date	ha	Number
	Lgn_psur	The potential surface area for habitats available to eel at a time prior to the land use modification (agricultural, channelization, etc.). Consider all the changes that have occurred after about 1850 to the present date	ha	Number

	Rie_psur	The potential surface area for habitats available to eel at a time prior to the land use modification (agricultural, channelization, etc.). Consider all the changes that have occurred after about 1850 to the present date	ha	Number
Current surface		Available habitat at the present time		
	Riv_cur	Rivers: for the river basin, available habitat for eel under the first unsurpassable barrier (ha) at the present time. Counting a representative average channel width each 5 km and multiply these by the length of each representative channels (5 km). If there is another more accurate measurement, please use instead.	ha	Number
	Rie_cur	Estuaries, deltas or marshlands: available habitat for eel (ha) at the present time (Figure 2)	ha	Number
	Lgn_cur	Lagoons: available habitat for eel (ha) at the present time	ha	Number
	Lak_cur	Lakes: for those water bodies with an average depth of more than 20 m the area considered suitable for eels is calculated as 10% of the total lake surface. For lakes with an average depth of less than 20 m consider the entire surface	ha	Number
	Coast_cur	Available surface coastal waters on the land side of a line that is located at a distance of one nautical mile from the coast or the mouth of rivers. In the special case of areas where surface waters extend beyond one nautical mile, they should be considered as Coastal Marine Waters (CMW) and not as Open Marine Waters (OMW). The surface must be estimated whether or not the presence of eels has been detected	ha	Number
Connectivity	Conn	Only in rivers: percentage of basin area inaccessible to eel	%	Number
Lost surface	Lost	For lakes, lagoons, estuaries, deltas and marshlands: area currently not accessible to eels referred to the pre-reclamation surface (to calculate this area follow the instructions given above, see for instance Rie_cur, Lgn_cur and Lak_cur)	%	Number
Reclutability	Rec and Time_rec	For all types of habitats (LAK, RIV, RIE, LGN) and for each site separately, value the connection with the sea **during the migration period (this should be done for each year considered):**	0-2/days	Number/Number
		=> 2 when there is a free arrival (without barriers or these are open) of glass eels/elvers to the area		
		=> 1 when the arrival has been partially obstructed. In this case, show the periods of time (number of days) in which the barriers have been closed (variable Time_rec)		

		=> 0 when this arrival has been completely obstructed by barriers, obstacles, etc..		
Escapement	Esc and Time_esc	For all types of habitats (LAK, RIV, RIE, LGN) and for each site separately, value the connection with the sea **during the migration period (this should be done for each year considered):**	0-2/days	Number/Number
		=> 2 when there is a free escape (without barriers or these are open) of silver eels to the sea		
		=> 1 when the escape has been partially obstructed. In this case, show the periods of time (number of days) in which the barriers have been closed (variable Time_esc)		
		=> 0 when the escape has been completely obstructed by barriers, obstacles, etc..		
Water Exchange Index	Wei	Only for lagoons $\frac{\sum_{i=n}^{n} Tidal\ channel\ length_i\ (km)\ \times width_i\ (km)}{lagoon\ surface\ (km^2)} \times 100$		Number
River discharge		You can choose from any of the following variables:		
	AA_riv_disch	Accumulated Annual River discharge (km^3/year): refers to an entire river basin		
	AA_disch	Annual average discharge (m^3/s): refers to a given area within a river basin or an entire river basin. If the average is not calculated from all the months of the year, indicate below which ones are missing		
PHYSICO CHEMICAL CHARACTERISTICS				
To fill in this database, indicate the reason why there is a missing value (drop-down list) or fill in the data of the variable that is requested (drop-down lists or manually)				
Annual Average water temperature	Awt	Annual average water temperature (if known, indicate in brackets the number of measurements used to calculate this average). If the average is not calculated from all the months of the year, indicate below which ones are missing	ºC	Number
Trophic status		Consider any (or all) of the following parameters: Chlorophyll a (Chla); Total phosphorus (Pt); Total nitrogen (Nt);		
		Chlorophyll a (Chla):	µg/l	Number

	Ts_Chl_a and Ts_Chla_conc	Oligotrophic (Chla< 3)		
		Mesotrophic (3 <Chla< 7)		
		Eutrophic (7 <Chla< 40)		
		Hypereutrophic (Chla> 40)		
	Ts_P_t and Ts_Pt_conc	Total phosphorus (Pt):	µg/l	Number
		Oligotrophic (Pt < 15)		
		Mesotrophic (15 < Pt < 25)		
		Eutrophic (25< Pt < 100)		
		Hypereutrophic (Pt > 100)		
	Ts_N_t and Ts_Nt_conc	Total nitrogen (Nt):	µg/l	Number
		Oligotrophic (Nt< 400)		
		Mesotrophic (400 <Nt< 600)		
		Eutrophic (600 <Nt< 1500)		
		Hypereutrophic (Nt> 1500)		
Dystrophic crisis	Dtc	Subject of dystrophic crisis (algal blooms, anoxic crises, etc.) during summer.	Y/N	Character
Annual Average salinity	Av_sal	Annual average salinity. If the average is not calculated from all the months of the year, indicate below which ones are missing	g/l	Number
Saline typology	Sal_tip	Based on Average Salinity indicate typology according to:		Characters
		freshwater (Sal < 0,5 g/l)		
		oligohaline (0,5g/l < Sal <5 g/l)		
		mesohaline (5 g/l < Sal <c 18 g/l)		
		polihaline (18 g/l < Sal < 30 g/l)		
		euhaline (30 g/l < Sal < 40 g/l)		
		hyperhaline (Sal> 40 g/l)		
ENVIRONMENTAL QUALITY PARAMETERS				

Persistent Organic Pollutants (POPs)	POP_type; POP_type_conc and POP_sample_type	Indicate which one of the following pollutants have been estimated in the area considered, its concentration and if it has been obtained from:	µg/kg; µg/l	Character/Number
		sediment		
		water		
		eels		
		other live organisms		
		PCB (Polychlorine biphenyls)		
		Pesticides: [α-HCH, β-HCH, γ-HCH (Lindane), Dieldrin, Aldrin, Endrin, Hexachlorobenzene (HCB), p, p'-DDD (TDE), p, p_-DDT, p, p_-DDE, trans-nonachlor, Malathion (organophosphorous)]		
		Brominated flame retardants: [BDE 28, BDE 49, BDE 47, BDE 66, BDE 100, BDE 99, BDE 85, BDE 154, BDE 154 + BB153, BDE 153, BDE 183, sum PBDEs, HBCD]		
		Dioxins: [sum PCDD/Fs, sum DLPCBs, sum PCDD/Fs and DLPCBs, -TetraCDD, -PentaCDD, -HexaCDD, -HeptaCDD, OctaCDD (OCDD),-TetraCDF, -PentaCDF, -PentaCDF, -HexaCDF, -HeptaCDF, OctaCDF (OCDF)]		
		PAH (polycyclic aromatic hydrocarbons)		
		PFAS (perfluoroalkyl substances): [PFOS, PFHxS, PFOSA, PFOA, PFNA, PFDA, PFUnA]		
		Others: e.g., emerging pollutants (EPs)		
Heavy metals	Heav_type; Heav_type_conc	Indicate which one of the following heavy metals have been estimated in the area considered and if the concentration has been obtained from sediment, water, eels or other live organisms	µg/kg; µg/l	Character/Number

	and Heavy_sample_type	Cd Hg Pb Cr Ni Cu Zn As Se Mn Co V Ba Sr		
Land uses	Land_type and Land_type_%	Indicate % of type of land use in the drainage area of the site considered (Figure 3) Agr: Agricultural (including silviculture) Nf: Natural forestry Urb: urban Ind: Industrial	%	Character/Number
Riparian vegetation	Rip_veg_level	Conservation status of the river basin riparian vegetation: (high; medium; low): low if less than 30% of the riparian vegetation is conserved; medium if between 30% and 60% and high if more than 60%. High Medium Low		Character
Number of invasive species	Inv_type and Inv_n_type	Indicate number of species belonging to each of the following categories: Ot: others (macroalgae; cianobacteria, fungi, macrophytes, etc.) Mac: Macroinvertebrates		Character/Number

		Fis: Fishes		
		Ov: Other vertebrates related to the aquatic environment (coypu, american mink, florida turtle, etc…)		
Protected surface	Prot_sur and Prot_type	Percentage of protected area in the natural element considered (river basin, lake basin, lagoon basin, etc.). Please also indicate the type of specific network protection, e.g., NATURA 2000, Ramsar, regional level, etc.	%/Conservation Type	Number/Character
NATURAL MORTALITY				
Piscivorous birds	Pred_brd_type and Pred_brd_n	Co: Presence of cormorants; if known, indicate number of individuals.	Y-N/number	Character
		Ob: Presence of other piscivorous birds; if known, indicate species and number of individuals.	Y-N/species-number	Character
Otter	Pred_ot	Presence Presence Presence of piscivorous fishes including invasive ones. If known, indicate species	Y N	Character
Piscivorous Fishes	Pred_fish and Pred_fish_sp	*Anguillicola crassus:* Prevalence (Number of infected eels/Total number of eels)	Y-N/species	Character
Parasites	Ac_prev	*Anguillicola crassus:* Prevalence (Number of infected eels/Total number of eels)		Number
	Par	Other parasites		
		Trypanosoma sp		
		Myxidium sp		
		Paraquimperia sp		
		Pseudactylogyrus sp		
		Pomphorhynchuslaevis		
		Others (indicate species)		
	Par_prev	Prevalence (Number of infected eels/Total number of eels)		Number
Bacteria	Bac	*Edwardsiella* sp		Number
		Vibrio sp		
		Aeromonas septicaemia		

		Others (indicate (species)		
	Bac_prev	Prevalence (Number of infected eels/Total number of eels)		
Viruses	Virus	*Herpesvirus:* IPN, EVE, EVEX		Number
		Herpesvirus anguillidae		
	Virus_prev	Prevalence (Number of infected eels/ Total number of eels)		
ANTHROPOGENIC MORTALITY				
Legal Fishery	Leg_Fish_type and Leg_Fish_presence	G: glass eel	Type and Y/N	Character
		Y: yellow eel		
		S: silver eel		
		YS: yellow eel+ silver eel		
		GY: glass eel + yellow eel		
		AL: Aggregation of the above life stages		
Illegal Fishery	ILleg_fish_type and ILleg_Fish_presence	G: glass eel; Y: yellow eel; S: silver eel; YS: yellow eel+ silver eel; GY: glass eel + yellow eel; AL: Aggregation of the above life stages	Type and Y/N	Character
Fishing lagoon Barriers	Flb	Presence of fishing lagoons barriers (e.g., pantena, lavoriero, capechade, etc.)	Y/N	Character
Turbines	Ntb	Number of dams with turbines downstream between the site considered and the estuary		Number
Turbines with eel pass	Per_Ntb	Percentage those turbines having a **silver eel** pass	%	Number
Pumping stations	Nps	Number of dams with pumping stations downstream between the site considered and the estuary		Number
Pumping stations with eel pass	Per_Nps	Percentage of those pumping stations having a **silver eel** pass	%	Number

CHAPTER 2. QUANTITATIVE ANALYSIS OF THE MEDITERRANEAN EEL HABITATS

ABSTRACT

The quantitative section of the habitat database includes evaluation of the current and lost surfaces of all habitats for eels at site level. The aims of this chapter are to quantify the total wetted areas for eels in the Mediterranean basin and to assess the total amount of lost surface, in order to compare lost habitat for each habitat type and in each country. Information on a total of 618 sites was collected and stored in a database (see also Chapter 1), encompassing 275 lagoons, 148 rivers, 150 estuaries and 45 lakes. For each site, the current surface area and the surface area no longer available were calculated, along with the coordinates of each site. The largest available area for eels corresponded to lagoon habitats (about 755 000 ha), which was present in all countries with Egypt, Greece, Italy and Tunisia having the largest lagoon surface areas. Most of the surface area of rivers is no longer accessible to eels, with more than 50 percent of potential surface area lost in almost all countries. Although the Nile delta shows the highest surface area available to eel in estuarine habitats, most of the other estuaries have large portions of habitat not accessible to eel. The wetted area of lakes was only evaluated in a few countries. Although all countries provided habitat censuses that were as complete as possible, quantitative data and the results of this analysis must be considered with caution. Although all available data were used, a uniform methodology for the calculation of areas has yet to be established so there was variation from country to country.

HIGHLIGHTS

- Information on wetted areas was documented for the 618 sites where information was available in the habitat database, including 275 lagoons, 148 rivers, 150 estuaries and 45 lakes.
- The largest available area for eels was in lagoon habitats, which were present in all countries.
- In all countries, most of the river surface area has been lost and is no longer accessible to eels.
- Surface area data estimations must be considered with caution. The calculation method was not homogeneous across countries and there were missing values in the lost surface areas.

2.1 INTRODUCTION

The loss of eel habitats over time, including through the destruction of habitats and the inaccessibility of habitats due to migration barriers, is one of the main anthropogenic impacts believed to be responsible for the decline in eel populations (Drouineau *et al*., 2018; ICES, 2020). The most substantial loss of European eel habitat across its area of distribution (Europe and north Africa) has occurred over the last century (Feunteun, 2002), but specific work focusing on the quantification of eel habitat and loss of eel habitat has been limited, and the results of the work that has been carried out are not particularly relevant to understanding the impact of habitat loss on production of eels (ICES, 2020).

When addressing habitat loss for a migratory species such as the European eel, most of the attention is usually given to the inability of glass eels or young yellow eels to reach the upstream part of riverine systems and migrate back to sea as yellow or silver eels. As a result, a substantial body of literature describes the impact of barriers delaying or blocking eel migration.

In the Mediterranean region, less information is available on the impact of longitudinal river continuity alterations on eels. In the Mediterranean, the overexploitation of water resources, possibly coupled with natural and human-induced climate change, has led to a 20 percent decrease in river run-off within the past half-century, simultaneously increasing the frequency and duration of low flow events (Karaouzas *et al.*, 2018). In the large permanent rivers of this region, water flows can be so low that the longitudinal connectivity is affected or interrupted, even if rivers do not dry up completely. Meanwhile the abundant temporary rivers and streams in the Mediterranean region, dry up during the summer resulting in habitat loss for fish communities and eels (Arthington, Bernardo and Ilhéu, 2014; Karaouzas *et al.*, 2018).

River flows may also play a significant role in glass eel recruitment to inland waters, probably because reductions in river flow negatively affect their attraction into the river mouths, exerting a negative effect on local eel stocks (Tesch, 2004). This has been highlighted for many estuaries, such as the Mondego (Domingos, 1992), Guadalquivir (Arribas *et al.*, 2012) and Minho (Correia *et al.*, 2018). Although not strictly habitat loss, reductions in river flow can be considered as habitat alteration, potentially influencing recruitment and causing overall species decline (Kettle, Vøllestad and Wibig, 2011).

Another critical habitat loss factor for the eel has been land reclamation in coastal zones, which has been extensive over the entire distribution area. Reclamation and surface area reductions of transitional waters and wetlands have probably played a significant role in the Mediterranean region. An important proportion of the eel population is found in coastal lagoons, habitats that eels colonize at the glass eel stage and where they can spend their entire growing phase, up to silvering and migration to sea. The importance of these habitats for eel has been highlighted, with particular reference to coastal lagoon habitats (Aalto *et al.*, 2016; Cataudella, Crosetti and Massa, 2015). Many coastal lagoons have survived through time only because of social and economic interest in fish production, but massive reclamation interventions have progressively caused the disappearance of several coastal wetland areas over the centuries (Cataudella, Crosetti and Massa, 2015). Furthermore, the coverage and fate of lagoons have been impacted by human population growth, agricultural needs and measures taken to address malaria epidemics, especially in rural areas.

An evaluation of available habitats, by type and country, across the entire European eel area of distribution was carried out in 2010, bringing together data presented by countries in national assessments for management plans (ICES, 2010). The results showed that there were inconsistent estimates within and between countries and that data were not used uniformly in national assessments, while most data from the southern area and specifically the Mediterranean, were missing.

Further efforts in 2020 focused on understanding the processes and quantifying the impact of habitat loss on eel production (ICES, 2020), when a case study of Mediterranean lagoons was selected for its representativeness and to provide a realistic view of the complexities encountered when analysing habitat loss. The analysis included the case of the Comacchio lagoons, on the Adriatic coast of northern

Italy, an example of massive intervention due to reclamation of a site where eels have been exploited for ages and many studies have been carried out (Rossi, 1979; De Leo and Gatto, 1996; 2001; Castaldelli *et al.*, 2014; Ciccotti, 2015; Aschonitidis *et al.*, 2015; 2016). In this preliminary analysis, the role of habitat loss, changes in environmental quality and ecological functionality of coastal lagoons, socio-economic changes and resulting increased anthropogenic pressure were highlighted as factors linked to decreasing eel populations in the Mediterranean, in combination with intrinsic factors affecting global eel stocks, particularly the overall decline in recruitment (Aalto *et al.*, 2016).

The aim of this chapter was to fill the information gap for the Mediterranean region, by:

- quantifying the wet areas of habitat available and not available to eels;
- assessing the total amount of lost surface area;
- comparing current and lost surface areas in each habitat type and in each country; and
- obtaining detailed information on past and present wetted areas at the site level, as provided by the habitat database, to contribute to the assessment to be carried out at site level in Work Package 4 (Stock Assessment).

2.2 METHODS

2.2.1 Habitat definition and surface area calculation

The calculation of wetted areas was carried out in all sites considered suiTable 2.for eels, where its presence was certain (excluding areas such as temporary pools, salt pans and ditches), in four main habitat typologies of lagoons, rivers, river estuaries and lakes.

The ***current surface*** area is considered as the whole wetted area available to eels. It was calculated differently, depending on the different habitats:

- *Estuaries, deltas or marshlands*: the current surface area was measured from the mouth of the river up until 30 km upstream of the main channel, or by considering the extent of the permanently saline wedge (when available).
- *Rivers*: the current surface area was considered as the freshwater area from the end of the estuary zone to the first unsurpassable barrier (see below), at the present time. When a precise measurement was missing, the surface area was estimated by calculating the average width of the river for each representative segment (or every five km) and adding together the surface areas of each segment.
- *Lagoons*: the current surface area was the available habitat for eels at the present time.
- *Lakes*: for water bodies with an average depth of more than 20 m, the current surface area considered suiTable 2.for eels was calculated as ten percent of the total lake surface. For lakes with an average depth less than 20 m, the entire surface area was considered.
- *Coastal waters*: the available surface area for eels was considered as the marine area within one nautical mile (1 852 m) from the coast. The surface area was calculated by splitting the coastal areas into segments: these corresponded to EMUs, or into smaller segments that provided precise information on the area.

The potential surface area is the habitat surface area currently not accessible to eels (referred to the pre-reclamation surface area, or the surface area prior to any intervention), therefore it is considered as a ***lost surface area***.

- *Rivers*: the lost surface area is the wetted area above the first unsurpassable barrier without an eel-pass, up to an altitude of 1 000 m above sea level. The first unsurpassable barrier was defined as any obstacle, without an eel-pass, that alters the natural dynamics of migration and free movement of eels. Similar to the current surface area, the lost surface area was calculated by estimating the average width of the river every 5 km and adding up the areas of each representative segment, or by using a more accurate measurement when available.

- *Lagoons and estuaries*: the lost surface area corresponded to the habitat available to eels at a time prior to land use modification (for example, agricultural, channelization or land reclamation), considering all the changes that have occurred since the mid-1800s.
- *Lakes*: the lost surface area corresponds to the habitat available to eels at a time prior to land use modification (for example, extraction or drainage), considering all the changes that have occurred since the mid-1800s. For water bodies with an average depth of more than 20 m, the lost surface area was calculated as 90 percent of the total lake surface.
- *Coastal waters*: the lost surface area consisted only of the area presently occupied by large ports.

For all habitat typologies, a percentage of lost surface area was also calculated, as the proportion of inaccessible area (lost surface area) divided by the total surface area (current + lost).

Each habitat surface was geo-referenced in decimal degrees with the projection WGS84-EPSG4326:

- *Lagoons and lakes*: the central point of the water body was used;
- *Rivers* were considered as a whole and the coordinates assigned to the midpoint (or centroid) of the catchment area;
- *Estuaries*: the coordinates were those of the midpoint of the estuary area;
- *Coastal waters*: the coordinates were the centroid of the segments into which the coastline has been divided.

2.2.2 Quality check and data analysis

Before performing quantitative analysis on the surfaces, a technical quality check was carried out. Corrections included duplicate rows, site names with spelling errors, inconsistencies between coordinates and site errors (for example, the same site with different coordinates, or same coordinates for different sites), in the attribution of current and lost surface areas, and empty cells.

After a cross-check with the fishery database and to meet the requests of Work Package 4 (Stock Assessment, Chapter 13), it was necessary to ask the country providers for data integration and corrections. As the information collected on coastal marine waters was scattered and often not reliable, this habitat type was excluded from the analysis. At the same time, all the sites for which the wetted area was not reported and those in which migratory movement (both recruitment and escapement) was completely hindered were also excluded.

Finally, following a long and detailed revision of the entire database, a final agreed version was available, that was used for the quantitative analysis in the following habitat types: lagoons, rivers, estuaries and lakes.

The sites in the database were plotted in maps showing their location and habitat type, as well as their accessibility to eels. Single site surfaces were aggregated and analysed by habitat type as well as separately according to each country, comparing the current and lost (not accessible) areas. The mean percentage of lost surface areas by country and habitat were also calculated and compared.

All the maps were made using the software QGIS (2021). All the graphs were made through the "ggplot2" package (Wickham, 2016) of R software (R Core Team, 2021).

2.3 RESULTS

2.3.1 Overview of the sites

Figure 2.1 shows the geographical distribution of all eel sites, for all habitat types. Data on wetted areas were documented for 618 sites in the habitat database. Most were lagoons (275 sites), followed by estuaries (150 sites), rivers (148 sites) and lakes (45 sites). The countries with the highest number of sites were Italy (148 sites, of which 70 percent were lagoons), Spain (124 sites, evenly distributed between lagoons, estuaries and rivers) and France (97 sites, of which almost half were lagoons) (Table 2.1).

All nine countries recorded lagoon habitat, three countries did not record lakes (Egypt, France and Spain), while estuary habitat information was not available for Albania and Tunisia did not record rivers (Table 2.1).

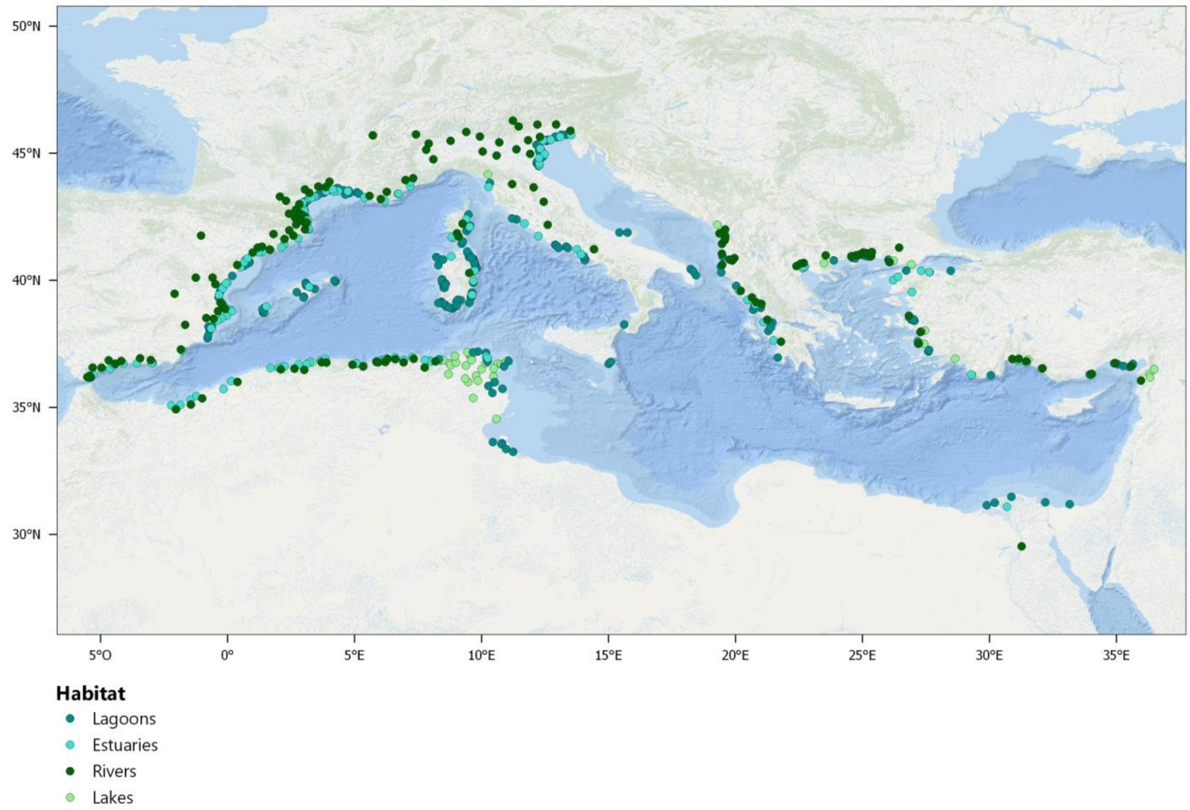

Figure 2.1. Map of all sites recorded in the database, distinguished by type of habitat.

Table 2.1. Distribution of sites by habitat and country (number of sites)

Country	Habitat				
	Lakes	Lagoons	Estuaries	Rivers	Total
Albania	1	8	0	10	19
Algeria	3	2	29	20	54
Egypt	0	5	1	1	7
France	0	46	27	24	97
Greece	2	32	11	19	64
Italy	1	103	19	25	148
Spain	0	38	49	37	124
Tunisia	26	19	4	0	49
Türkiye	12	22	10	12	56
Total	45	275	150	148	618

2.3.2 Total wetted areas

The largest amount of wetted area (current surface area) was found in Egypt, Greece, Italy and Tunisia. Egypt, Italy and Türkiye showed the highest values for lost surface area (not accessible), whereas Greece had the lowest amount of lost surface area. However, the information on lost surface area was incomplete for France and Tunisia, as the estimation was missing for many sites (Figure 2.2, Table 2.2).

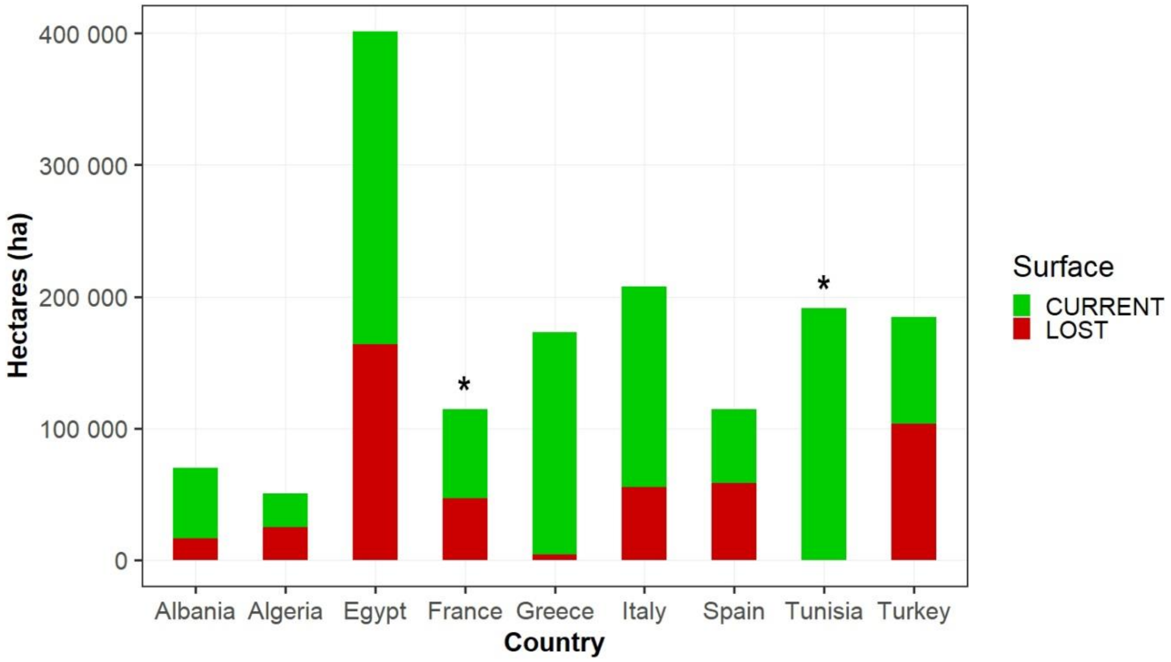

Figure 2.2. Total current and lost surface areas by country (hectares)

*lost surface area not available for some sites

Table 2.2. Total current and lost surface area of eel habitat by country (hectares), with indicative number and percentage of sites where there was no data (ND)

Country	Current surface area (ha)	ND (percent)	Lost surface area (ha)	ND (percent)	Number of sites	Number of ND sites
Albania	53 448	0	16 552	0	19	0
Algeria	25 428	0	25 222	0	54	0
Egypt	237 923	0	163 722	0	7	0
France	67 334	0	47 052	49	97	48
Greece	168 608	0	4 128	0	64	0
Italy	152 318	0	55 601	0	148	0
Spain	55 756	0	58 687	0	124	0
Tunisia	191 079	0	0	94	49	46
Türkiye	80 648	0	103 614	0	56	0

2.3.3 Wetted areas by habitat

The surface area of lakes was available for nearly all countries, except for a large amount of lost surface area for Turkish lakes and there was no information about lake lost surface area for Tunisia. In Italy only one lake was considered, whereas in Egypt, France and Spain, lakes were not evaluated (Figure 2.3, LAK).

Lagoon surface area accounted for the highest surface area among all habitats, totalling around 755 000 ha (Figure 2.1; Tables 2AR1.1–2AR1.4 in Additional Results Part I). Only in Albania, Algeria and Greece was all lagoon surface area considered as accessible to eels. Egypt showed the highest value for lagoon lost surface area while in France and Tunisia there was no information on lost surface area for almost all lagoon sites (Figure 2.3, LGN).

Egypt showed the highest surface area available to eels in estuarine areas (more than 20 000 ha in the Nile Delta). In Spain most of estuarine area was lost, as well as in Türkiye where more than half of the total surface area was not currently available. For France, information on lost surface area for this habitat was only available for a few sites, whereas information was missing for all Tunisian estuaries and Albanian estuaries were not evaluated (Figure 2.3, RIE).

The highest values for current surface area in rivers were found in Türkiye, Spain, Egypt and Italy. However, rivers were the habitat with the largest share of lost surface area in all countries, especially in Türkiye, France and Spain. In Tunisia, rivers were not evaluated (Figure 2.3, RIV).

For more details, see Figure 2.1 and Tables 2AR1.1–2AR1.4 in Additional Results Part I.

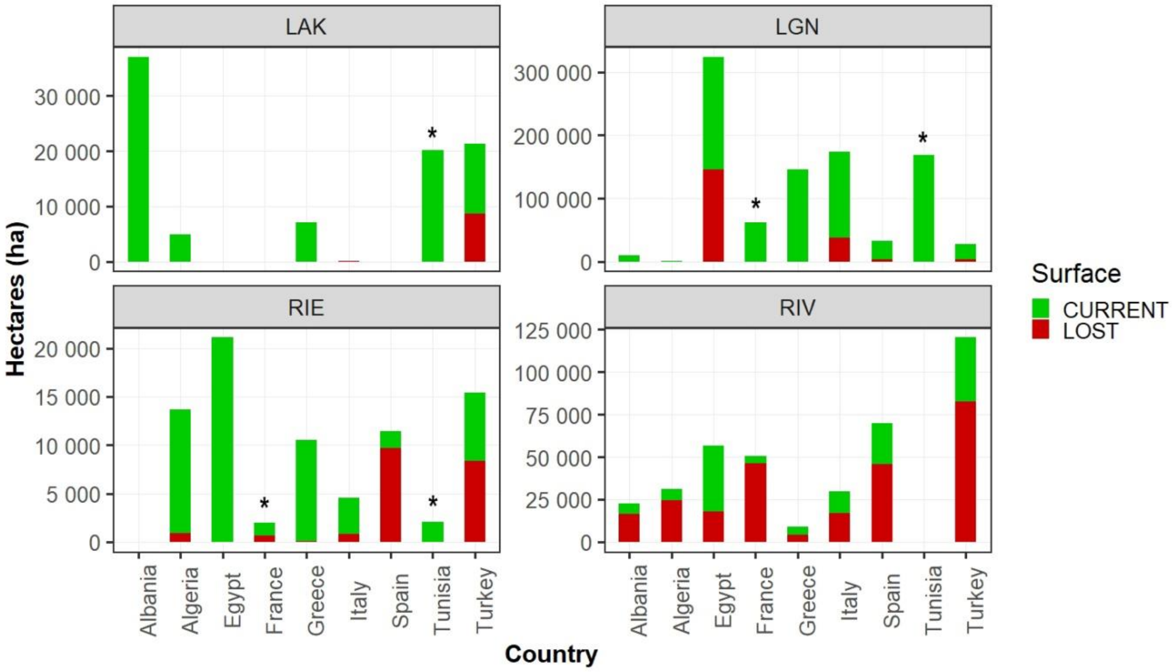

Figure 2.3. Current and lost surface areas for the four habitat types (LAK: lakes; LGN: lagoons; RIE: estuaries; RIV: rivers) by country (ha).

*lost surface area not available for some sites.

Note the different scale on the y-axis (hectares) for each habitat.

2.3.4 Lost surface area

The highest percentage of lost surface area was observed in rivers. For most countries, it was estimated that more than 50 percent of eel habitat had been lost. Estuaries had large amounts of habitat that were no longer accessible to eels, especially in Spain and Türkiye, but also in France (more than 25 percent). Italy appeared to have the highest percentage of habitat not accessible to eels for lakes, but this evaluation was based on a single lake so the data were not considered representative for the habitat. Forty percent of Turkish lake surface area was not accessible while in Egypt almost 50 percent of the lagoon surface was lost and there was no information on lost surface area in Tunisian habitats (Figure 2.4).

The total amount of lost surface area in each type of habitat (Figure 2.5), highlighted that rivers were the most inaccessible habitats (65 percent of surface lost), followed by estuaries (25 percent), lagoons (20 percent) and lakes (ten percent).

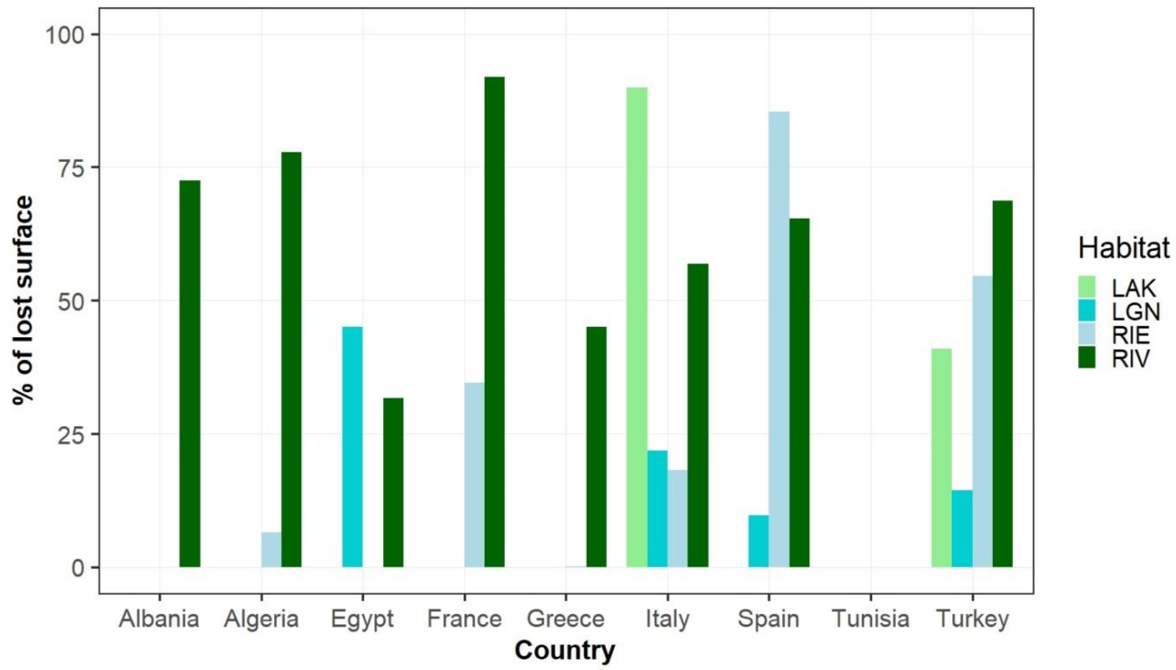

Figure 2.4. Proportion (from 0 to 100 percent) of lost surface area by country and habitat (LAK: lakes; LGN: lagoons; RIE: estuaries; RIV: rivers)

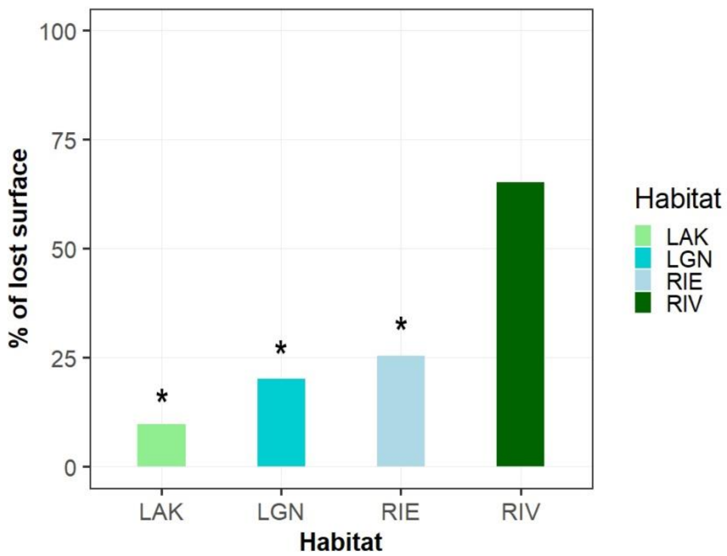

Figure 2.5. Proportion (from 0 to 100 percent) of lost surface by habitat (LAK: lakes; LGN: lagoons; RIE: estuaries; RIV: rivers).

*lost surface area not available for some sites.

Figure 2.6 shows the degree of accessibility for eels in each site, indicating that 53 percent of the sites surveyed were completely accessible (lost surface = 0), 27 percent had variable amounts of lost surface (two thirds of which had lost surface values greater than 50 percent) while five percent of the sites were completely inaccessible to eels (lost surface = 100). For 94 sites out of 618 (15 percent), there was no information about lost surface area, mainly distributed in lagoons and lakes (Table 2.3).

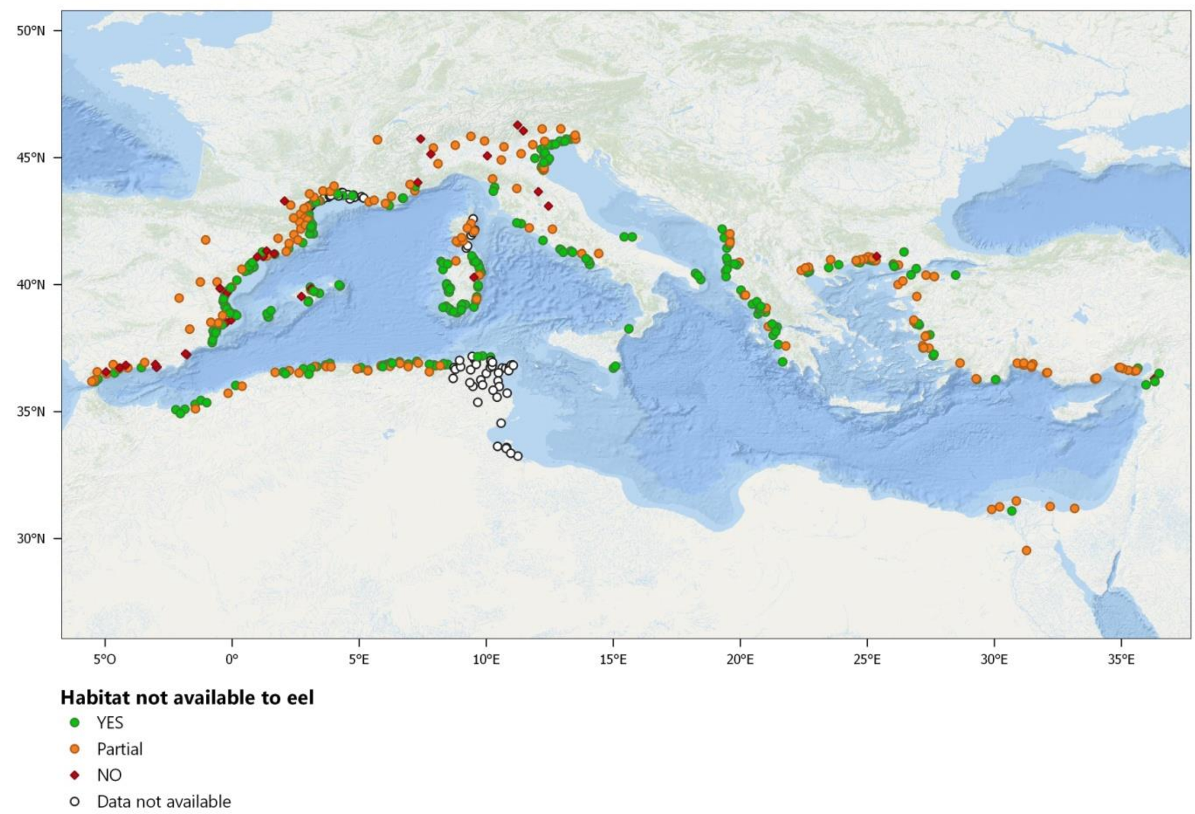

Figure 2.6. Map of the availability of sites to eels: green = all the wetted area is accessible (100 percent); orange = only a portion of the wetted surface is accessible (1–99 percent); red = all habitat surface area has been lost (0 percent accessible)

Table 2.3. Accessibility of sites to eels by proportion of lost surface area (percent) and habitat type

Habitat	Number of totally accessible sites Lost 0%	Number of partially accessible sites Lost < 50%	 Lost > 50%	Number of inaccessible sites Lost 100%	ND (percent)	Number of ND sites	Total number of sites
LAK	11	6	1	1	58	26	45
LGN	192	12	5	4	23	62	275
RIE	98	12	28	6	4	6	150
RIV	28	28	72	20	0	0	148
Total	329	58	106	31		94	618

ND: no data

2.3.5 Wetted areas by country

Albania. Although only one lake was evaluated, its current surface (37 000 hectares) covered the largest extent of all wetted areas in Albania. On the other hand, almost 75 percent of river surface was not accessible to eels. Estuaries were not evaluated (Figure 2.7).

Algeria. The predominant habitats in Algeria were estuaries (28 sites) and rivers (20 sites). Rivers also had the highest value for lost surface area (more than 75 percent) (Figure 2.7).

Egypt. Egypt had the largest wetted area of all the countries surveyed (228 000 hectares). The largest surface area was in lagoons, although almost 50 percent of lagoon surface area was not accessible to eels (Figure 2.7).

France. The current and accessible surface of French lagoons was more than 60 000 hectares, but no quantification was provided on the lost surface area. Rivers were for the most part inaccessible to eels (only 4 000 ha out of 46 400 ha). Lakes were not evaluated (Figure 2.7).

Greece. All habitats in Greece were completely accessible to eels, except for 50 percent of the river surface. The largest surface area share was represented by lagoons (146 000 ha) (Figure 2.7).

Italy. The predominant eel habitat in Italy was represented by lagoons (103 sites, 135 600 ha), whose lost surface area amounted to approximately 20 percent. Rivers had a large proportion of not accessible surface area (57 percent) (Figure 2.7). A noteworthy situation regarding Italian lakes was that all sites, except the only one considered in the analysis, do not presently have a connection with the sea. However, significant eel commercial fisheries are present in 13 lakes (see Chapter 10, Eel landings) that hold residual eel local stocks based on past recruitment and on stocking activities to support the eel fishery. The current wetted areas of these lakes were not included in the analysis, because they cannot presently be considered as a natural habitat, as they are not accessible. However, they are considered a potentially available surface (Table 2.4) in a hypothetical scenario where obstacles to natural migration are removed (see Chapter 13, Assessment).

Table 2.4. Potentially available surfaces of Italian lakes presently not connected to the sea, if obstacles were removed.

Site name	EMU	Surface area potentially available (ha)
Bolsena	IT_Lazi	1 145
Bracciano	IT_Lazi	575
Chiusi	IT_Tosc	387
Comabbio	IT_Lomb	359
Como	IT_Lomb	1 455
Corbara	IT_Umbr	115
Garda	IT_Lomb, IT_Vene, IT_Tren	3 690
Idro	IT_Lomb	114
Iseo	IT_Lomb	618

Maggiore	IT_Lomb	2 122
Montepulciano	IT_Tosc	188
Trasimeno	IT_Umbr	12 800
Varese	IT_Lomb	1 456
	Total	25 024

Spain. Lagoons and rivers represented the largest proportion of the wetted areas available to eels (54 000 ha in total) while 65 percent of river surface area was lost and the not accessible proportion increased to 85 percent for estuaries. Lakes were not evaluated (Figure 2.7).

Tunisia. The predominant habitat in Tunisia was represented by lagoons (169 000 ha), followed by lakes (20 000 ha). No quantification of the lost surface area for any of the habitats was provided. Rivers were not evaluated (Figure 2.7).

Türkiye. The current surface of wetted areas was mainly distributed in rivers (37 600 ha), lagoons (23 400 ha) and lakes (12 500 ha). Rivers showed the highest value for lost surface area (69 percent), but lakes and estuaries also had a large share of area not accessible to eels (more than 40 percent) (Figure 2.7).

For more details, see Figure 2.1 and Tables 2AR2.1–2AR2.9 in Additional Results Part II.

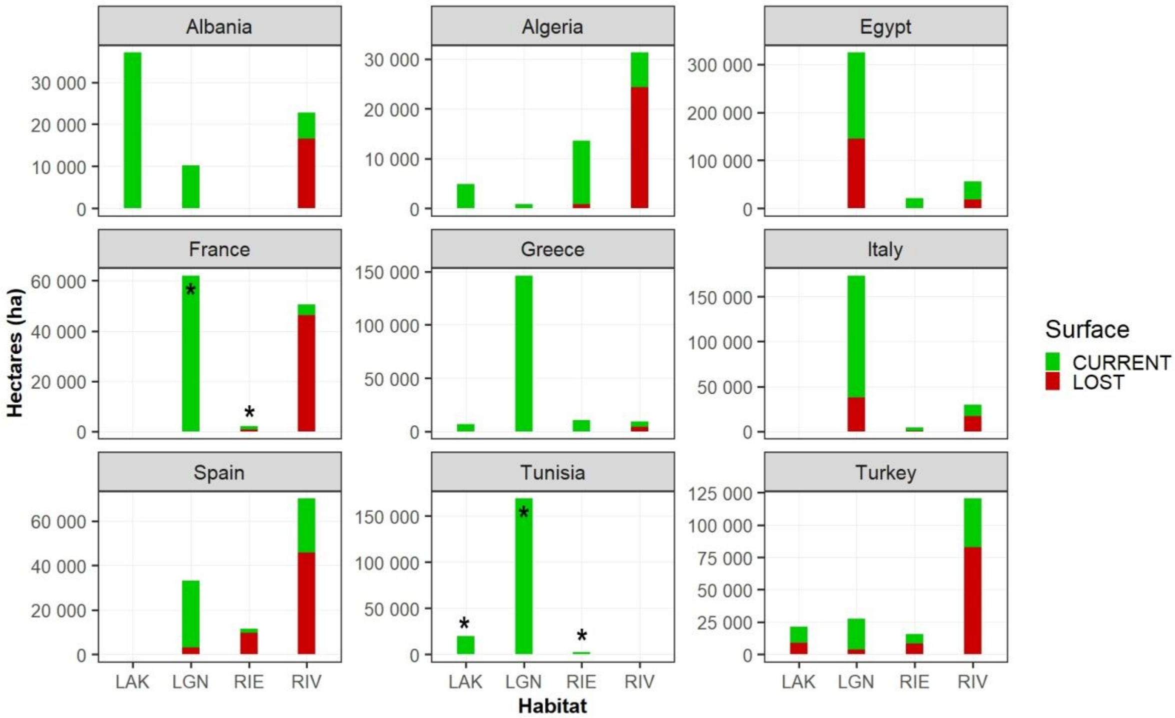

Figure 2.7. Current and lost surface areas for the nine countries by habitat type: (LAK: lakes; LGN: lagoons; RIE: estuaries; RIV: rivers).

*lost surface area not available for some sites.

Note the different scale on the y-axes (hectares) for each country.

2.4 DISCUSSION AND CONCLUSIONS

The results of this analyses provided, for the first time, an evaluation of wetted areas available to eels in nine countries in the Mediterranean region, including most sites that are eel habitat and where local eel stocks are present. All countries provided a census of elective sites for eels as complete as possible, for a total of 700 sites for which information was collected. Current surface areas were provided for each site, but there were missing data for lost surface areas, due to the complexity of estimating or finding historical information, especially for pre-reclamation surface areas.

Wetted areas for all habitat types were evaluated, for both brackish (lagoons and estuaries) and freshwater (rivers and lakes) habitats. The database also includes an estimate of coastal marine waters for some countries, but data were scattered and often not reliable, therefore this habitat was excluded from the analysis.

The largest available area for eels was in lagoon habitats, where traditional fisheries and specific management schemes are present in most countries, as well as the management and exploitation of eel stocks.

Lagoons showed the lowest percentage of lost surface area, compared to other habitats. On the contrary, rivers and estuaries had large shares of surface area presently inaccessible to eels. Lake surface areas were evaluated only by some countries. In many of them, lakes were not connected to the sea and consequently, the habitat could not be reached by eels by natural means, so they were not considered. It is worth noting the case of 13 Italian lakes where natural migration is presently hindered but which, thanks to restocking activities, significant eel fishing activities are supported.

Results of this quantitative analysis on the current and lost surface areas should be considered with caution. Although the ‘read-me’ of the database included general guidelines on how to calculate wetted areas for the five habitat types, each country calculated them on the basis of available data and information sources, using the methodology considered most appropriate. Further quality control measures for standardization are advisable, as well as the integration of data for missing sites in some countries.

Nevertheless, this assessment and measurement of wetted areas at site level is an important step as it is the first time that lost and current eel habitats in the Mediterranean region have been quantified. It also forms an important dataset for subsequent analyses carried out in the other tasks and WPs of the project. These include assessment of eel habitat quality (Chapter X), eel productivity (Chapter 10) and evaluation of present and potential management strategies at site level (WP4, Chapter 13). It is also important from a methodological point of view, because it constitutes the prerequisite for any evaluation of the state of eel populations.

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Additional Results Part I – Current and lost wetted areas (ha) of eel habitats by typology (cumulative and by country), total number of sites surveyed and percentage of sites for which data were not available

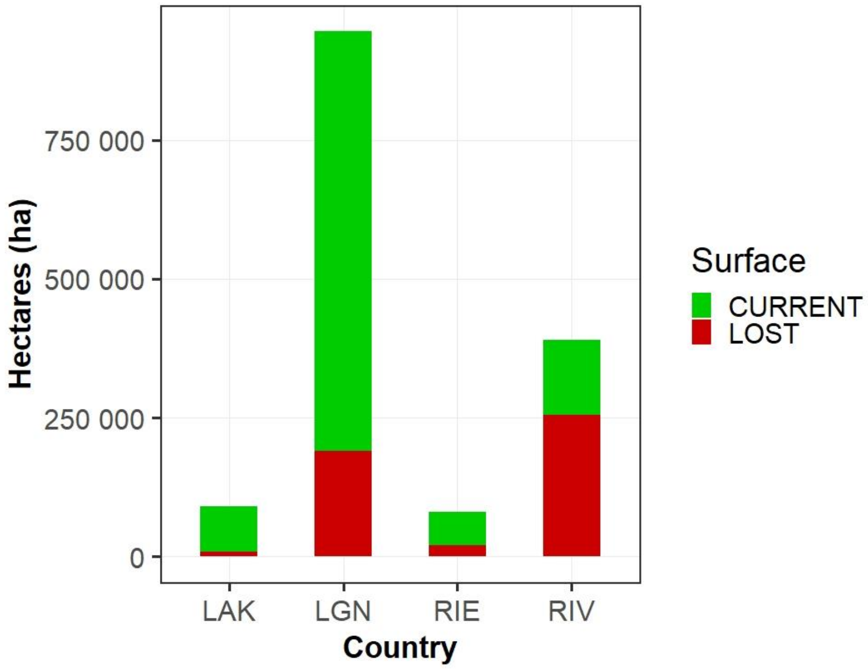


Figure 2AR1.1. Cumulative surfaces of all Countries per habitat.

In the following tables (Tables 2AR1.1–2AR1.4), per each habitat are reported:

- the current and the lost surfaces (in hectares),
- the percentage of unavailable area value, no data (ND percent),
- the total number of sites and the number of sites with no data (ND).

Table 2AR1.1. Lakes

LAKES						
	Current surface area (ha)	ND (percent)	Lost surface area (ha)	ND (percent)	Number of sites	Number of ND sites
Albania	37 000	0	0	0	1	0
Algeria	4 875	0	0	0	3	0
Egypt	0	0	0	0	0	0
France	0	0	0	0	0	0
Greece	7 048	0	0	0	2	0
Italy	4	0	35	0	1	0

Spain	0	0	0	0	0	0
Tunisia	20 097	0	ND	100	26	26
Türkiye	12 565	0	8 711	0	12	0
Total	81 589		8 746			

ND = No data

Table 2AR1.2. Lagoons

LAGOONS						
	Current surface area (ha)	ND (percent)	Lost surface area (ha)	ND (percent)	Number of sites	Number of ND sites
Albania	10 160	0	0	0	8	0
Algeria	871	0	0	0	2	0
Egypt	178 078	0	145 722	0	5	0
France	61 985	0	ND	100	46	46
Greece	146 110	0	0	0	32	0
Italy	135 641	0	37 737	0	103	0
Spain	29 868	0	3 180	0	38	0
Tunisia	168 892	0	0	84	19	16
Türkiye	23 444	0	3 935	0	22	0
Total	755 049		190 574			

ND = No data

Table 2AR1.3. Estuaries

ESTUARIES						
	Current surface area (ha)	ND (percent)	Lost surface area (ha)	ND (percent)	Number of sites	Number of ND sites
Albania	0	0	0	0	0	0
Algeria	12 748	0	896	0	29	0
Egypt	21 100	0	0	0	1	0
France	1 307	0	692	7.4	27	2
Greece	10 432	0	20	0	11	0

Italy	3 751	0	835	0	19	0
Spain	1 670	0	9 729	0	49	0
Tunisia	2 090	0	ND	100	4	4
Türkiye	6 988	0	8 379	0	10	0
Total	60 086		20 551			

ND = No data

Table 2AR1.4. Rivers

RIVERS						
	Current surface area (ha)	ND (percent)	Lost surface area (ha)	ND (percent)	Number of sites	Number of ND sites
Albania	6 288	0	16 552	0	10	0
Algeria	6 934	0	24 326	0	20	0
Egypt	38 745	0	18 000	0	1	0
France	4 043	0	46 359	0	24	0
Greece	4 999	0	4 090	0	19	0
Italy	12 922	0	16 993	0	25	0
Spain	24 218	0	45 778	0	39	0
Tunisia	0	0	0	0	0	0
Türkiye	37 651	0	82 589	0	12	0
Total	135 800		254 687			

ND = No data

Additional Results Part II – Current and lost wetted areas (ha) of eel habitats by country (cumulative and by habitat typology), total number of sites surveyed, and percentage of sites for which data were not available

Variability of wetted areas per country

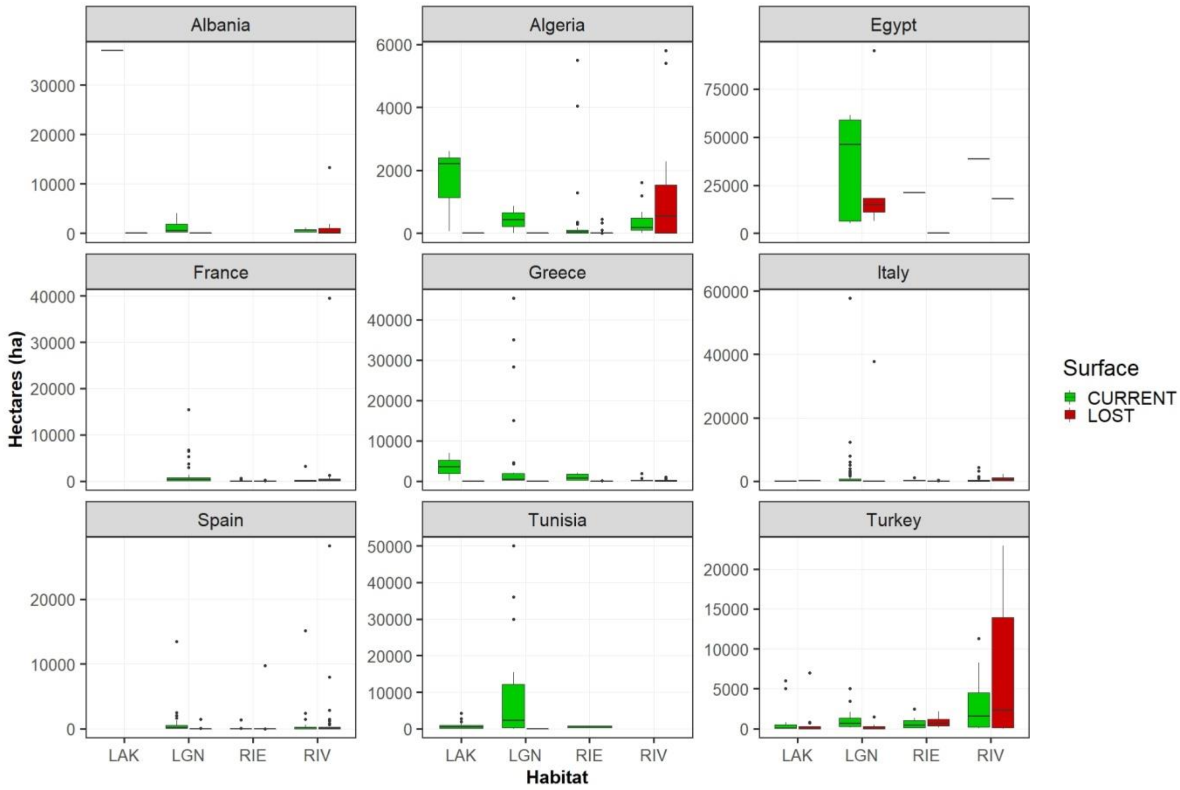


Figure 2AR2.1. Current and lost surface areas in each country for the four habitat typologies (LAK: lakes; LGN: lagoons; RIE: estuaries; RIV: rivers). Note the different scale on the y-axes (hectares) for each country.

Surface areas per country

In the following tables (Tables 2AR2.1–2AR2.9), the surface areas for each country and habitat (LAK: lakes; LGN: lagoons; RIE: estuaries; RIV: rivers) include:

- the current and the lost surface areas (in hectares),
- the percentage of unavailable area values with no data (ND),
- the total number of sites and the number of sites with no data (ND).

Table 2AR2.1. Albania

	Current surface area (ha)	ND (percent)	Lost surface area (ha)	ND (percent)	Number of sites	Number of ND sites
LAK	37 000	0	0	0	1	0
LGN	10 160	0	0	0	8	0

RIE	0	0	0	0	0	0
RIV	6 288	0	16 552	0	10	0

Table 2AR2.2. Algeria

	Current surface area (ha)	ND (percent)	Lost surface area (ha)	ND (percent)	Number of sites	Number of ND sites
LAK	4 875	0	0	0	3	0
LGN	871	0	0	0	2	0
RIE	12 748	0	896	0	28	0
RIV	6 934	0	24 326	0	20	0

Table 2AR2.3. Egypt

	Current surface area (ha)	ND (percent)	Lost surface area (ha)	ND (percent)	Number of sites	Number of ND sites
LAK	0	0	0	0	0	0
LGN	178 078	0	145 722	0	5	0
RIE	21 100	0	0	0	1	0
RIV	38 745	0	18 000	0	1	0

Table 2AR2.4. France

	Current surface area (ha)	ND (percent)	Lost surface area (ha)	ND (percent)	Number of sites	Number of ND sites
LAK	0	0	0	0	0	0
LGN	61 985	0	ND	100	46	46
RIE	1 307	0	692	7.4	27	2
RIV	4 043	0	46 359	0	24	0

Table 2AR2.5. Greece

	Current surface area (ha)	ND (percent)	Lost surface area (ha)	ND (percent)	Number of sites	Number of ND sites

LAK	7 048	0	0	0	2	0
LGN	146 110	0	0	0	32	0
RIE	10 432	0	20	0	11	0
RIV	4 999	0	4 090	0	19	0

Table 2AR2.6. Italy

	Current surface area (ha)	ND (percent)	Lost surface area (ha)	ND (percent)	Number of sites	Number of ND sites
LAK	4	0	35	0	1	0
LGN	135 641	0	37 737	0	103	0
RIE	3 751	0	835	0	19	0
RIV	12 922	0	16 93	0	25	0

Table 2AR2.7. Spain

	Current surface area (ha)	ND (percent)	Lost surface area (ha)	ND (percent)	Number of sites	Number of ND sites
LAK	0	0	0	0	0	0
LGN	29 868	0	3 180	0	38	0
RIE	1 670	0	9 729	0	49	0
RIV	24 218	0	45 778	0	39	0

Table 2AR2.8. Tunisia

	Current surface area (ha)	ND (percent)	Lost surface area (ha)	ND (percent)	Number of sites	Number of ND sites
LAK	20 097	0	ND	100	26	26
LGN	168 892	0	0	84	19	16
RIE	2 090	0	ND	100	4	4
RIV	0	0	0	0	0	0

Table 2AR2.9. Türkiye

	Current surface area (ha)	ND (percent)	Lost surface area (ha)	ND (percent)	Number of sites	Number of ND sites
LAK	12 565	0	8 711	0	12	0
LGN	23 444	0	3 935	0	22	0
RIE	6 988	0	8 379	0	10	0
RIV	37 651	0	82 589	0	12	0

CHAPTER 3. EEL HABITATS IN THE MEDITERRANEAN: OVERVIEW OF MAIN ENVIRONMENTAL FEATURES

ABSTRACT

Environmental data in the habitat database were used to describe the basic environmental features of eel habitats in the Mediterranean in lagoons, river estuaries, rivers and lakes, based on the available data collected for each site where eels were present and to give an overview by country. The data used were the basic physicochemical parameters at each site including annual average temperatures, annual average salinities, salinity typologies, total chlorophyll-a concentrations, total phosphorus concentrations and total nitrogen concentrations. Data provided for single sites spanned the period between 1979 and 2020. For most parameters, the data provided for lagoon sites were abundant and exhaustive, while data for estuaries and freshwater habitats were incomplete. Results showed that in transitional waters (lagoons and river estuaries) annual average temperatures were higher than in river and lake habitats. Based on trophic status parameters, most Mediterranean lagoons can be classified as being mesotrophic or eutrophic.

HIGHLIGHTS

- This chapter presents information on the data availability for specific environmental parameters in eel sites, on the annual average temperatures, on annual average salinities and salinity typologies, as well as on the trophic status of all sites, based on total chlorophyll-a, phosphorus, and nitrogen concentrations.
- Descriptions of site-level environmental features are important for the work on assessment of eel habitats under Work Package 4 of the eel research programme.
- Coastal lagoons have physicochemical characteristics that make them ideal eel habitats, in terms of productivity, salinity and temperature.
- The susceptibility of coastal lagoons to increases in temperature and salinity, that could trigger changes in trophic status in response to climate change, emerged as an important factor to be taken into account when envisioning future eel management scenarios, particularly in light of its status as an umbrella species.

3.1. INTRODUCTION

When addressing habitat-related issues for eel, there is agreement on the need to investigate the potential role of habitat quality and degradation, along with habitat loss, based on the awareness that a combination of natural causes and anthropogenic pressures has been impacting the eel stock and its habitats over the entire distribution range of the species, including the Mediterranean (Jacoby *et al.*, 2015; Miller, Feunteun and Tsukamoto, 2016; Drouineau *et al.*, 2018). This requires consideration of a number of different issues including loss of longitudinal connection in rivers and river flow regulation, reduced connectivity with the sea in coastal lagoons, chemical contamination and eutrophication, competition and predation from indigenous and invasive non-indigenous species and the spread of species-specific diseases.

For eels, the link between abundance and habitat quality may not be straightforward. Feunteun (2002) proposed using the eel as a bio-indicator of environmental changes stating that when eels disappear from a river, the aquatic system is in a bad state and restoration is required. However, the eel is a resilient species that can adapt to different conditions when there is an opportunity to migrate to better conditions or habitats, whether these are in coastal, transitional or inland waters (Arai, Kotake and McCarthy, 2006; Daverat *et al.*, 2006; Marohn, Jakob and Hanel, 2013).

Brehmer *et al.* (2013) found no link between the relative abundance of European eel and habitat quality (eutrophication and ecotoxicity levels) in three coastal lagoons. On the other hand, Capoccioni *et al.* (2020), found that eel quality evaluation matched the results of the environmental quality assessment in Italian coastal lagoons.

Some aspects of the possible effects of habitat degradation on eel stocks were considered in 2020 by the joint European Inland Fisheries and Aquaculture Advisory Commission (EIFAAC)/International Council for Exploration of the Sea (ICES)/GFCM Working Group on European Eel (WGEEL) (ICES, 2020), that focused mainly on understanding the processes and quantifying the impact of habitat loss on eel production. This review pointed to the fact that such effects are mentioned and considered in many studies, in national assessments and eel management plans, but rarely taken fully into account. Information on habitat status for detailed analysis related to eel is often incomplete or inconsistent.

In this context, addressing the issue of eel habitat characterization requires a multi-step approach that should consider the regional scale, because of the geographic and climatic peculiarities of the different parts of the eel distribution range. Therefore, one of the main aims of the research programme (RP) was to start to fill information gaps for the Mediterranean region and establish a methodology to gather, analyse and summarize data related to eel habitats. The approach followed in the RP, as outlined in Chapter 1, was to study the information obtained by the habitat-related data collection in Work Package (WP) 3 at three levels, starting with quantitative analysis of eel habitats (Chapter 2), followed in this chapter by descriptive analysis and characterization of each type of eel habitat, based on the main physicochemical parameters. This chapter also includes a comprehensive qualitative analysis taking into account parameters such as pollutants and habitat-use, to provide site-level estimates of habitat quality for eel.

Results are presented relative to descriptive features at the site-level to obtain a description of the main environmental features for the four habitat typologies of lagoons, rivers, river estuaries and lakes, as well as a preliminary overview of the main environmental features of eel habitats at the country level.

3.2. METHODOLOGY

The work relied on the environmental data collected in WP3, using the methodology specified in Chapter 1. Site-level data were provided for each country, based on reports and archive material from environmental agencies, integrated with grey literature (for example, reports from monitoring programmes carried out within any framework) and with scientific literature as detailed in the

Introduction. It must be clearly stated here that the habitat data were not exhaustive, due to the limits set by the timing of the RP and the COVID-19 pandemic, while also considering that they required in-depth research and consultation with institutions and agencies operating in very different areas. The number of sites for which there was adequate coverage, in terms of the variables provided, time spans and overall representativeness, was variable between the various countries and the different habitat types. However, it was considered useful to proceed with this descriptive work, to validate the methodology for storing data and representing results, and to give a general overview, including of the main critical issues. Available data are described in detail in Table 3.1.

The final database used to describe eel habitat included numerical and descriptive data. Numerical data included annual average temperature (ºC, Awt), annual average salinity (g/L, Av_sal), total chlorophyll-a concentration (µg/L, Ts_Chla_conc), total phosphorus concentration (µg/L, Ts_Pt_conc) and total nitrogen concentration (µg/L, Ts_Nt_conc). For these datasets, mean, standard deviation and range (min–max) were calculated, by habitat type, for each country with R software (R Core Team, 2021) using the “descr” package (Aquino *et al.*, 2015) to generate descriptive overviews.

Descriptive data included salinity typology (Sal_tip) and trophic status. Salinity typologies were categorized as freshwater, oligohaline, mesohaline, polihaline, euhaline, and hyperhaline (WFD CIS, 2003). The trophic status of each site (by year, if available) was categorized as oligotrophic, mesotrophic, eutrophic, hypereutrophic (if there is evidence of dystrophic conditions), based on numerical data values for Ts_Chla_conc, Ts_Pt_conc, and Ts_Nt_conc (Carlson, 1977). For these variables, relative frequencies were calculated by habitat type for each country using the“ggplot2” package (Wickham *et al.*, 2016) in R Software (R Core Team, 2021).

3.3. RESULTS

3.3.1. General information on data availability

The number of sites where the presence of eel was documented and for which at least some environmental data were provided, by country and habitat type, along with the percentage of sites for which data were reported by habitat type and by country are shown in Table 3.1, Table 3.2 and Figure 3.1. Data were available for a total of 699 sites, mostly lagoons (278 sites), but also rivers (198 sites) and estuaries (176 sites), while data for lakes were provided for only a few sites. The highest number of datasets from single sites was provided by Spain (142 sites) and the lowest number by Egypt (6 sites). In the habitat database, the most frequent source of environmental data was from lagoon habitats. Italy reported data for 103 lagoon sites, more than 70 percent of the sites in the country, and Egypt contributed data for all lagoons in the country representing 83 percent of Egyptian sites (Table 3.1). Tunisia reported the most data for lakes (27 sites and 28 percent of total eel sites in the country), while Egypt, France, and Spain reported no lake habitats for eel. Most of the environmental data for river habitats for eels were reported by Tunisia (48 sites, 49 percent of Tunisian sites), while most of the data for river-estuary habitats were from Spain (65 sites, 46 percent of total eel sites in the country).

In general, the numeric and descriptive variables in the datasets covered the years 1994–2020 and 1979–2020, respectively. Only a few sites had continuous datasets over time for the reported variables. Most sites did not have any temporal datasets and some sites did not have any records at all. Consequently, the annual averages for each variable were calculated using available data, by habitat type, for each country.

Table 3.16. Number of sites where eel presence was documented and for which environmental data were provided, by country and habitat typology

Country	Lagoon	Lake	River	River-estuary	*TOTAL*
Albania	8	1	10	0	***19***
Algeria	2	3	20	29	***54***

Egypt	5	0	0	1	***6***
France	49	0	25	29	***103***
Greece	32	2	19	11	***64***
Italy	103	1	17	19	***140***
Spain	38	0	39	65	***142***
Tunisia	19	27	48	4	***98***
Türkiye	22	13	20	18	***73***
TOTAL	***278***	***47***	***198***	***176***	***699***

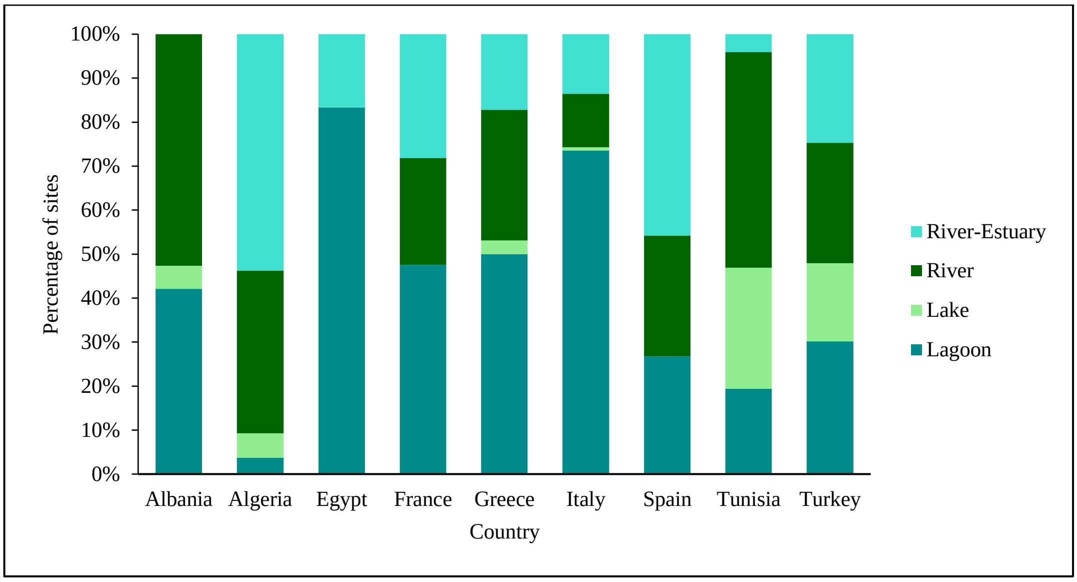


Figure 3.14. Frequency of sites (percent) where eel presence was documented and for which environmental data were provided, by country and habitat typology.

Table 3.2. Number of sites for which data were reported, by habitat type, country and years of data collected.

Country	**Awt**	**Ts_Chl$_a$_conc**	**Ts_P$_t$_conc**	**Ts_N$_t$_conc**	**Dtc**	**Av_sal**	**Years**
Lagoon sites							
Albania	8	7	8	8	8	8	2003–2015
Algeria	2	1	2	2	0	1	2005–2018
Egypt	5	5	5	4	5	5	2020
France	0	0	35	35	0	35	1998–2020
Greece	10	1	2	2	7	13	na
Italy	27	26	22	24	23	22	2010–2019
Spain	36	9	7	7	1	9	2008–2020
Tunisia	3	3	3	2	0	11	1994–2020
Türkiye	6	1	0	0	1	1	1997–2016
Lake sites							
Albania	1	1	1	1	1	0	2013–2014
Algeria	3	3	3	3	1	2	2000–2017
Egypt	np	np	np	np	np	np	np
France	np	np	np	np	np	np	np
Greece	1	0	1	1	1	1	na

Italy	0	0	0	0	1	0	na
Spain	np	np	np	np	np	np	np
Tunisia	0	0	0	0	0	0	2007
Türkiye	2	0	0	0	2	2	1993–2015
River sites							
Albania	7	0	10	10	np	1	2004–2020
Algeria	10	1	11	12	1	6	1983–2019
Egypt	na	na	na	na	na	na	na
France	25	0	0	0	0	0	2018–2020
Greece	6	1	9	10	0	1	na
Italy	11	0	9	9	0	0	2019–2020
Spain	38	2	4	4	0	0	2015–2020
Tunisia	5	0	0	0	0	36	1994–2017
Türkiye	6	0	0	1	0	0	2002–2012
River estuary sites							
Albania	np	np	np	np	np	np	np
Algeria	14	2	10	12	0	8	1979–2020
Egypt	1	1	1	1	1	1	2020
France	25	0	3	3	0	3	2001–2019
Greece	2	0	2	2	0	0	na
Italy	1	0	2	2	0	0	2019
Spain	45	10	13	12	0	0	2007–2020
Tunisia	0	0	0	0	0	1	2007
Türkiye	0	0	0	0	np	0	2010

Notes: Awt = annual average temperature; Ts_Chla_conc = total chlorophyll a concentration; Ts_Pt_conc = total phosphorus concentration; Ts_Nt_conc = total nitrogen concentration; Dtc = dystrophic crisis; Av_sal = annual average salinity; np = not pertinent because no sites for the habitat type; na = sites reported but no data available.

3.3.2. Annual average water temperature

Most of the data on annual average temperatures were from lagoon sites, which had good data coverage (Table 3.3). The highest annual average temperature (23.6 ± 0.6 ºC) was in Egyptian lagoons, with the highest average temperatures reported in two coastal lagoons, Lake Burullus and Edko (maximum value 24 ºC). The lowest average temperatures were reported for rivers (11.3 ± 3.1 ºC in France). Only a few temperature datasets were reported from lake habitats with no data available for lake sites in Italy and Tunisia, while Spain, France and Egypt reported no freshwater lakes as eel habitats.

3.3.3. Total chlorophyll-a concentration

The majority of data reported for total chlorophyll-a concentration were from lagoon sites, except for France and Türkiye where no data related to this habitat typology was provided (Table 3.4). Based on available data, the highest mean concentration of total chlorophyll-a was reported by Egypt (65.4 ± 47.7 µg/L) from lagoon habitats (Table 3.3).

3.3.4. Total phosphorus concentration

Most of the data on total phosphorus concentrations were reported for lagoons and all countries, except Türkiye, reported data (Table 3.5). For lagoon habitats, the highest mean Ts_Pt_conc value was reported in Egypt (598.6 µg/L) and the lowest value in France (5.5 µg/L). Meanwhile the highest Ts_Pt_conc values were reported from a river-estuary site in Spain.

3.3.5. Total nitrogen concentration

All countries reported data on total nitrogen concentrations, for most habitat types, except for lakes, where only Albania and Algeria reported data (Table 3.6). All countries, except Türkiye, reported Ts_Nt_conc data for lagoons, with varying and wide-ranging concentrations. The highest values were reported for river-estuary and river habitats, such as the Soummam site in Algeria (5 783.3 µg/L) and the Fuengirola site in Spain (38 173.0 µg/L)

3.3.6. Annual average salinity

The majority of available data for annual average salinity values were from lagoon sites (Table 3.7). Within lagoons, salinity ranges were highly variable. The highest salinity was reported from the Bardawil Lagoon in Egypt (48.0 g/L) while few data were reported from other habitat types.

Table 3.3. Annual average water temperature (ºC), by habitat type and country

Country	Lagoon			Lake			River			River-estuary		
	mean ± sd	min–max	n	mean ± sd	min–max	n	mean ± sd	min–max	n	mean ± sd	min–max	n
Albania	16.7 ± 3	14–21	13	20.0	na	1	14.5 ± 0.7	14–15	7	np	np	np
Algeria	20.6 ± 1.5	19–23	6	20.0 ± 2.2	17.0–24.0	11	18.4 ± 2.6	14–25	19	19 ± 4.1	10.3–26	14
Egypt	23.6 ± 0.6	23–24	5	np	np	np	na	na	na	24	na	1
France	na	na	0	np	np	np	11.3 ± 3.1	5–18	31	12.4 ± 2	8–14	25
Greece	19.9 ± 3.0	15–25	10	22.0	na	1	15.4 ± 2.3	12–19	6	15 ± 1.4	14–6	2
Italy	18 ± 2.4	12–23	27	na	na	0	14.4 ± 2.7	10–19	11	21	na	1
Spain	17.3 ± 2.0	16–25	42	np	np	np	16.0 ± 1.4	13–20	79	17.1 ± 1	15–19	105
Tunisia	20 ± 1.4	19–22	4	na	na	0	18.0 ± 1.1	16.8–19.2	5	na	na	0
Türkiye	20.6 ± 5.0	15–29	8	15.8 ± 9.6	9.0–22.5	5	14.2 ± 4.7	10–23	6	22	na	1

Notes: sd = standard deviation; min = minimum; max: = maximum; n = number of records; np = not pertinent, no sites reported as eel habitat; na = not available, sites reported as eel habitats, but no temperature data provided.

Table 3.4. Total chlorophyll-a concentrations (µg/L), by habitat type and country

Country	Lagoon			Lake			River			River-estuary		
	mean ± sd	min–max	n	mean ± sd	min–max	n	mean ± sd	min–max	n	mean ± sd	min–max	n
Albania	3.1 ± 3	0–8	11	10	na	1	na	na	0	np	np	np
Algeria	56.0 ± 34.9	16–80	3	64.0 ± 99.9	4–262	7	20 ± 14.1	10–30.0	2	14 ± 4.2	11–17	2
Egypt	65.4 ± 47.7	1–133	5	np	np	np	na	na	na	2.11	na	1
France	na	na	0	np	np	np	na	na	0	na	na	0
Greece	5	na	1	na	na	0	1	na	1	na	na	0
Italy	7.7 ± 1	0–59	26	na	na	0	na	na	0	na	na	0
Spain	16.6–33.4	0–105	9	np	np	np	1.7 ± 2.2	0–6	9	10 ± 17.9	0–98	47
Tunisia	4.0 ± 2.8	0–6	4	na	na	0	na	na	0	na	na	0
Türkiye	na	na	1	na	na	0	na	na	0	na	na	0

Notes: sd = standard deviation; min = minimum; max: = maximum; n = number of records; np = not pertinent, no sites reported as eel habitat; na = not available, sites reported as eel habitats, but no total chlorophyll-a concentration data provided.

Table 3.5. Total phosphorus concentrations (µg/L), by habitat type and country

Country	Lagoon			Lake			River			River-estuary		
	mean ± sd	min–max	n	mean ± sd	min–max	n	mean ± sd	min–max	n	mean ± sd	min–max	n
Albania	66.4 ± 114.3	0–350	10	30.0	na	1	277 ± 500	0-1 490	10	np	np	np
Algeria	376 ± 343.7	133–619	2	767.9 ± 881.1	7.0–2 402.0	9	601 ± 841	0–3 204	28	720.8 ± 1 425.7	13–5 580	31
Egypt	598.6 ± 376.3	76–1 003	5	np	np	np	na	na	na	21	na	1
France	5.5 ± 7.7	0–35.7	484	np	np	np	na	na	0	2.9 ± 1.3	1.6–4.6	19
Greece	240 ± 58	199–281	2	552.0	na	1	853 ± 1 866	38—5 800	9	281 ± 90.5	217–345	2
Italy	45.9 ± 35.8	9–178	22	na	na	0	66.8 ± 23.8	41–116	11	194 ± 203.7	50–338	2
Spain	64 ± 117	0–313	22	np	np	np	937 ± 2 815	13–11 005	36	2 095.3 ± 5 549	16–22 650	66
Tunisia	6.8 ± 8.9	1–20	4	na	na	0	na	na	0	na	na	0
Türkiye	na	na	0	na	na	0	na	na	0	na	na	0

Notes: sd = standard deviation; min = minimum; max: = maximum; n = number of records; np = not pertinent, no sites reported as eel habitat; na = not available, sites reported as eel habitats, but no total phosphorus concentration data provided.

Table 3.6. Total nitrogen concentrations (µg/L), by habitat type and country

Country	Lagoon			Lake			River			River-estuary		
	mean ± sd	min–max	n	mean ± sd	min–max	n	mean ± sd	min–max	n	mean ± sd	min–max	n
Albania	264.2 ± 366.7	6–1 071	18	500	na	1	2876 ± 5 259.7	3–18 200	21	np	np	np
Algeria	280	na	2	373 ± 250	166–931	8	8 184.5 ± 14 310.4	146–5 3051	29	5 783.3 ± 10 065.6	272–32390.7	34
Egypt	3 053.8 ± 1 515.4	1 095–4 750	4	np	np	np	na	na	na	403	na	1
France	107.4 ± 90	18.0–404	484	np	np	np	na	na	0	110.1 ± 21.9	85–125.2	19
Greece	180.5 ± 205.8	35–326	2	na	na	0	865.1 ± 1 212.9	32–3 793	10	322 ± 407.3	34–610	2
Italy	1 356 ± 1 019	76–3 810	24	na	na	0	1 955.8 ± 933.7	100–3 200	11	2 350 ± 636.4	1900–2800	2
Spain	432 ± 1 197	2–3 395	14	np	np	np	8 033.5 ± 8143.6	736–35 666	37	5 171.3 ± 8 067.8	209–38 173	60
Tunisia	166.3 ± 254.3	19–460	3	na	na	0	na	na	0	na	na	0
Türkiye	na	na	0	na	na	0	905	na	1	na	na	0

Notes: sd = standard deviation; min = minimum; max: = maximum; n = number of records; np = not pertinent, no sites reported as eel habitat; na = not available, sites reported as eel habitats, but no total nitrogen concentration data provided.

Table 3.7. Annual average salinity (g/L) by habitat type and country

Country	Lagoon			Lake			River			River-estuary		
	mean ± sd	min–max	n	mean ± sd	min–max	n	mean ± sd	min–max	n	mean ± sd	min–max	n
Albania	31.3 ± 9.3	20–41.5	10	na	na	0	na	na	1	np	np	np
Algeria	29.5 ± 0.7	29–30	2	0.6 ± 1.3	0–3	8	1 ± 1.9	0–5	9	9.3 ± 11.2	1–33	10
Egypt	13.4 ± 19.4	3–48	5	np	np	np	na	na	na	0.1	na	1
France	23.6 ± 12.5	1–42	484	np	np	np	na	na	0	36.3 ± 12.5	24.5–49.4	19
Greece	32.2 ± 4.3	20–38	13	7.4	na	1	1.1	na	1	na	na	0
Italy	26.1 ± 12.1	0–44	22	na	na	0	na	na	0	na	na	0
Spain	14.9 ± 11.6	1–38	26	np	np	np	na	na	0	na	na	0
Tunisia	30.2 ± 11.8	9–39	13	na	na	0	0.8 ± 1	0–4	42	1.9	na	1
Türkiye	40.3 ± 8.1	34.5–46.8	3	11.8 ± 1.3	10.5–13	5	na	na	0	na	na	0

Notes: sd = standard deviation; min = minimum; max: = maximum; n = number of records; np = not pertinent, no sites reported as eel habitat; na = not available, sites reported as eel habitats, but no salinity data provided.

3.3.7. Trophic status based on total chlorophyll-a

An evaluation of trophic status based on total chlorophyll-a data can be given for lagoons in most countries, as data were frequently reported for this habitat type (Figure 3.2). According to the total chlorophyll-a data, all lagoons in Greece were mesotrophic, while all lagoons in Türkiye were oligotrophic (Figure 3.2A). In other countries (except for France where no lagoon data were provided), lagoons had varying trophic status levels with a high percentage of sites being eutrophic and hypereutrophic in Algeria and Egypt. Only three countries (Albania, Algeria and Italy) provided data on total chlorophyll-a in lakes, allowing evaluation of their trophic status. Albanian lakes were oligotrophic and mesotrophic, while Algerian lakes were mostly eutrophic and hypereutrophic and Italian lakes were mostly mesotrophic (Figure 3.2B). The few data provided for river sites indicated that most Albanian river sites were mesotrophic and Algerian river sites were eutrophic, while Greek and Spanish river habitats were mostly oligotrophic (Figure 3.2C). In Spain, the trophic status of river-estuaries ranged from oligotrophic to eutrophic, while Algerian river-estuaries were eutrophic (Figure 3.2D).

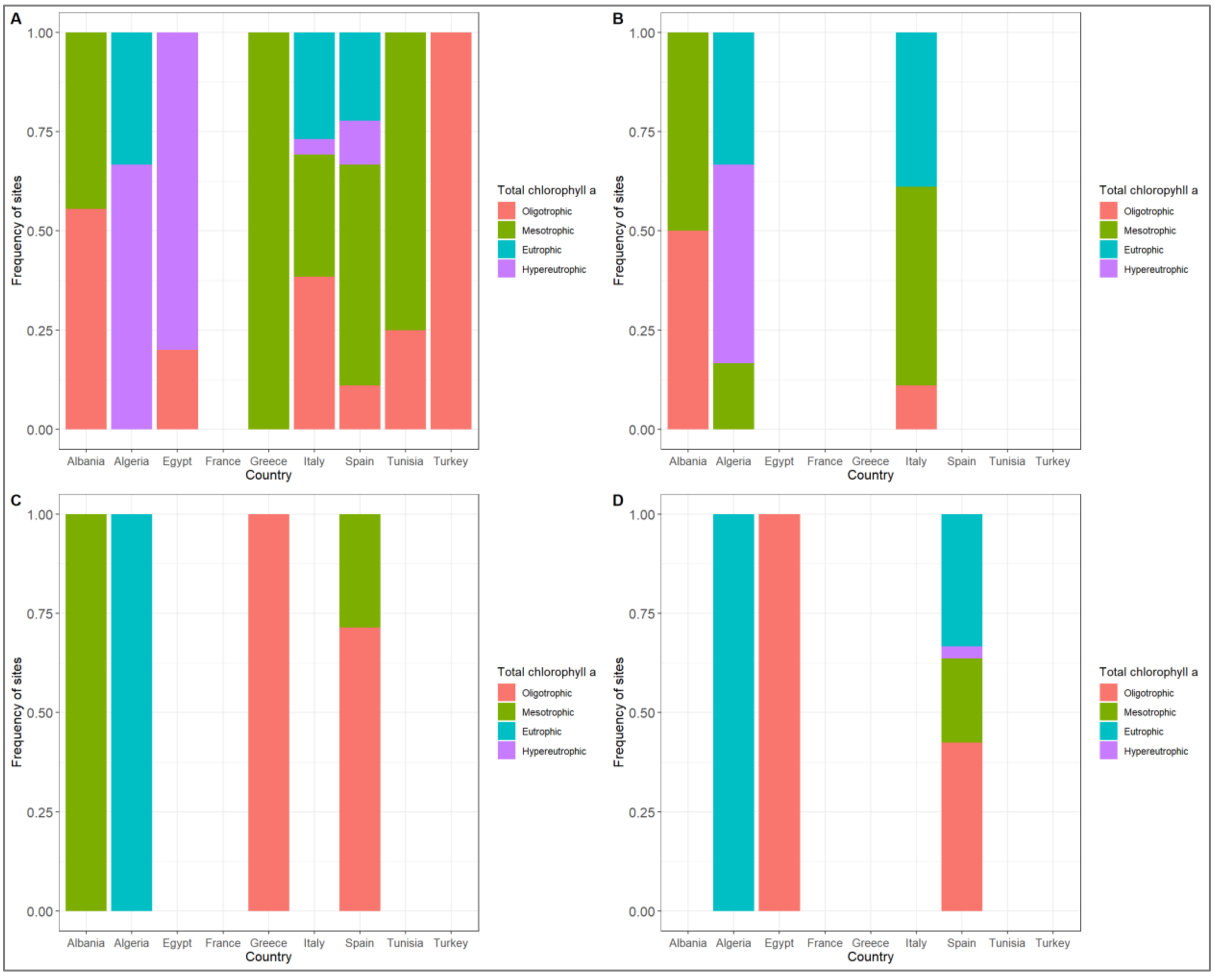


Figure 3.15. Proportion of sites (on an overall scale from 0 to 1) attributed to the different trophic categories, based on total chlorophyll-a, by country and habitat typology (A: Lagoon; B: Lake; C: River; D: River-estuary)

3.3.8. Trophic status based on total phosphorus

Total phosphorus data for lagoons showed that most lagoons in Albania, France, Spain, Tunisia, and Türkiye were oligotrophic, while in Algeria, Egypt, and Greece most lagoons for which total phosphorus data were available had hypereutrophic status (Figure 3.3A). Lakes in Albania and Italy were mostly eutrophic, while in Algeria and Greece they were hypereutrophic (Figure 3.3B). Total phosphorous data from river sites showed that Albanian and Italian rivers were mostly eutrophic, while in Algeria, Greece and Spain a high number of sites were hypereutrophic (Figure 3.3C). The trophic status of the river-estuary habitats differed according to data availability between countries (Figure 3.3D). River-estuary sites in Algeria, Greece, Spain and half of Italian sites were hypereutrophic while the Nile estuary in Egypt was classified as mesotrophic, based on Ts_Pt values provided in the database, and all French estuaries were oligotrophic.

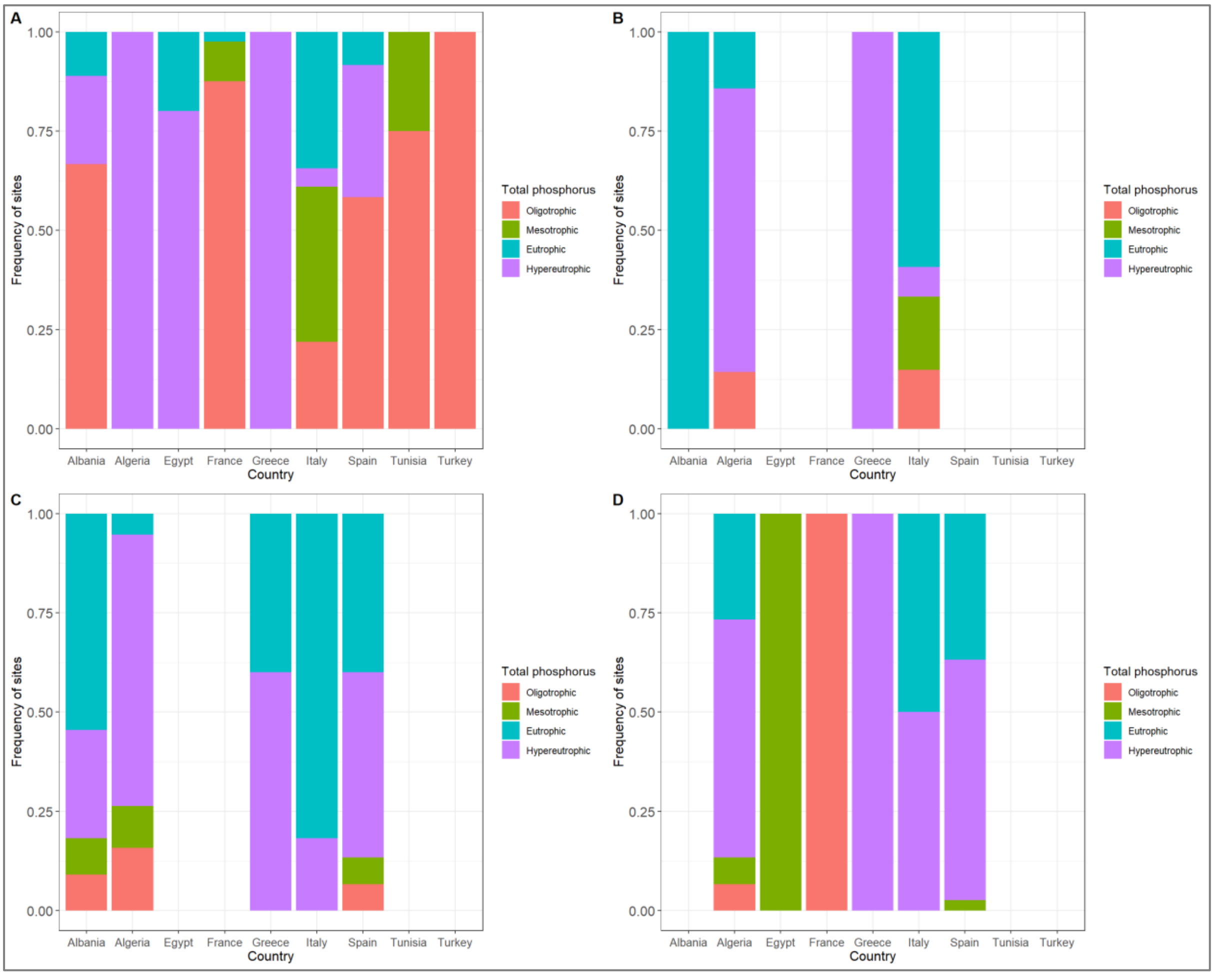


Figure 3.16. Proportion of sites (on an overall scale from 0 to 1) attributed to the different trophic categories, based on total phosphorus, by country and habitat typology (A: Lagoon; B: Lake; C: River; D: River-estuary)

3.3.9. Trophic status based on total nitrogen

Total nitrogen data were available for more lagoon sites than other habitat types. In most countries, lagoons were classified as mesotrophic (Figure 3.4A), based on total nitrogen concentrations, except for Algerian lagoons which were eutrophic and Egyptian lagoons which were hypereutrophic.

Lake habitats in Egypt and Greece were classified as mesotrophic, based on total nitrogen levels, while Albanian lakes were eutrophic, Algerian lakes were hypereutrophic and Italian lake habitats were oligotrophic (Figure 3.4B). Most of the river habitats were hypereutrophic, with the exception of Greek rivers which were classified as oligotrophic and rivers in Türkiye which were eutrophic (Figure 3.4C). River-estuary habitats showed varying total nitrogen-based trophic status levels in different countries (Figure 3.4D). Algerian, Italian, and Spanish river-estuary habitats were hypereutrophic, Egyptian river-estuary habitats were mesotrophic and French habitats were classified as oligotrophic (Figure 3.4D).

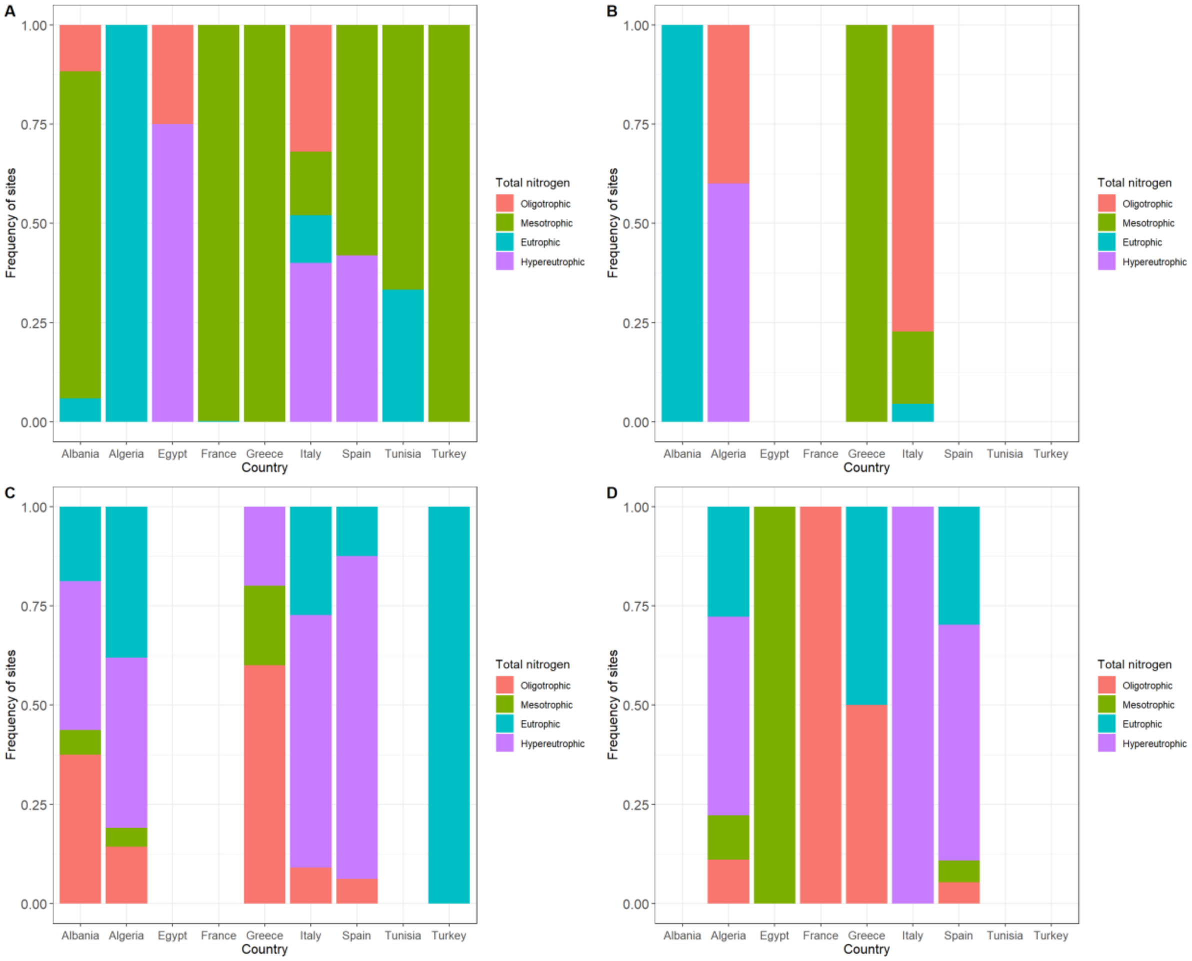


Figure 3.17. Proportion of sites (on an overall scale from 0 to 1) attributed to the different trophic categories, based on total nitrogen, by country and habitat typology (A: Lagoon; B: Lake; C: River; D: River-estuary)

3.3.10. Saline typology

According to the salinity data provided by countries, lagoon sites ranged between polihaline, euhaline, and hyperhaline conditions, but most can be classified as euhaline (Figure 3.5A). Considering lakes, all Italian sites are freshwater, while in Türkiye, all lakes were classified as mesohaline, as were lake sites found in Greece (Figure 3.5B). Most rivers in most countries were classified as being freshwater (Figure 3.5C), apart from Algerian and Tunisian river habitats that were classified as oligohaline. The river-estuary habitats in Egypt and Greece were classified as freshwater, while Algerian and Tunisian river-estuary habitats were oligohaline (Figure 3.5D).

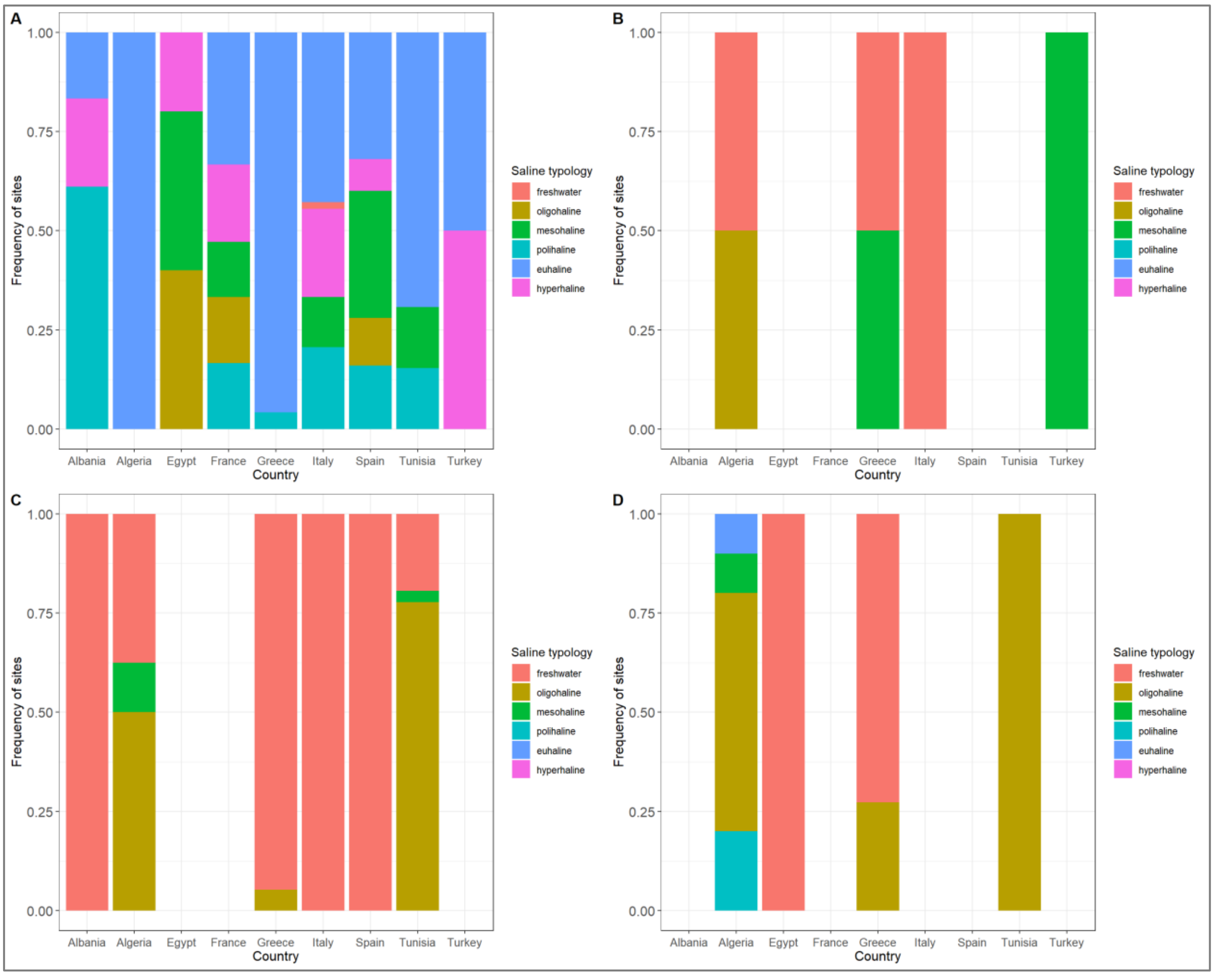


Figure 3.18. Proportion of sites (on an overall scale from 0 to 1) attributed to the different trophic categories, based on saline typology, by country and habitat typology. (A: Lagoon; B: Lake; C: River; D: River-estuary)

3.3.11. Dystrophic crisis

Information on the occurrence of dystrophic crisis conditions was provided for lagoon and lake sites. The highest occurrence of dystrophic crisis data for lagoons was from sites in Egypt, Spain and Türkiye (Figure 3.6A), while lake sites in Türkiye and Greece had the highest number of records for dystrophic crisis (Figure 3.6B).

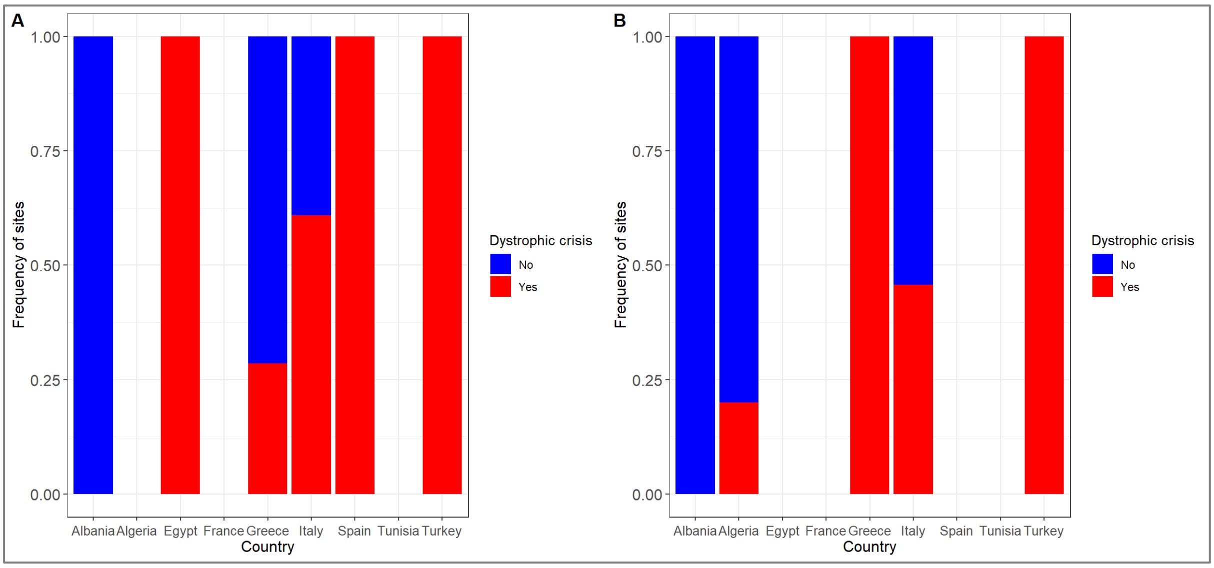
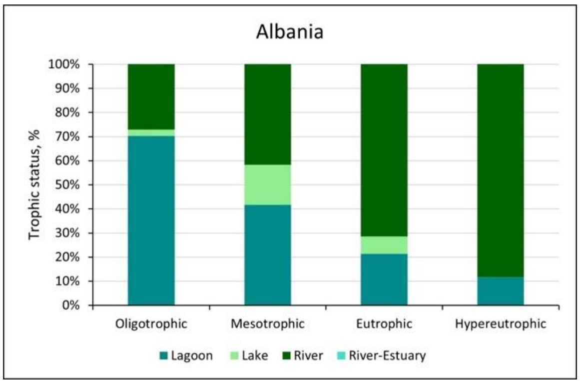
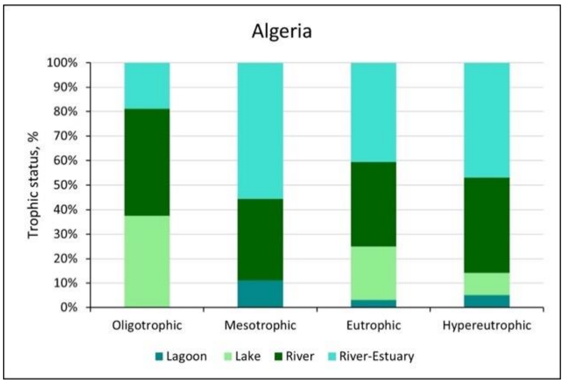
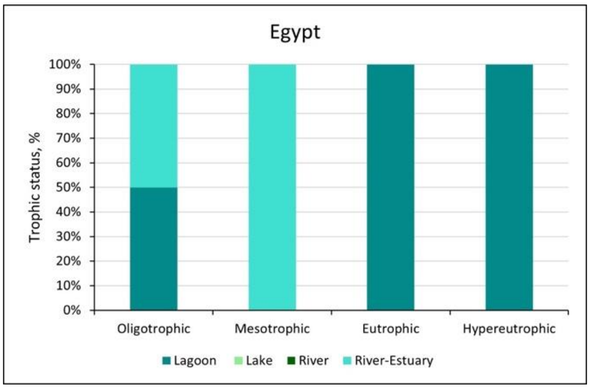
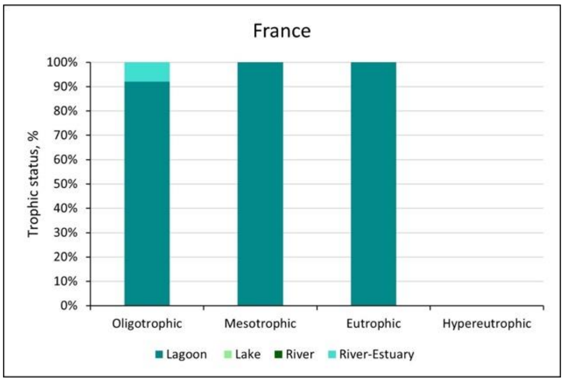


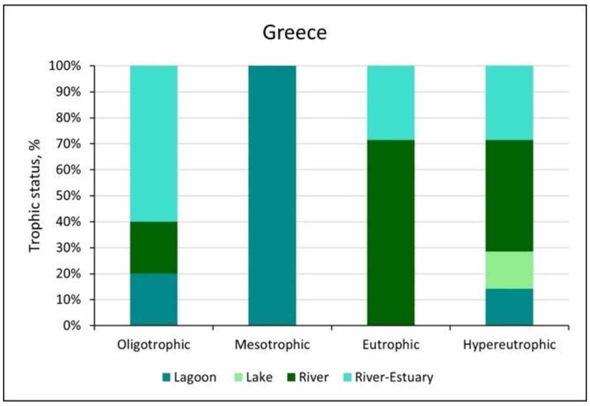
Figure 3.19. Proportion of sites (on an overall scale from 0 to 1) where dystrophic crisis were recorded, by country (A: lagoons; B: lakes).


Albania
Trophic status, %
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Oligotrophic
Mesotrophic
Eutrophic
Hypereutrophic
Lagoon
Lake
River
River-Estuary


Algeria
Trophic status, %
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Oligotrophic
Mesotrophic
Eutrophic
Hypereutrophic
Lagoon
Lake
River
River-Estuary


Egypt
Trophic status, %
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Oligotrophic
Mesotrophic
Eutrophic
Hypereutrophic
Lagoon
Lake
River
River-Estuary


France
Trophic status, %
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Oligotrophic
Mesotrophic
Eutrophic
Hypereutrophic
Lagoon
Lake
River
River-Estuary


Greece
Trophic status, %
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
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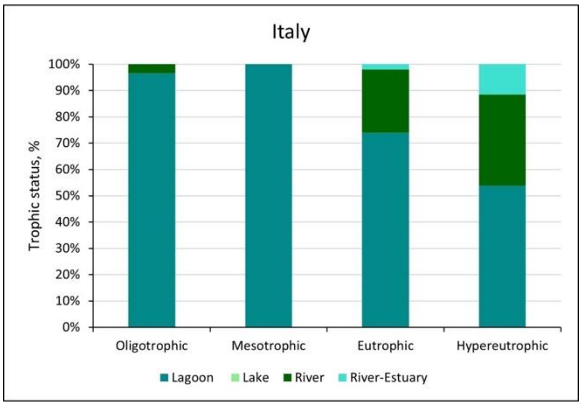
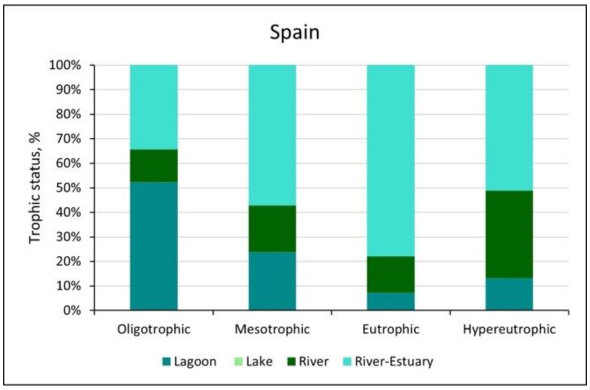
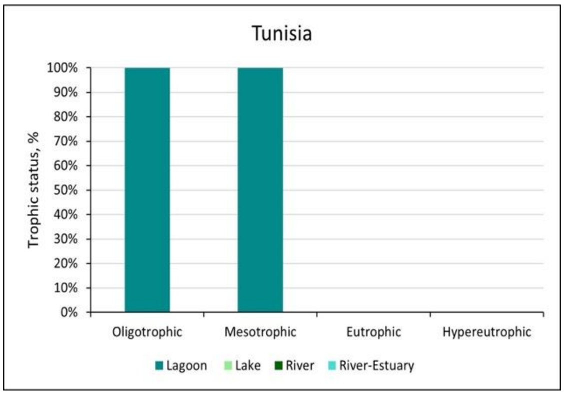
Mesotrophic
Eutrophic
Hypereutrophic
Lagoon
Lake
River
River-Estuary


Italy
Trophic status, %
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Oligotrophic
Mesotrophic
Eutrophic
Hypereutrophic
Lagoon
Lake
River
River-Estuary


Spain
Trophic status, %
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Oligotrophic
Mesotrophic
Eutrophic
Hypereutrophic
Lagoon
Lake
River
River-Estuary


Tunisia
Trophic status, %
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Oligotrophic
Mesotrophic
Eutrophic
Hypereutrophic
Lagoon
Lake
River
River-Estuary

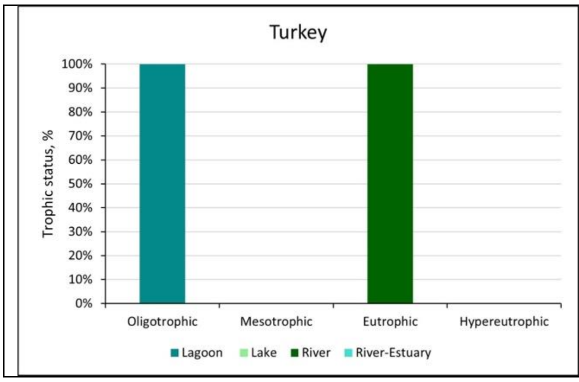


Figure 3.7. Relative frequency (percent) of sites, by trophic status and habitat type, for each country, based on chlorophyll-a, total phosphorus, and total nitrogen concentrations.

3.4. DISCUSSION AMD CONCLUSIONS

This chapter provides a preliminary overview of eel habitats in the Mediterranean, based on the main physicochemical parameters used to describe their features in relation to their suitability for eel. Results were constrained by the availability of data, as they were not exhaustive, particularly regarding site coverage for some types of habitats and over time. However, they outline methodologies for the collection and analysis of data that will be useful in subsequent work. This is confirmed by the overview that can be given for lagoon habitats where the data coverage was more complete than for other habitats.

Lagoons are the main habitat of the European eel in the Mediterranean and in this respect, the habitats for which available data were provided are consistent with eel fishery habitats. Nevertheless, it is noteworthy that limited or no environmental data were provided for some sites that are important habitats for eel fishing because the data were not easily available.

In terms of fisheries, due to their ecological features, coastal lagoons are the most productive ecosystems in the Mediterranean (Pérez-Ruzafa, Marcos and Pérez-Ruzafa, 2011). The trophic status of Mediterranean lagoons, which ranges from oligotrophic to eutrophic and hypereutrophic, supports high levels of productivity. While a wide number of habitats with varying trophic status levels are relevant for eel across its entire distribution range, Mediterranean lagoons are ideal (Tesch, 2003; Dekker, 2003). The trophic status is an important factor for eel distribution, as they prefer eutrophic habitats (Aalto *et al.*, 2016; Schiavina *et al.*, 2015). The environmental characteristics of Mediterranean lagoons are shaped by multiple anthropogenic pressures both within lagoons, such as tourism, fishing and aquaculture (Aliaume *et al.*, 2007) and in surrounding areas including agricultural land use, urbanization and industrialization. Together, these pressures have led to environmental changes such as pollution and eutrophication (Oliver *et al.*, 2015; Aalto *et al.*, 2016), although there was evidence of a positive relationship between the production of silver eels and eutrophication in the Baltic Sea (Andersson, Florin and Petersson, 2012). In the habitat database, most countries have provided data on the trophic status of habitats and this can be considered a very important parameter in relation to the evaluation of suitable habitats for eel. The trophic status results for each country are shown in Figure 3.7, although data scarcity and lack of temporal and spatial representativeness for many countries suggest a need for caution in their use.

Salinity is an important component that influences both the physiology and ecology of the species that live in brackish waters. In general, Mediterranean lagoons can have a wide range of salinities based on local climatic conditions, also depending on the degree of connectivity to inland waters and the open sea (Pérez-Ruzafa *et al.*, 2019). The salinity reported for lagoons ranged between 0.1 g/L and 48.3 g/L. Salinity influences the growth of European eels, with faster growth rates in more saline waters and slower growth in freshwater (Acou *et al.*, 2003; Daverat and Tomas, 2006; Cairns *et al.*, 2009).

Lagoon habitats are naturally stressed and physically regulated systems (Pérez-Ruzafa, Marcos and Pérez-Ruzafa, 2011), and a key role is played by temperature. This influences all features of the eel life cycle in continental waters, from colonization to growth and sexual maturation. Coastal lagoons and river estuaries could be considered the most suitable habitats for eel, based on salinity and temperature ranges. However, extreme temperatures can cause eel mortalities in lagoons (Bevacqua *et al.*, 2011; ICES, 2018), particularly in relation to the spread of disease and direct mortality as a result of dystrophic events. The consequences of global warming in coastal lagoons may be reflected in both temperature and salinity in the Mediterranean and this is a cause for concern for eel stocks and eel habitats in the future.

3.5. REFERENCES

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Additional Results Part I – Availability of data for eel habitat main environmental features in the WP3 habitat database

Table 3AR1.1. Number of sites for which data are reported, for single environmental parameters, in lagoons, by country, and relative time span for which data have been collected (Awt: Annual average temperature; Ts_Chla_conc: Total Chlorophyll a concentration; Ts_Pt_conc: Total phosphorus concentration; Ts_Nt_conc: Total nitrogen concentration; Dtc: Dystrophic crisis; Av_sal: Annual average salinity; np: not pertinent because no sites are reported for the habitat typology; na: sites are reported for the habitat typology but no data available)

Country	Awt	$Ts\_Chl_a\_conc$	$Ts\_P_t\_conc$	$Ts\_N_t\_conc$	Dtc	Av_sal	Years
Albania	8	7	8	8	8	8	2003-2015
Algeria	2	1	2	2	0	1	2005-2018
Egypt	5	5	5	4	5	5	2020
France	0	0	35	35	0	35	1998-2020
Greece	10	1	2	2	7	13	na
Italy	27	26	22	24	23	22	2010-2019
Spain	36	9	7	7	1	9	2008-2020
Tunisia	3	3	3	2	0	11	1994-2020
Türkiye	6	1	0	0	1	1	1997-2016

Table 3AR1.2. Number of sites for which data are reported, for single environmental parameters, in lakes, by country, and relative time span for which data have been collected (Awt: Annual average temperature; Ts_Chla_conc: Total Chlorophyll a concentration; Ts_Pt_conc: Total phosphorus concentration; Ts_Nt_conc: Total nitrogen concentration; Dtc: Dystrophic crisis; Av_sal: Annual average salinity; np: not pertinent because no sites are reported for the habitat typology; na: sites are reported for the habitat typology but no data available)

Country	Awt	$Ts\_Chl_a\_conc$	$Ts\_P_t\_conc$	$Ts\_N_t\_conc$	Dtc	Av_sal	Year
Albania	1	1	1	1	1	0	2013-2014
Algeria	3	3	3	3	1	2	2000-2017
Egypt	np	np	np	np	np	np	np
France	np	np	np	np	np	np	np
Greece	1	0	1	1	1	1	na
Italy	0	0	0	0	1	0	na
Spain	np	np	np	np	np	np	np
Tunisia	0	0	0	0	0	0	2007
Türkiye	2	0	0	0	2	2	1993-2015

Table 3AR1.3. Number of sites for which data are reported, for single environmental parameters, in rivers, by country, and relative time span for which data have been collected (Awt: Annual average temperature; Ts_Chla_conc: Total Chlorophyll a concentration; Ts_Pt_conc: Total phosphorus concentration; Ts_Nt_conc: Total nitrogen concentration; Dtc: Dystrophic crisis; Av_sal: Annual average salinity; np: not pertinent because no sites are reported for the habitat typology; na: sites are reported for the habitat typology but no data available)

Country	Awt	$Ts\_Chl_a\_conc$	$Ts\_P_t\_conc$	$Ts\_N_t\_conc$	Dtc	Av_sal	Year
Albania	7	0	10	10	np	1	2004-2020
Algeria	10	1	11	12	1	6	1983-2019
Egypt	na	na	na	na	na	na	na
France	25	0	0	0	0	0	2018-2020
Greece	6	1	9	10	0	1	na
Italy	11	0	9	9	0	0	2019-2020
Spain	38	2	4	4	0	0	2015-2020
Tunisia	5	0	0	0	0	36	1994-2017
Türkiye	6	0	0	1	0	0	2002-2012

Table 3AR1.4. Number of sites for which data are reported, for single environmental parameters, in river-estuaries, by country, and relative time span for which data have been collected (Awt: Annual average temperature; Ts_Chla_conc: Total Chlorophyll a concentration; Ts_Pt_conc: Total phosphorus concentration; Ts_Nt_conc: Total nitrogen concentration; Dtc: Dystrophic crisis; Av_sal: Annual average salinity; np: not pertinent because no sites are reported for the habitat typology; na: sites are reported for the habitat typology but no data available)

Country	Awt	$Ts\_Chl_a\_conc$	$Ts\_P_t\_conc$	$Ts\_N_t\_conc$	Dtc	Av_sal	Year
Albania	np	np	np	np	np	np	np
Algeria	14	2	10	12	0	8	1979-2020
Egypt	1	1	1	1	1	1	2020
France	25	0	3	3	0	3	2001-2019
Greece	2	0	2	2	0	0	na
Italy	1	0	2	2	0	0	2019
Spain	45	10	13	12	0	0	2007-2020
Tunisia	0	0	0	0	0	1	2007
Türkiye	0	0	0	0	np	0	2010

Additional Results Part II –Trophic status of eel habitats per country and habitat

This section reports relative frequency of sites of the four categories of trophic status by habitat typologies, for each country, based on the data provided in the habitat database for chlorophyll-a, total phosphorus, and total nitrogen concentrations.

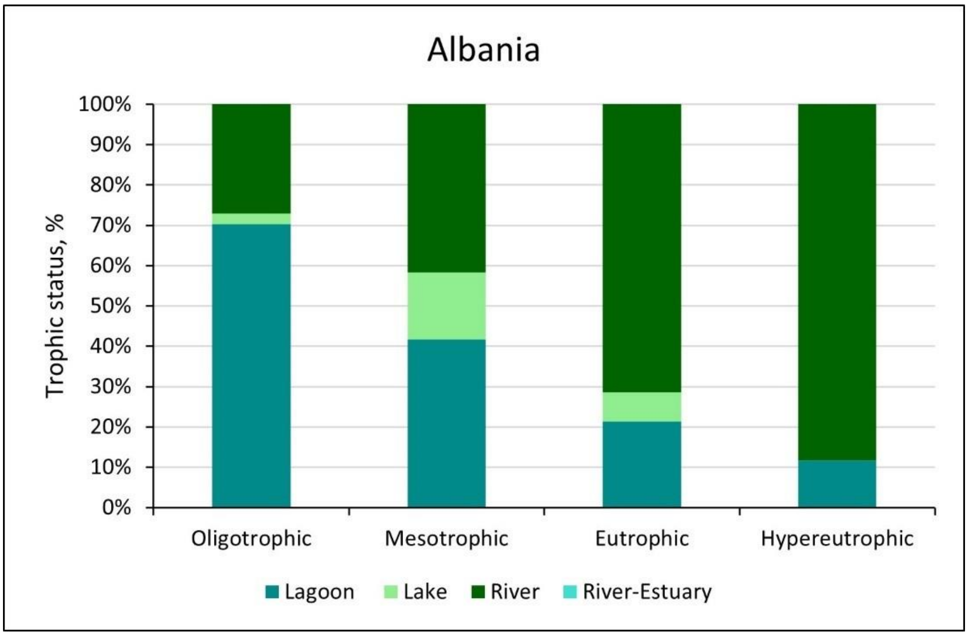


Figure 3AR2.1. Frequency (%) of sites attributed to the different trophic categories, by habitat typology, in Albania.

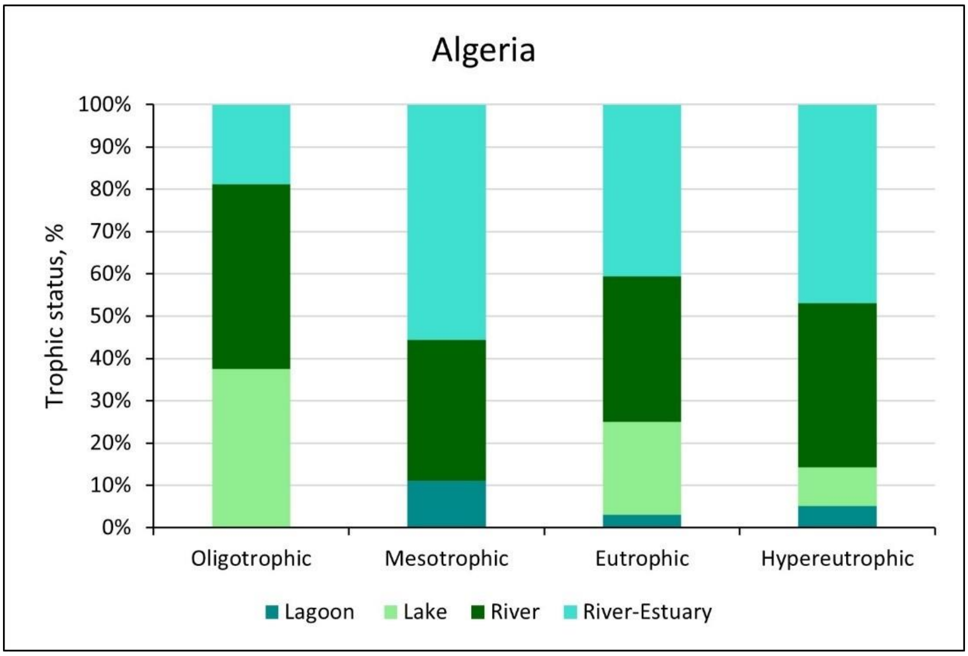


Figure 3AR2.2. Frequency (%) of sites attributed to the different trophic categories, by habitat typology, in Algeria.

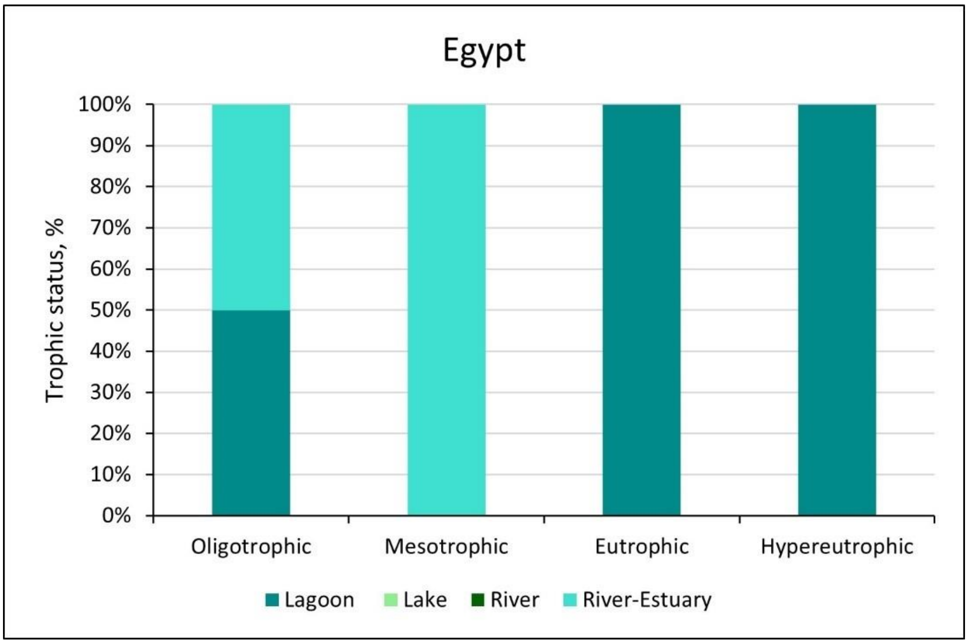


Figure 3AR2.3. Frequency (%) of sites attributed to the different trophic categories, by habitat typology, in Egypt.

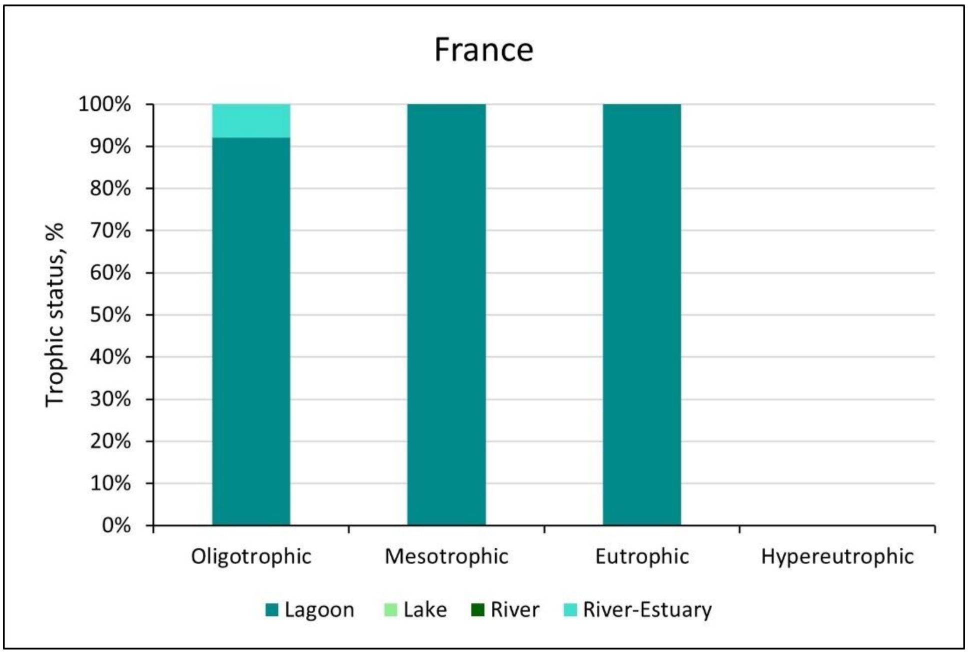


Figure 3AR2.4. Frequency (%) of sites attributed to the different trophic categories, by habitat typology, in France.

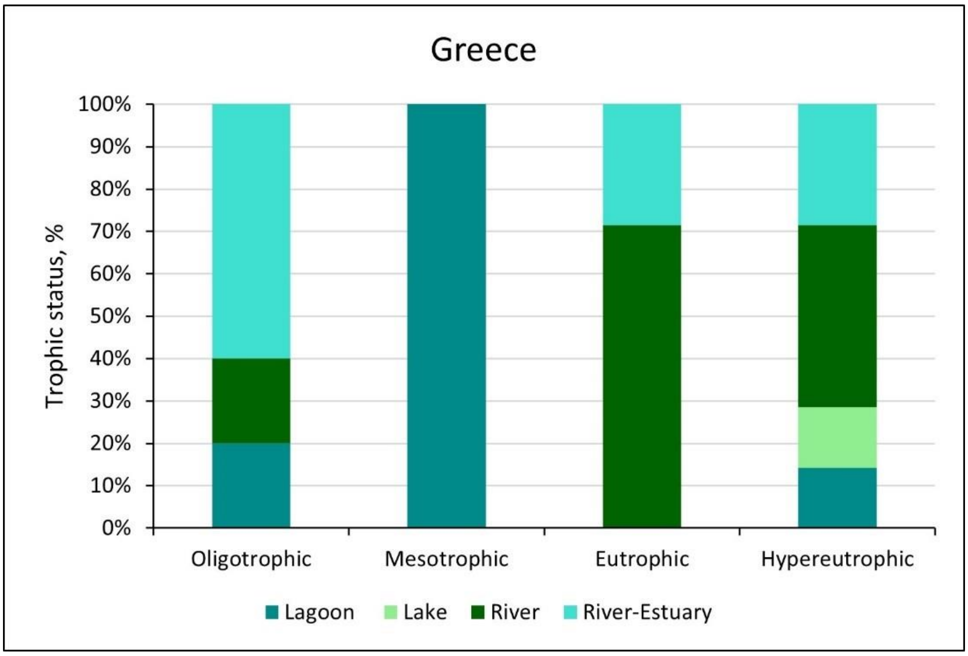


Figure 3AR2.5. Frequency (%) of sites attributed to the different trophic categories, by habitat typology, in Greece.

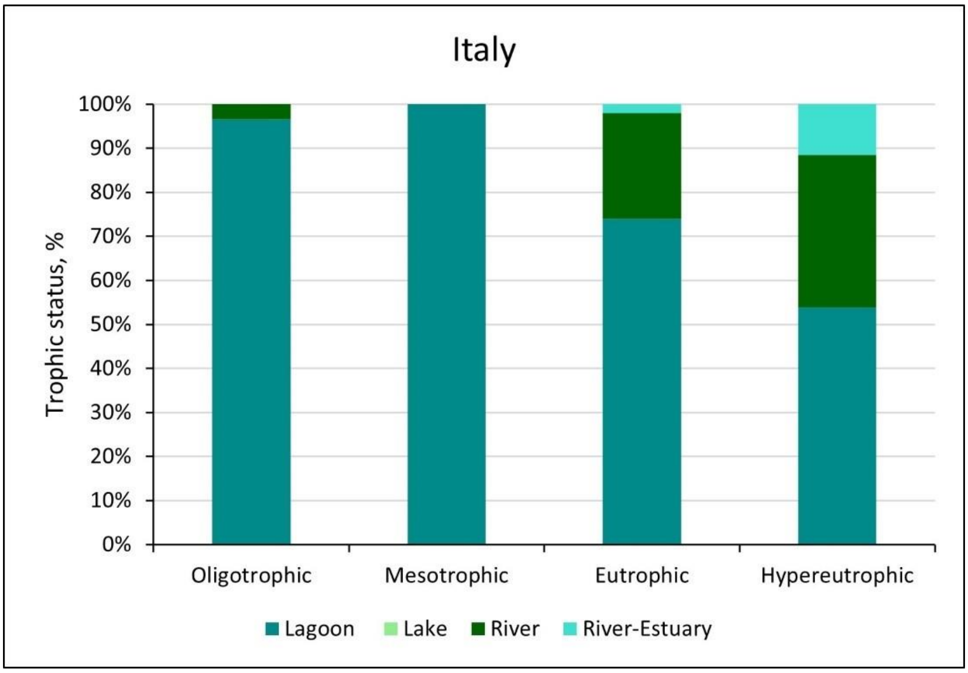


Figure 3AR2.6. Frequency (%) of sites attributed to the different trophic categories, by habitat typology, in Italy.

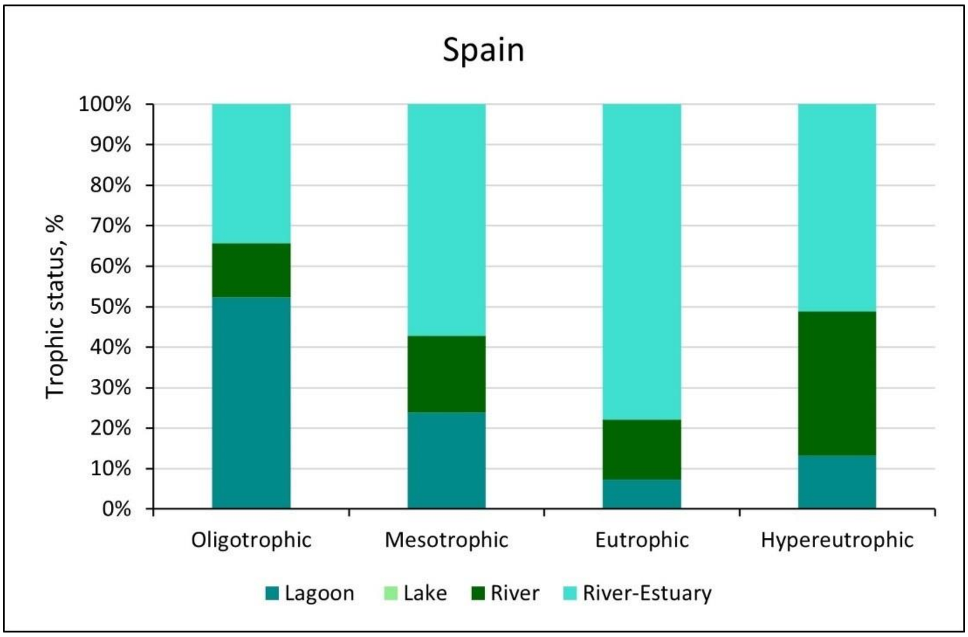


Figure 3AR2.7. Frequency (%) of sites attributed to the different trophic categories, by habitat typology, in Spain.

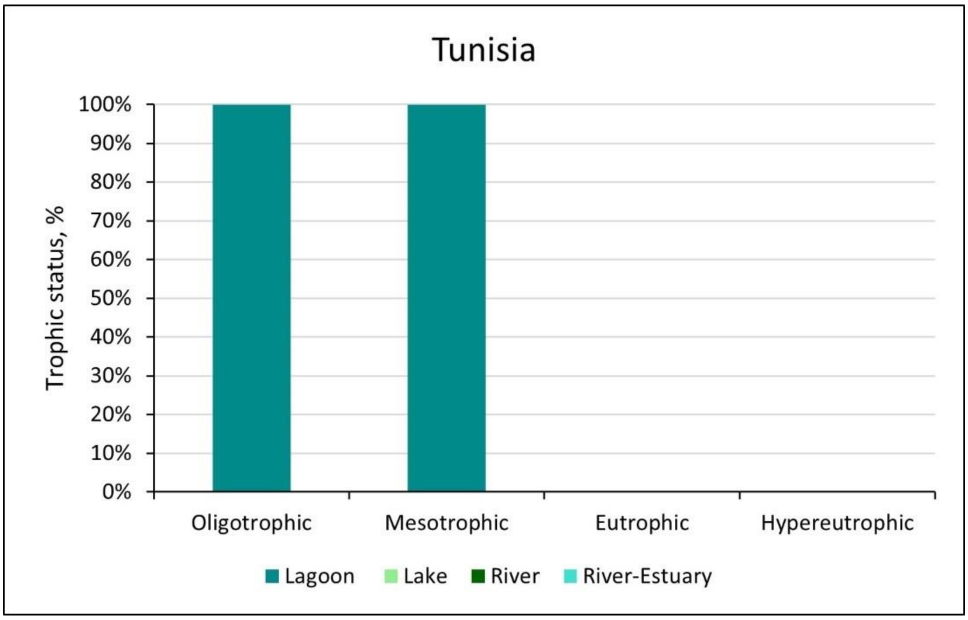


Figure 3AR2.8. Frequency (%) of sites attributed to the different trophic categories, by habitat typology, in Tunisia.

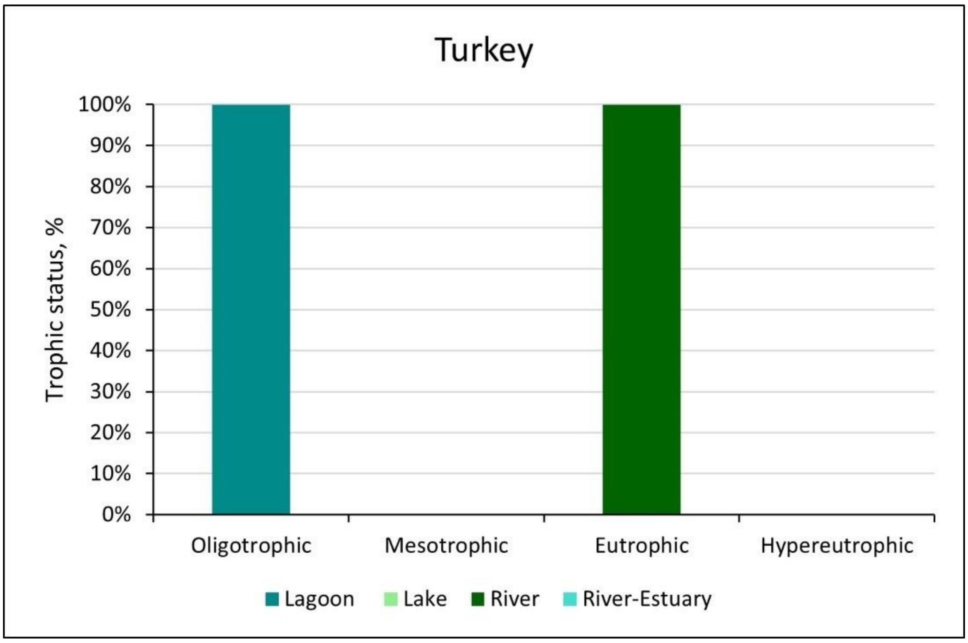


Figure 3AR2.9. Frequency (%) of sites attributed to the different trophic categories, by habitat typology, in Türkiye.

CHAPTER 4. ASSESSMENT OF EEL HABITAT QUALITY IN THE MEDITERRANEAN

ABSTRACT

The habitat quality of geo-referenced sites in the habitat database was evaluated, identifying the main conservation problems in the four main Mediterranean habitat typologies of coastal lagoons, rivers, estuaries and lakes. From a total of 728 sites in nine partner country habitat databases, 645 were selected, and variables were grouped into five categories for further analysis; habitat overview, migration, pollutants, natural mortality and anthropogenic mortality.

The presence of non-uniform information made it necessary to develop a system of individual quality checks for each variable by measuring the degree of uncertainty with which each habitat quality score was awarded. Subsequently, both habitat quality and reliability scores were categorised into *high*, *medium* and *low* classes.

Poor habitat quality and the presence of pollutants were the main concerns observed in estuaries and rivers. In coastal lagoons the main problem was anthropogenic mortality associated with fishing pressure, while the presence of pollutants and high levels of natural mortality were also important factors. In lakes, the scarcity of data prevented any relevant conclusions, although there were suggestions of conservation problems associated with anthropogenic mortality.

A general lack of data and poor data quality was detected throughout the study, particularly for variables related to the presence of pollutants, particularly persistent organic pollutants (POPs), natural mortality (parasites and pathogens) and variables in the habitat overview category. For the habitat overview, the absence of information may have been because existing information was not provided, while for other categories of variables there were probably no data available. There were two serious gaps, the lack of information and poor data quality, highlighting the need for further investigations, as the evaluation of habitat quality at site level is a key feature when dealing with eel habitats and possible conservation measures in the Mediterranean.

HIGHLIGHTS

- Habitat quality was assessed at site level for 645 water bodies belonging to four habitat types: lakes, lagoons, rivers and estuaries.
- Incomplete provision of data made it necessary to develop a system for assessing the quality of data for each variable and site, in order to evaluate the uncertainty with which habitat quality scores were awarded.
- The main pressures detected in rivers and estuaries were habitat degradation and pollution.
- In lakes and lagoons, anthropogenic mortality associated with fishing pressure was the most important factor affecting habitat quality, while lagoon sites were also impacted by pollution.
- A general lack of data was detected, mainly addressing two fundamental issues in the habitat evaluation for eel, pollutant levels (mainly POPs) and natural mortality (parasites and pathogens).
- In many cases, the information provided was of very poor quality, either because it was incomplete or it was impossible to evaluate.
- In order to comprehensively assess habitat quality it will be necessary to obtain more information and complete database compilation by filling data gaps for many sites.
- The work carried out in this task offered an important methodological contribution, by proposing a habitat assessment method for eel at the site level. Its application and extension to a wider range of sites will depend on whether it will be possible for partner countries to complete the provision of information for the database.

4.1. INTRODUCTION

The key focus of this chapter, following the quantitative and descriptive analyses was to assess the quality of the habitat. In other words, what state is eel habitat in?

The main problems faced by eel populations during the continental phase of their life cycle, include the presence of obstacles to migration and the consequent loss of suitable habitat, the presence of turbines and fishing activities that affect mortality, water eutrophication and water pollution, as well as the presence of parasites or pathogens (Miller, Feunteun and Tsukamoto, 2016; Drouineau *et al*., 2018; ICES, 2019; ICES, 2020; ICES, 2021a). These are threats that affect local eel stocks and the degree of impacts varies between different sites and habitat typologies. Therefore, a comprehensive assessment of habitat quality at the site level from the point of view of its suitability for eel in the different stages of the life cycle (glass eel recruitment, yellow eel growth and silver eel escapement) is a useful approach not only to support local level stock assessments, but also to understand the overall role of most of the habitat-related factors that were identified as contributing to the decline of the species.

The aims of the eel habitat assessment were to:

- explore a methodological approach to comprehensively evaluate the habitat quality for eel at the site level;
- evaluate the individual quality status of geo-referenced sites in the habitat database;
- understand the role of the different variables, or sets of variables, in the quality evaluation of each habitat type; and,
- identify the main environmental issues for eel in each type of habitat, through a joint and comparative analysis of all selected variables.

4.2. METHODS

4.2.1. Habitat quality and data quality scoring

As the main objective was to determine the quality of geo-referenced eel habitats in the databases provided by the country partners, a preliminary selection of sites that met two fundamental requirements was carried out. Firstly, the current area available for colonisation by eels should be greater than zero. Secondly, migration routes should naturally allow both recruitment and escapement, even if one or both were partially hindered, with the intention that this would provide an assessment of the habitats in which eels actually live. Following these two criteria, 645 sites out of 930 geo-referenced in the databases provided by the partners were retained for evaluation.

However, in the country WP3-habitat databases provided by partners, there were many records with no data, or data of varying quality as well as incomplete data. In order to avoid discarding useful data, it was necessary to develop a system to assess data quality, which made it possible to measure the degree of uncertainty with which each habitat quality score was awarded.

Records with no data or missing data in the country databases, as well as the presence of partial data or low-quality data, made any evaluation extremely difficult. It could penalize some sites, since the absence of data could be confused with a score awarded due to environmental variables, resulting in a biased evaluation. Therefore, a data reliability scoring system that considered the presence or absence (total or partial) of data and their quality was developed for each variable. This system had the advantage of providing a context for each habitat quality score by indicating how reliable the score was It also helped to explain the meaning of some poor quality scores, since in any point allocation system the partial or total absence of data tends to contrast, in a biased way, with sites of good environmental quality and an abundance of data with those for which there is incomplete or absent information. Meanwhile it allowed the use of partial information, characterising it with lower reliability than situations with complete and high-quality information.

The evaluation was performed at the site level, scoring for decreasing quality and adding unreliability according to the absence of data or its quality.

For both evaluations (habitat quality and data reliability) a series of variables were selected, grouped and valued as indicated in Table 4.1. In general, fewer points for both habitat quality and data reliability meant better habitat quality and better data reliability. In other words, maximum scores were awarded in each category for the worst habitat quality and lack of data.

Habitat quality was assessed at site level in relation to six groups of variables: habitat overview, migration pathways, organic pollutants, heavy metals, natural mortality and anthropogenic mortality.

Table 4.1. Overview of habitat quality and data reliability scoring

VARIABLE	SCORE	RELIABILITY
HABITAT OVERVIEW		
Habitat loss: proportion of the area of the water body currently not accessible to eels	0 to 1	0 (data) / 1 (lack of data)
Land use (sum of percentages "non-natural" uses)	0 to1	0 (data) / 1 (lack of data)
Presence of non-indigenous species - NIS (yes/no)	0/1	0 (data) / 1 (lack of data)
Lack of protected surface (percent unprotected area)	0 to1	0 (data) / 1 (lack of data)
Trophic status (presence of hypereutrophic status)	0/1	0 (data) / 1 (lack of data)
Maximum Score	**5**	**5**
MIGRATION		
Both migrations are partially obstructed	2	
Only one migration is partial	1	
Both migrations are free	0	
Maximum Score	**2**	**0 (data) / 2 (lack of data)**
POLLUTION		
POPs		
A **maximum of six pollutants** evaluated Cyclodiene pesticides (Aldrin, Dieldrin Eldrin), Brominated diphenylethers (PBDE and BDE), HCHs, PAHs, PCBs, DDTs, PFOS, Endosulfan, HCB...]		3 (lack of data) Incomplete Data: 0.5 for each pollutant (of the maximum of the six pollutants to be assessed) for which no data are available or for which the concentration is not assessable (maximum 2.75)
The concentration does **not exceed** the Environmental Quality Standard (EQS) of Directive 2013/39/EU or the concentration **is not assessable**.	0.25 for each of the six pollutants present	
Concentration exceeds the Environmental Quality Standard (EQS) of Directive 2013/39/EU	0.5 for each of the six pollutants present	

Eel samples: the contamination levels determined for the ICES EQIcont (2015) have been used and scores have been assigned according to the degrees of contamination specified in that report	EQI result	0 (maximum reliability)
Maximum Score	**3**	**3**
Heavy Metals		
A maximum of four heavy metals are assessed classified as Priority Substances by Directive 2013/39/EU (Cd, Pb, Hg and Ni) with Environmental Quality Standard (EQS).		3 (lack of data)
The concentration does **not exceed** the Environmental Quality Standard (EQS) of Directive 2013/39/EU or the concentration **is not assessable**.	0.25 for each of the four heavy metals present	Incomplete Data: 0.75 for each Priority heavy metal (of the maximum of the four to be assessed) for which no data are available or for which the concentration is not assessable (maximun 2.75)
Concentration exceeds the Environmental Quality Standard (EQS) of Directive 2013/39/EU	0.75 for each of the four heavy metals present	
Eel samples: the contamination levels determined for the ICES EQIcont (2015) have been used and scores have been assigned according to the degrees of contamination specified in that report	EQI result	0 (maximum reliability)
Maximum Score	**3**	**3**
NATURAL MORTALITY		
Presence of predators (yes/no): Piscivorous birds, piscivorous fishes and otters	0.33 for each one	0 (data) to 1 (lack of data)
Parasites and pathogens: presence or prevalence Prevalence of *A. crassus*: Prevalence = 0 percent or SDI=0 => equivalent to the “Not infected” class (1) of the EQIdis. Prevalence > 0 and ≤ 33 percent or SDI = 1-2 => equivalent to the “Slightly infected” class (2) of the EQIdis. Prevalence > 33 perecnt and ≤ 67 percent or SDI = 3 => equivalent to the “Moderately infected” class (3) of the EQIdis. Prevalence > 67 percent or SDI = 4, equivalent to the “Strongly infected” class (4) of the EQIdis Other parasites: presence Bacteria: presence Viruses: EVEX and AngHV-1, presence, equivalent to the “Strongly infected” class of the EQIdis	0 1 2 3 => 0.5 0.5 3	0 (data) / 3 (lack of data) 0 (data) / 0.5 (lack of data) 0 (data) / 0.5 (lack of data) 0 (data) / 3 (lack of data)
Maximum Score	**8**	**8**
ANTHROPOGENIC MORTALITY		
Presence of Fisheries (yes/no)		
Glass eel fisheries	**3**	0 (data) / 3 (lack of data)
Glass eel fisheries + Y/S fisheries	**3**	0 (data) / 3 (lack of data)
Illegal Fisheries	**1**	0 (data) / 1 (lack of data)
Fishing lagoons barriers	**1**	0 (data) / 1 (lack of data)
Maximum Score	**8**	**8**
Turbine Mortality (presence yes/no)	**3**	0 (data) / 3 (lack of data)

Pumping Stations Mortality (presence yes/no)	**3**	0 (data) / 3 (lack of data)
Maximum Score	**6**	**6**

Habitat overview included variables related to the general characteristics of each site, including:

- Habitat loss (proportion of the water body that is currently not accessible to eels).
- Land use (proportion of non-natural habitats in the drainage area of the water body).
- Presence or absence of non-indigenous species (NIS).
- Protected surface (proportion of unprotected area in the drainage area of the water body).
- Trophic status (presence of hyper-eutrophic conditions in the habitat)

Migration evaluated whether the anadromous and catadromous migration pathways were hampered. The score ranged from zero (both migration ways free) to two (both migrations partially obstructed).

Pollution recorded data on the quality of the habitat with respect to EU priority substances, both for organic pollutants (POPs) and heavy metals. Evaluation of contaminants was carried out differently, depending on whether the concentrations were measured in water and biota or in eel samples:

- Water and biota samples were assessed according to the standards of Directive 2008/105/EC of the European Parliament and of the Council of 16 December 2008 on environmental quality standards in the field of water policy that specifies maximum concentration levels for each contaminant to comply with an "Environmental Quality Standard (EQS)". Since EQS are calculated on samples that are not eels (but only water or biota) and guided by the precautionary principle, scores were given for the presence in the environment of the pollutants, even if their concentrations did not exceed the EQS as their effects on eels at lower levels are not known.
- Eel sample contaminant levels were based on information contained in the databases and obtained from literature. The ICES Eel Quality Index for Contaminants (EQI_{cont}), initially developed in ICES (2010; 2011), and further implemented by ICES (2012), was used as a means of combining the effects of different quality factors into an estimate of overall eel quality (ICES, 2015 and Chapter 7 **-** Eel quality in Mediterranean countries). Pollution scores were given according to the degrees of pollution specified for the EQI_{cont} in the ICES report (ICES, 2015).

The reliability of each pollutant evaluation was based on the origin of the sample from which the concentrations were obtained. If the concentrations were evaluated in water, biota or eel, either by EQS (water/biota) or EQI_{cont} (eels), the data could be considered as reliable. However, if the data were from other sources, for example, from sediments, they lacked standardised levels for comparison, in which case, the data was unreliable. Also, the presence of incomplete or partial data, that is a low number of pollutants available for a particular site, impacted the reliability score.

Organic pollutants (POPs) included a maximum of six substances from those included in the EU Directive; Cyclodiene pesticides (Aldrin, Dieldrin Eldrin), brominated diphenylethers (PBDE and BDE), hexachlorocyclohexane (HCHs), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane and its derivatives (DDTs), perfluorooctane sulfonic acid and its derivatives (PFOS), endosulfan and hexachlorobenzene (HCB).

Heavy metal contamination was based on a maximum of four heavy metals listed as priority substances in the EU Directive (with measured concentrations in water/biota); cadmium, lead, mercury and nickel. Where the concentrations were measured in eel samples, all the heavy metals available were considered.

If the concentration in water or biota did not exceed the EU EQS or the concentration could not be evaluated, 0.25 points were given for each of the four heavy metals evaluated. If it exceeded the EQS, 0.75 points were added for each of the four pollutants evaluated. If the concentration was measured in eels, the EQI_{cont} (ICES, 2015) was calculated on the average concentration of the stock. EQI_{cont} values, calculated and classified according to ICES standards (ICES, 2015) were scored from zero to three to match the scores given to water or biota samples.

Natural mortality was assessed using two variables, the presence of predators, such as otters and piscivorous fish or birds, and presence of parasites or pathogens.

The presence of parasites and pathogens, was based on information contained in the databases as well as information obtained at a later stage from literature. Prevalence data were obtained from literature sources including on the swimbladder degenerative index (SDI), a very reliable method for estimating the damage caused by the parasite, *Anguillicola crassus.* (Lefebvre, Contournet and Crivelli, 2002). However, due to the paucity of information on the SDI (data were only obtained for eight populations), it was not possible to calculate the ICES Eel Quality Index for Diseases (EQI_{dis}) according to the specific ICES standards (ICES, 2015). Instead, a slightly different Infection Index to the EQI_{dis} was developed as it included the presence of parasites other than just *Anguillicola crassus*, although it scaled the prevalence of *A. crassus* and gave the highest score to the presence of Eel virus European X (EVEX) and Anguillid herpesvirus 1 (AngHV-1) viruses. The presence of bacteria was also included as *A. crassus* swim bladder damage often leads to secondary bacterial infections (Kirk, 2003).

In the eight populations for which SDI and prevalence data were available, the validity of quality class scores obtained for *A. crassus* were checked against the EQI_{dis} and the Infection Index. In seven of the eight cases, the quality class of the degree of infection, was fully consistent, while in one, the degree of *A. crassus* infection was different (lower according to the Infection Index), because the data on SDI and prevalence came from different bibliographic sources. In this case, the information corresponding to the SDI was used.

Anthropogenic mortality included fishing as well as turbine and pump station mortalities. Fishing was scored up to a maximum of eight points, three points when a single eel life stage was exploited, six points when all life stages were fished, adding single points for reports of illegal fishing and if there were lagoon fishing barriers present at the site. Turbine and pump station mortality scoring was up to three points for each reports of turbine mortality and pump mortality bringing the maximum to six. Reliability was measured by the lack of turbine or pump mortality data, with three points in each case up to a maximum of six.

4.2.2. Habitat quality classes

Once the habitat quality scores and reliability scores were obtained for each variable at site level, the two scores were added to obtain a single score (except for migration and pollutants where the two scores were considered separately) that allowed categorisation according to the degree of degradation at each site. The matrix for these classifications is shown in Table 4.2 and the criteria are explained below.

Table 4.2. Habitat quality categories and their correspondence with those already established for each variable

Quality Status/ Variable	Habitat Overview	Migration	Pollutants (POPs + Heavy Metals)	Natural Mortality	Anthropogenic Mortality
Degraded	*Slightly altered*	*Both migrations not obstructed**	*Low/Slightly polluted*	*Low*	*Low*
Highly degraded	*Altered*	*One migration partially obstructed*	*Polluted*	*Medium*	
	-	*Both migrations partially obstructed*	-	-	*High*
Strongly degraded	*Strongly altered*	-	*Strongly polluted*	*High*	*Very high*

*See Section 5.2.3. Interpreting Quality Statuses

Habitat overview

There were a large number of variables with no data, especially for land use (67.9 percent), trophic status (67.2 percent) and presence of NIS (85.7 percent). For this reason, all the sites in which the total sum of reliability points were greater than or equal to three (which indicated an absence of data simultaneously in three or more variables of the group) were not evaluated.

This made it necessary to classify the scores based on their degree of reliability. In sites where data were rated as very reliable, when the sum of habitat and reliability scores were less than 1.67, the habitat status was assessed as slightly altered (green), between 1.67 and 3.33 the habitat status was altered (yellow) and when the sum of scores was greater than 3.33, the habitat status was strongly altered (red).

Sites where data reliability was rated as reliable had slightly lower thresholds: slightly altered (green) = sum of scores less than 1.33; altered (yellow) = sum of scores between 1.33 and 2.67; strongly altered (red) = sum of scores greater than 2.67. Sites with unreliable data had even lower thresholds: slightly altered (green) = sum of scores less than 1; altered (yellow) = sum of scores between 1 and 2; strongly altered (red) = sum of scores greater than 2.

Migration

A strongly altered (red) category was not considered for migration, as it would correspond to sites where migrations were not naturally possible so they were removed from the assessment. The green habitat status was allocated to sites where there were no obstructions to migration (score = 0), yellow (altered) for sites with one migration partially obstructed (score = 1) and an orange status for sites where both migrations were partially obstructed (score = 2)

Organic Pollutants (POPs)

Sites with scores of less than 1 were classified as low pollution/slightly polluted (green), scores between 1 and 2 classified as Polluted (yellow) and between 2 and 3 rated as strongly polluted

Heavy Metals

Where data quality was rated as very reliable, the low pollution/slightly polluted status (green) was for sites with scores below 1, the polluted status (yellow) for scores between 1.5 and 2, and the strongly polluted status (red) for scores greater than 2. Where data quality was reliable, low pollution/slightly polluted (green) was for scores less than 0.75, polluted (yellow) was for scores between 1.75 and 2, while strongly polluted (red) was for scores above 2.

Score thresholds were lower for sites where data quality was unreliable and even lower for sites with very unreliable data quality. Unreliable: low/slightly polluted (green) = scores less than 0.5; polluted (yellow) = scores between 0.75 and 1.75, strongly polluted (red) = scores above 1.75. Very unreliable: low pollution/slightly polluted (green) = scores less than 0.25; polluted (yellow) = scores between 0.25 and 0.5; strongly polluted (red) = scores greater than 0.5.

Natural mortality

Data were scarce and dispersed so reliability had to be considered when analysing scores.

The sum of the scores obtained in the evaluation based on the presence of predators and parasites and pathogens was used to assign habitat quality categories. Low mortality (green) was from a low score (less than 0.33) for the presence of predators and a low or very low prevalence of parasites/pathogens (scores less than 1.5). Medium mortality (yellow) was for medium to high scores the presence of predators (scores below 1) and low to medium parasites/pathogen scores (scores less than 2.5). High mortality (red) includes sites with a high score in the presence of predators (scores above 1 plus high scores for parasites/pathogens (scores greater than 3).

Anthropogenic mortality

For anthropogenic mortality, there was no medium category as the existence of mortality due to fishing or the presence of turbines or pumps already inferred poor habitat quality. Low (green) was for low or no fishing and turbine/pump mortality (scores less than 1), high (orange) for medium to high mortality from fishing or mortality from turbines/pumps (scores around 2 to 4), and very high (red) for very high fishing mortality or simultaneous presence of fishing mortality and turbines/pumps (scores around 5 to 7).

4.2.3. Interpreting Quality Statuses

It may be useful to make a series of clarifications that help to put into context and correctly interpret the general meaning of each of the habitat quality statuses:

Low impact or slight impact statuses (marked in green in the habitat database and the analyses) do not in themselves indicate good quality, but are set in comparison to the other quality categories. This does not mean that there is no alteration, but that the alteration is of lesser intensity than in the other categories. In other words, the pressure exerted by a certain factor (such as pollution or mortality) on the eel population is of lesser magnitude, not that there is no pressure. This is true for all variables with the sole exception of migration, where it means that migration faces no obstructions. For example, the low impact/slight impact status, in general, may include the presence of NIS or a major modification of land use, from a habitat overview point of view. In pollution, they include sites where two EU priority substances are present, although they do not exceed the EQS. However, the uncertainty with which this situation is assessed must be considered if the concentrations are measured in water because of the impossibility of estimating or discerning their real effect on eels. Finally, these statuses may occur at sites where there is no legal fishing but illegal fishing is present or one third of the eels may be infected with *A. crassus*.

Medium impact status (marked in yellow) should not be considered as being of minor concern, but that there is a state of intermediate intensity of each effect. For example, in the habitat overview category there may be sites that have lost up to two-thirds of their original surface area coupled with the presence of NIS or with hypereutrophic states. For contamination, sites where the four EU priority heavy metals are present can be included, without, as indicated above, being able to infer their effect on eel populations. Finally, sites where *A. crassus* is present at prevalence rates of up to 67 percent could be included.

High impact and very high impact status are not only the worst on a comparative basis but indicate sites where there are serious concerns, especially those with very high impact status. These may include situations where the prevalence rate of *A. crassus* is higher than 67 percent or where there is, in the worst case, there is *A. crassus* infection as well as viral infections. In anthropogenic mortality, situations can occur where fishing mortality affects more than one eel life stage (glass eels, yellow eels and silver eels). In the pollution category there may be scenarios where the concentration of six assessed POPs exceeds the EU EQS. Finally, in habitat overview, sites may have lost more than 75 percent of their original surface area and unnatural land use of 70 percent as well as degraded trophic states with hypereutrophic conditions.

4.2.4. Data analysis

Once all the variables had been categorized, the data showing acceptable levels of reliability, which was usually data assessed as reliable or very reliable, although as explained in the results, the criteria were different for some variables, analysis was carried out to establish whether there were relationships between the variables.

For each group of variables (habitat overview, migration, pollutants, natural mortality, anthropogenic mortality), the relationship between frequency of appearance of each quality state and type of habitat was explored using a Pearson's Chi-Square test (χ^2). Then, a two-proportions z-test was performed to detect the presence of significant differences between the frequencies of occurrence of specific habitat types and quality categories (Daniel and Cross, 2013).

The overall objective was to compare the influence of the different variables to identify, as far as possible, the pressures to which each type of habitat was subjected. In other words, to identify the influence of each of the variables on the overall habitat quality in each of the habitat types, lakes, lagoons, estuaries and rivers. For this purpose, the data corresponding to the quality status of the reliable categories of each variable were used for each habitat type.

Contamination by POPs and heavy metals were combined into a single variable. Likewise, new quality categories were established (Table 4.2), together with their correspondence with those used for the study of each variable separately.

for each habitat type, the independence of the frequencies of occurrence of each quality status in the five variables was tested using a Pearson's Chi-Square test (χ^2). A correspondence analysis was then used to explore possible associations between the five variables and the different levels of degradation.

In the Pearson's Chi-Square tests (χ^2), an approximation to Fisher's exact test with 10^5 simulations was used to correct for the effect of small samples or frequencies lower than 5. Statistical analysis was performed with SPSS v.24 (IBM® SPSS® Statistics; International Business Machines Corporation, New York, USA) and R software 3.3.2 (R Development Core Team, 2021). Graphics were made using the ggplot library (Wickham, 2009).

4.3.RESULTS

4.3.1. Data collection

The WP3-Habitat country databases provided by the partners differed greatly with respect to the quantity and quality of data reported for habitat quality analysis. That is, there were differences in data provision between variables, habitat types and countries as well as a high number of records with no data, which prevented assessments in 1 794 (46.4 percent) out of the 3 870 possible records. A summary of the data submissions provided by each country according to the variables used in the different types of habitats and their degree of reliability can be found in Additional Results Part I.

This situation is summarized in Figure 4.1 which shows that 93.5 percent of sites were evaluated for anthropogenic mortality and 97.5 percent for migration while only 23.6 percent were evaluated for heavy metals and 15.7 percent for organic pollutants. By habitat type, lakes had the least number of assessments (39.9 percent), while other habitats had assessment percentages between 54 percent and 56 percent.

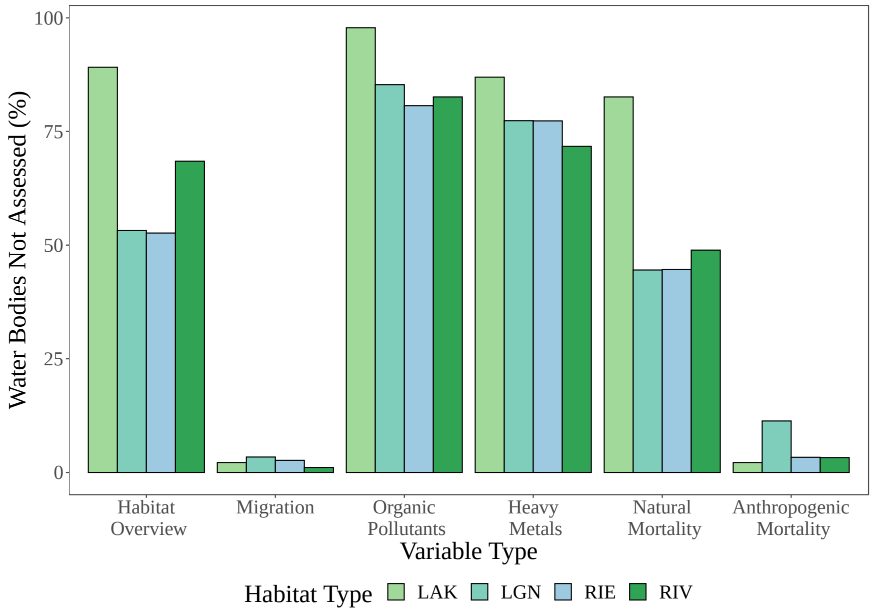


Figure 4.1. Percentage of "Not Assessed" water bodies by Habitat Type according to the variables used in the habitat quality analysis (LAK = lakes; LGN = lagoons; RIE = estuaries; RIV = rivers).

Once the data were cleaned and corrected, each of the variables in the 645 water bodies from the habitat quality analysis was analysed. The information is included in the Habitat Quality Scores database (available in the GFCM sharepoint). Of the total 645 sites analysed, 38 had a high percentage of reliable information as shown in Table 4.3.

Table 4.3. Eel sites with the highest proportion of reliable information

Country	Site Name	Area/River basin	Site coordinates		Habitat type
			Longitude	Latitude	
Albania	Karavasta	Adriatic sea	19.50	40.93	Lagoon
Algeria	Oubeira	Oubeira	8.39	36.85	Lake
Egypt	Lake Burullus	Northern Nile Delta basin	30.87	31.48	Lagoon
Egypt	Lake Mariout	Northern Lakes basin	29.90	31.15	Lagoon

Country	Site Name	Area/River basin	Site coordinates		Habitat type
			Longitude	Latitude	
France	Canet	Canet	3.02	42.67	Lagoon
France	Salses-Leucate	Salses-Leucate	3.00	42.85	Lagoon
France	Bages-Sigean	Bages-Sigean	3.00	43.08	Lagoon
Italy	Caprolace coastal lake	Lazio	12.97	41.35	Lagoon
Italy	Fogliano	Lazio	12.90	41.40	Lagoon
Italy	Lesina	Puglia	15.43	41.88	Lagoon
Italy	Monaci	Lazio	12.94	41.38	Lagoon
Italy	Orbetello	Toscana	11.20	42.43	Lagoon
Italy	Arno	Toscana	10.28	43.68	Estuary
Italy	Tevere	Lazio	12.61	42.18	River
Spain	Estany Pudent	Ibiza	1.44	38.73	Lagoon
Spain	Ses Salines d'Eivissa	Ibiza	1.37	38.86	Lagoon
Spain	Es Salobrar de Campos	Mallorca	3.00	39.36	Lagoon
Spain	Albufera de Mallorca	Mallorca	3.10	39.79	Lagoon
Spain	Albufereta de Pollensa	Mallorca	3.09	39.86	Lagoon
Spain	Albufera des Grau	Mallorca	4.25	39.95	Lagoon
Spain	Guadiaro	Guadiaro	-5.31	36.57	River
Spain	Guadalhorce	Guadalhorce	-4.68	36.85	River
Spain	Ebro	Ebro	-1.04	41.76	River
Spain	Turia o Guadalaviar	Turia o Guadalaviar	-1.25	40.10	River
Spain	Segura	Segura	-1.73	38.16	River
Spain	Palmones	Palmones	-5.45	36.17	Estuary
Spain	Verde	Verde	-4.95	36.49	Estuary
Spain	Guadalhorce	Guadalhorce	-4.46	36.67	Estuary
Spain	Guadalmedina	Guadalmedina	-4.43	36.71	Estuary
Spain	Velez	Velez	-4.11	36.73	Estuary
Spain	Ebro	Ebro	0.66	40.72	Estuary
Spain	Segura	Segura	-0.65	38.11	Estuary
Spain	Laguna del Hondo	Bajo Vinalopó	-0.75	37.18	Lagoon

Country	Site Name	Area/River basin	Site coordinates		Habitat type
			Longitude	Latitude	
Spain	Turia o Guadalaviar	Turia o Guadalaviar	-0.34	39.43	Estuary
Spain	Mijares	Mijares	-0.01	39.91	Estuary
Spain	Guadalfeo	Guadalfeo	-3.57	36.74	Estuary
Spain	Mar Menor	Mar Menor	-0.79	37.72	Lagoon
Spain	L'Albufera de Valencia	El Saler	-0.35	39.34	Lagoon

4.3.2. Habitat overview

Out of the total number of 645 sites, only 258 were assessed for this group of variables. There were 121 sites where data reliability was considered as very unreliable because only three variables out of five could be assessed. There were 119 sites where four variables were assessed and 18 sites where all five variables could be assessed and considered as reliable and very reliable, respectively.

Figure 4.2A shows the data reliability scores by habitat type. Only data for the 137 sites with data reliability rated as reliable and very reliable were considered valid for further analysis. The distribution of this information by country and by habitat type is shown in Figure 4.2B.

A χ^2 test showed significant association between habitat type and its quality status ($\chi^2 = 52.74$; $p < 0.0001$), while a z-test ($p < 0.05$) indicated (Figure 4.2C) that slightly altered status was significantly more frequent in lagoons, there were no significant differences between habitat types in the frequency of the altered condition and the strongly altered condition was significantly more frequent in rivers and estuaries than in lagoons.

Analysing within each of the habitat types, there were no significant differences between the different degrees of disturbance within lakes. In lagoons, the frequency was highest for slightly altered followed by altered and strongly altered states. In estuaries, altered and strongly altered states were more frequent than slightly altered while the frequency in rivers was highest for strongly altered, followed by altered, then slightly altered.

Estuaries and rivers had worse habitat overview statuses than lakes and lagoons, measured by the sum of altered and strongly altered sites. The main indicators of poor quality in rivers were the presence of NIS (100 percent of the cases that were assessed as having reliable data), land use, with 88.5 percent of the assessments showing more than two thirds of the basin had non-natural uses, and trophic status, which showed hypereutrophication peaks in 84.4 percent of the assessments. In rivers, the key indicators were the presence of NIS (100 percent of the cases assessed as reliable), trophic status, with 65.9 percent of sites in a hypereutrophic state, the absence of protected areas, with 57.6 percent of sites in which less than one third of the surface area was protected and lost surface area, where 49.6 percent of the assessments indicated surface area losses of more than 67 percent.

In lagoons the most frequent status was slightly altered, and the variables that presented the worst quality were the presence of NIS (again 100 percent) and land use, with 51.9 percent of sites with less than one third of natural use.

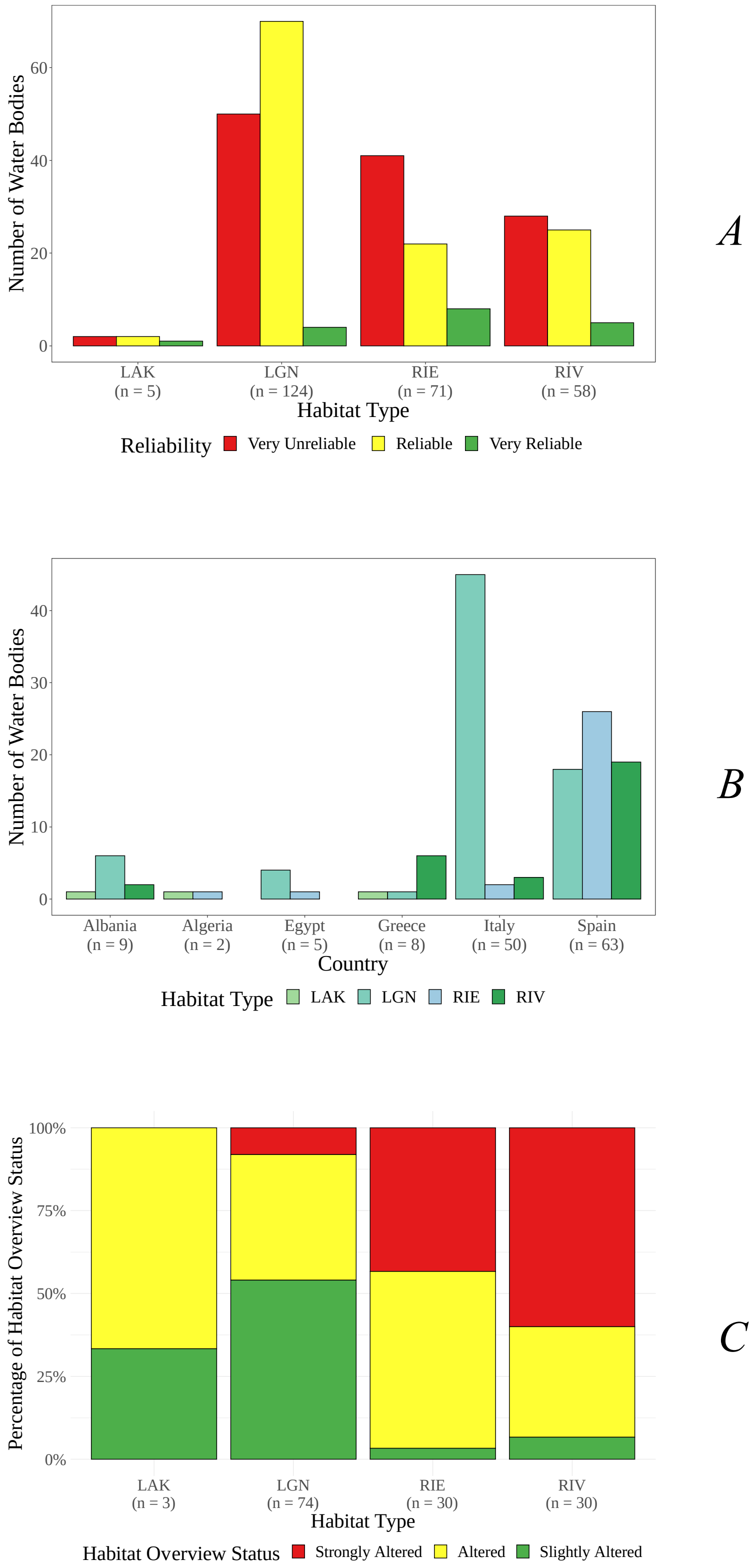


Figure 4.2. Habitat Overview: A) Number of water bodies where data was assessed to be very reliable, reliable and very unreliable by habitat type (LAK = lake, LGN = lagoon, RIE = estuary, RIV = river). B) Number of water bodies by habitat type and country selected for subsequent analysis. C) Proportion of sites (percent) assessed as strongly altered, altered and slightly altered by habitat type.

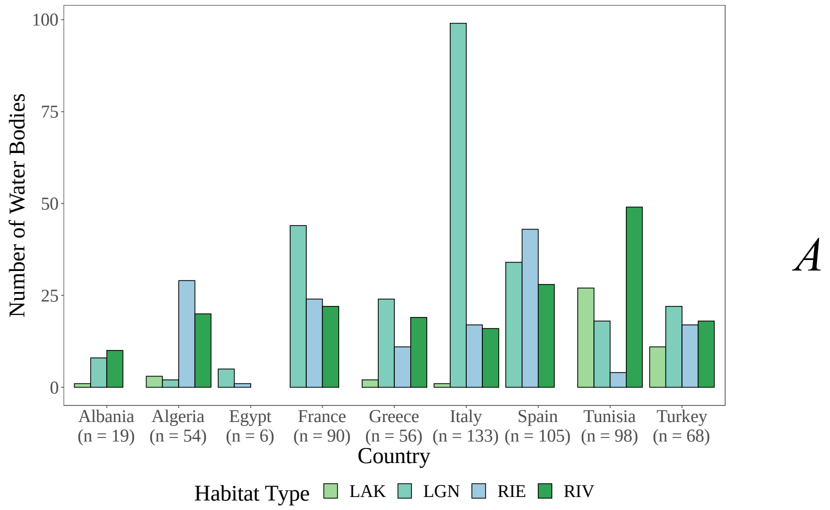
Migration

A total of 629 sites were assessed for reliability. The information provided by the country partners on migration pathways was very abundant and complete so data were rated as very reliable for all the water bodies (45 lakes, 256 coastal lagoons, 146 estuaries and 182 rivers). Figure 4.3A shows how the information was distributed by country and habitat type.

A χ^2 test showed significant differences between habitats in relation to migration pathways ($\chi^2 = 106.54$; $p < 0.0001$), while a z-test ($p < 0.05$) showed significant differences in analysing the frequencies of occurrence when comparing the states with each other and by habitat type (Figure 4.3B):

When the frequencies of occurrence of the different statuses were compared, "Both migrations not obstructed" (that is, free migration) was significantly less frequent in lagoons than in other habitats (Figure 4.3B). There were no significant differences in the occurrence of "Both migrations partially obstructed" between habitat types (Figure 4.3B), and "One migration partially obstructed" was more frequent in lagoons.

When the frequency of occurrence of each status, within each of the habitat types, was studied separately, it was observed that in all cases the least frequent status was "One partially obstructed", except in rivers, where this status was not present. The categories, "Both migrations not obstructed" and "Both migrations partially obstructed" showed no significant differences within any of the four habitat types (Figure 4.3B).



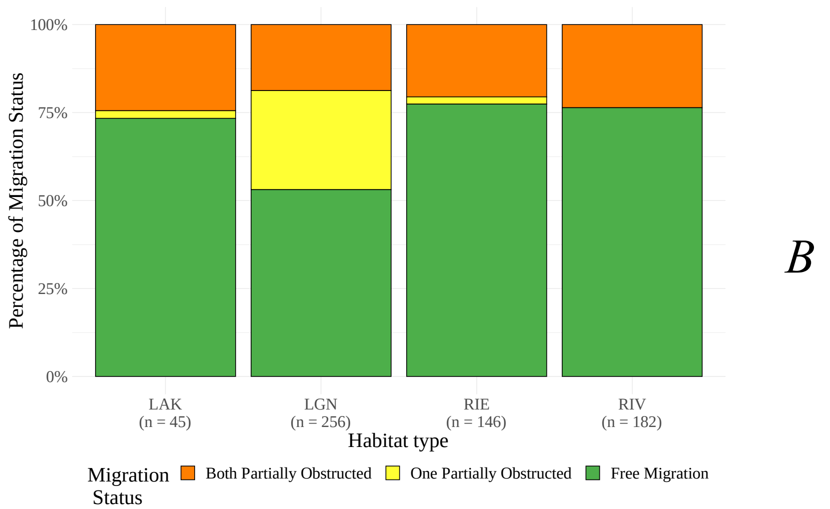


Figure 4.3.-Migration: A) Number of water bodies assessed by habitat type (LAK = lake, LGN = lagoon, RIE = estuary, RIV = river) and country. B) Proportion of sites (percent) with migration routes assessed as both partially obstructed, one partially obstructed and free migration by habitat type.

Organic pollutants (POPs)

This variable was the one for which the lowest amount of information was obtained and only 101 water bodies could be assessed. The result of the reliability evaluation indicated that there were eight sites where the data was very unreliable (none of the six compounds could be assessed), 16 sites where only one or two pollutants were assessed, 37 sites where data was assessed as reliable (three or four components were assessed), and 40 water bodies where data was rated as very reliable (assessment of five or six pollutants or estimated concentrations of organic pollutants in eels).

The different degrees of reliability distributed by habitat type are shown in Figure 4.4A. For the study of habitat quality according to the presence of POPs, only data from sites rated reliable and very reliable (77 water bodies) were considered valid, including 24 lagoons, 27 estuaries and 26 rivers. There was no reliable information on lakes. The way in which this information was distributed by country and habitat type can be seen in Figure 4.4B. It should be noted that, given the geographical origin of most of the data (more than 87.1 percent from Italy and Spain), the conclusions belong mostly to a very specific area of the Mediterranean (Figure 4.4B).

A χ^2 test showed significant differences in the frequency of occurrence of different degrees of POPs pollution and in their distribution between habitat types ($\chi^2 = 15.63$; $p < 0.05$). The most frequent status was "Polluted", which occurred in 54.3 percent of the assessments.

A z-test ($p < 0.05$) indicated that when the frequency of occurrence of each status, within each of the habitat types, was studied separately (Figure 4.4C), in lagoons the status "Low/Slightly polluted" was significantly more frequent (54.2 percent of cases), there were no significant differences in the frequency of occurrence of the three degrees of pollution in estuaries and the "Polluted" condition was more frequent in rivers (73.1 percent of sites).

When the frequencies of occurrence of the different statuses were compared, it was observed that the "Strongly polluted" status was the only one that did not show significant differences between habitat types.

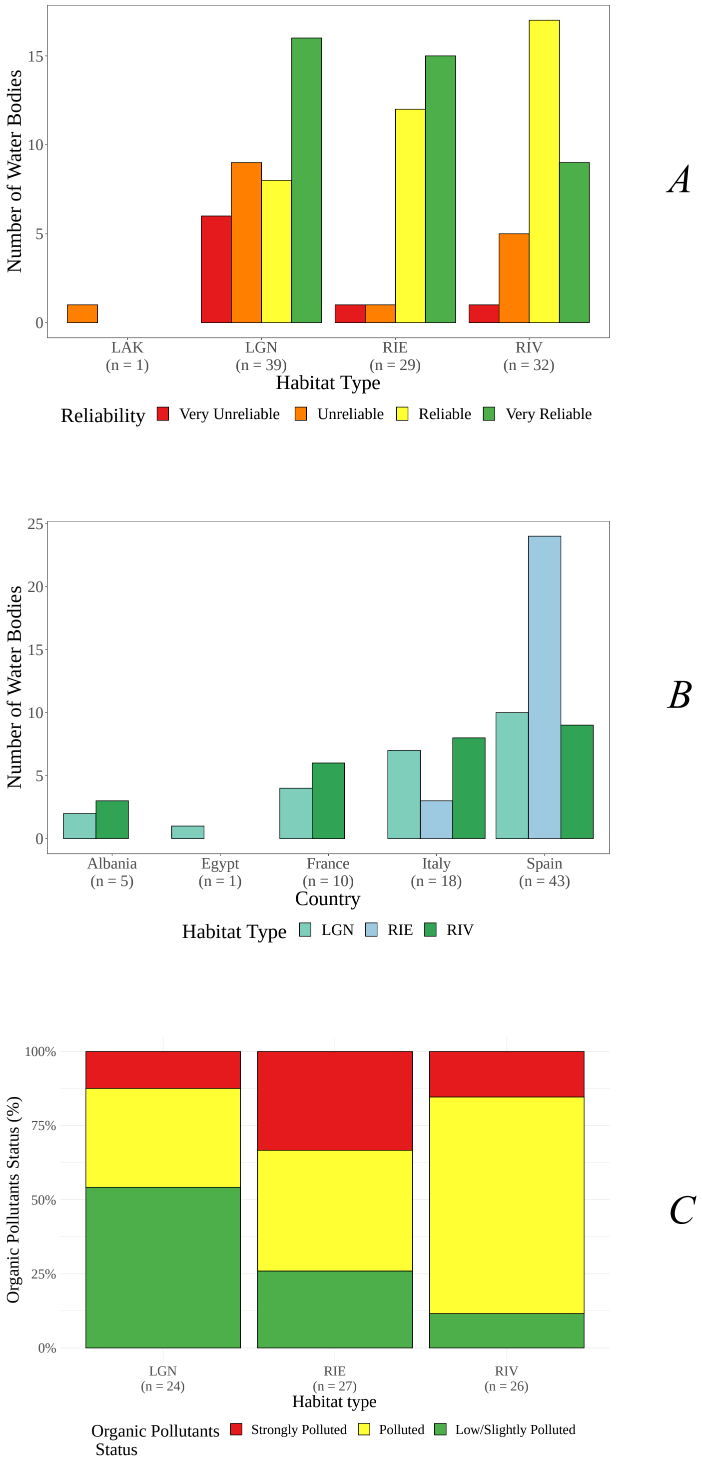


Figure 4.4. Organic Pollutants: A) Number of water bodies where data was assessed to be very reliable, reliable, unreliable and very unreliable by habitat type (LAK = lake, LGN = lagoon, RIE = estuary, RIV = river) B) Number of water bodies by habitat type and country selected for subsequent analysis. C) Proportion of sites (percent) assessed as strongly polluted, polluted and slightly polluted by habitat type

Heavy metals

There were very sparse data on heavy metal pollution, although slightly more than there was for POPs, resulting in 152 water bodies being assessed out of a total number of 645. The result of the reliability assessment indicated that data from 20 sites were very unreliable (no metals assessed), 29 sites had unreliable data (two or three concentrations of priority metals not assessed), 25 sites had reliable data (only one of the four metals nor assessed) and 78 water bodies were scored as very reliable (concentrations of all four priority metals were assessed or with estimated concentrations of heavy metal pollutants in eels).

The different degrees of reliability distributed by habitat type are shown in Figure 4.5A. For the assessment of habitat quality according to the presence of heavy metals, only the data corresponding to sites classified as reliable and very reliable (103 water bodies) were considered valid, including five lake sites, 46 lagoon sites, 17 estuary sites and 35 rivers. Distribution by country and habitat type is shown in Figure 4.5 B. As with POPs, most of the information came from Italy and Spain (50.5 percent of total data), although there was data from a larger number of countries.

A χ^2 test did not show any significant differences between habitat types and frequencies of occurrence of the different degrees of heavy metal contamination ($\chi^2 = 8.67$; $p = 0.193$).

The frequency with which the different states of contamination occurred for all habitats was 39.8 percent in “Low/Slightly polluted”, 33.0 percent “Polluted” and 27.2 percent “Strongly polluted” (Figure 4.5C).

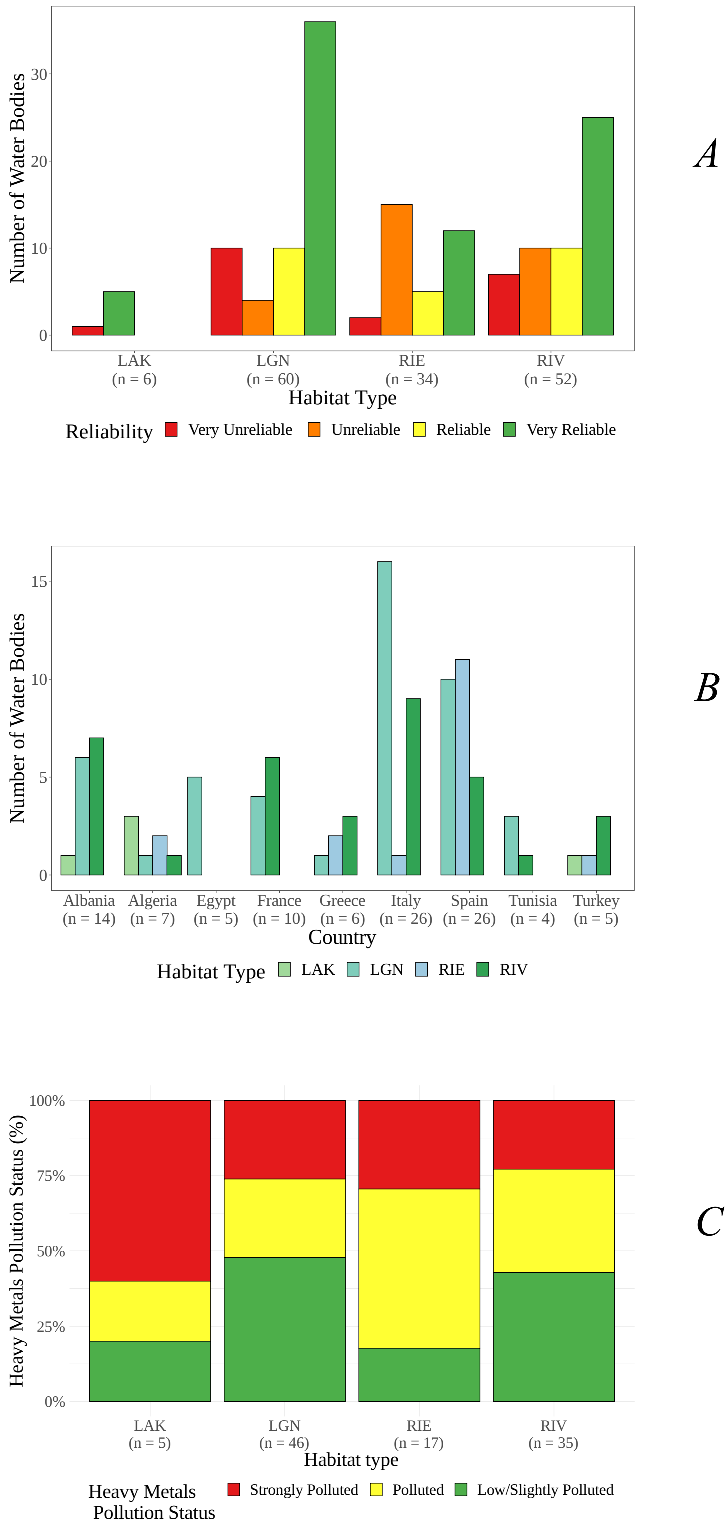


Figure 4.5. Heavy Metals: A) Number of water bodies where data was assessed to be very reliable, reliable and very unreliable by habitat type (LAK = lake, LGN = lagoon, RIE = estuary, RIV = river). B) Number of water bodies by habitat type and country selected for subsequent analysis. C) Proportion of sites (percent) assessed as strongly polluted, polluted and slightly polluted.

Natural mortality

Data reliability on natural mortality (presence of predators and presence of parasites and pathogens) was evaluated in 332 sites. However, the scarcity of data on parasites and pathogens as well as information of varying quality on the presence of predators led to a high frequency (274 sites) being assessed as having very unreliable data. Twenty-two water bodies had unreliable data based on low quality data on the presence of predators and reliable data on parasites and pathogens, 26 sites had reliable data with good quality data on both variables and ten sites had very reliable data on presence of predators as well as parasites and pathogens.

Figure 4.6A shows the different degrees of reliability by habitat type. Only data corresponding to the 58 sites classified as unreliable, reliable and very reliable (58 water bodies) were used in the analysis of natural mortality including three lakes, 40 lagoons, six estuaries and nine rivers. The distribution of these sites by country is shown in Figure 4.6B.

There were no significant differences (χ^2 test = 7.57; p = 0.271) between habitat types in relation to the frequency of occurrence of different degrees of natural mortality. The low number of sites, could have influenced the robustness of the analysis.

The frequencies with which the different natural mortality categories occurred for all habitats (Figure 4.6C) were 24.1 percent assessed as “Low”, 53.4 percent as “Medium” and 22.4 percent as “High”.

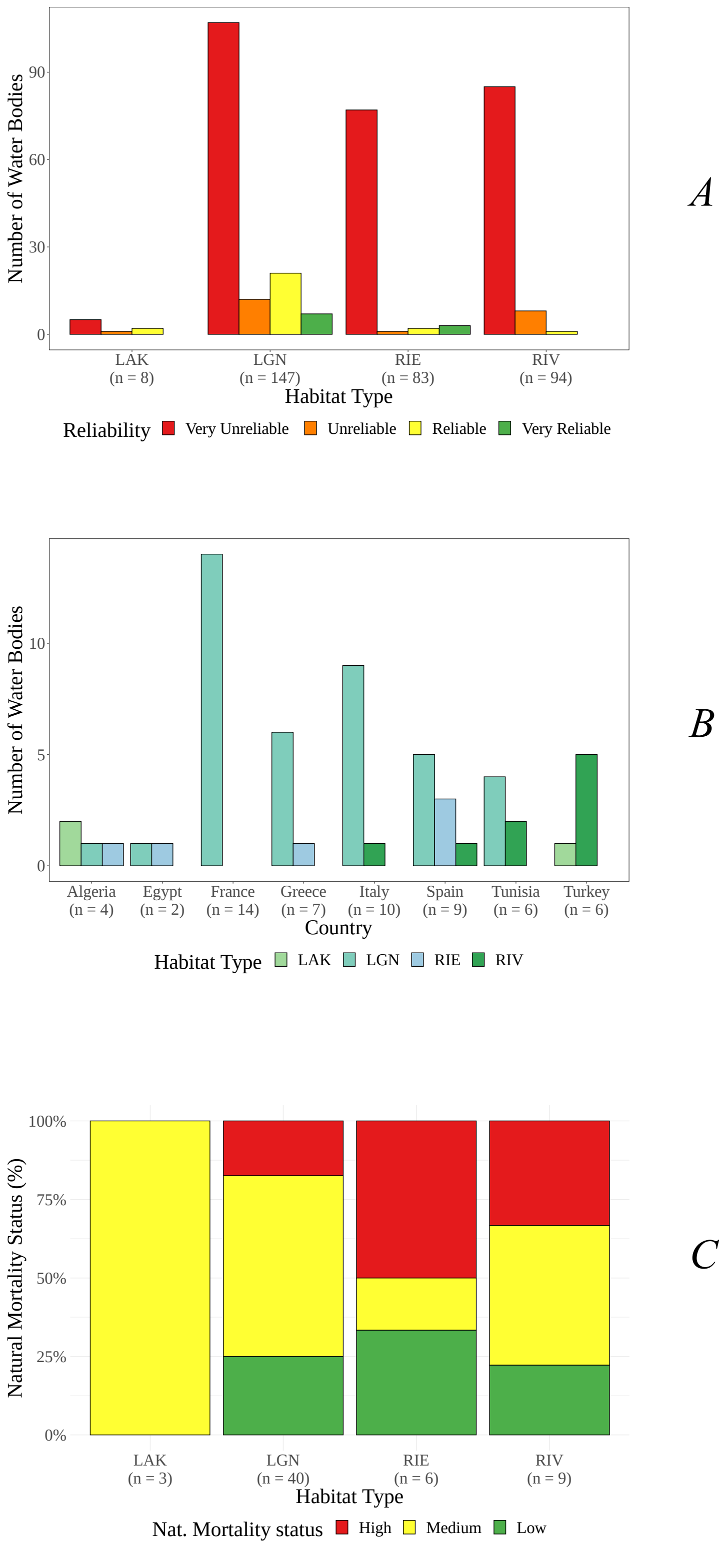


Figure 4.6. Natural mortality: A) Number of water bodies where data was assessed to be very reliable, reliable and very unreliable by habitat type (LAK = lake, LGN = lagoon, RIE = estuary, RIV = river). B) Number of water bodies by habitat type and country selected for subsequent analysis. C) Proportion of sites (percent) assessed as high mortality, medium mortality and low mortality.

Anthropogenic mortality

The reliability of anthropogenic mortality data (based on fishing mortality and mortality from turbines of pump stations) was assessed in 603 out of the total of 645 sites. This group of variables had the second-highest abundance of data, especially for data on fishing mortality.

Reliability was rated as very unreliable in 78 sites that had no data on fishing mortality but some information on turbine/pumping stations mortality, unreliable in 178 water bodies, generally with medium to high quality information on fishing mortality or, failing that, with good information on turbine/pumping station mortality, reliable in 79 sites with medium quality data on both types and very reliable in 268 sites with high quality data on both. Figure 4.7A shows distribution of data reliability by habitat type, while data from sites with very unreliable data were excluded from further analysis. The distribution of the 525 remaining water bodies by country and habitat type is shown in Figure 4.7B and included 27 lake sites, 223 lagoon sites, 144 estuary sites and 131 river sites.

The relative abundance and high quality of the data used in the analysis showed that, in all four habitat types, the variable most indicative of the degree of anthropogenic mortality was fishing mortality.

A χ^2 test showed significant differences between habitat types in relation to the degree of anthropogenic mortality ($\chi^2 = 89.24$; $p < 0.0001$). The frequencies of occurrence (as a percentage of the total) by habitat type and degree of anthropogenic mortality are shown in Figure 4.7C.

A significant z-test ($p<0.05$) indicated that the most frequent status category was “High” (58.1 percent of the assessments) and this status was encountered more in lakes (92.6 percent), than in lagoons (75.3 percent) and estuaries (41.2 percent) or rivers (40.3 percent). Conversely, the "Low" status was significantly more frequent in estuaries and rivers (40.2 percent and 38.1 percent respectively), while the "Very high” status (highly degraded) did not show significant differences between habitat types. (Figure 4.7C).

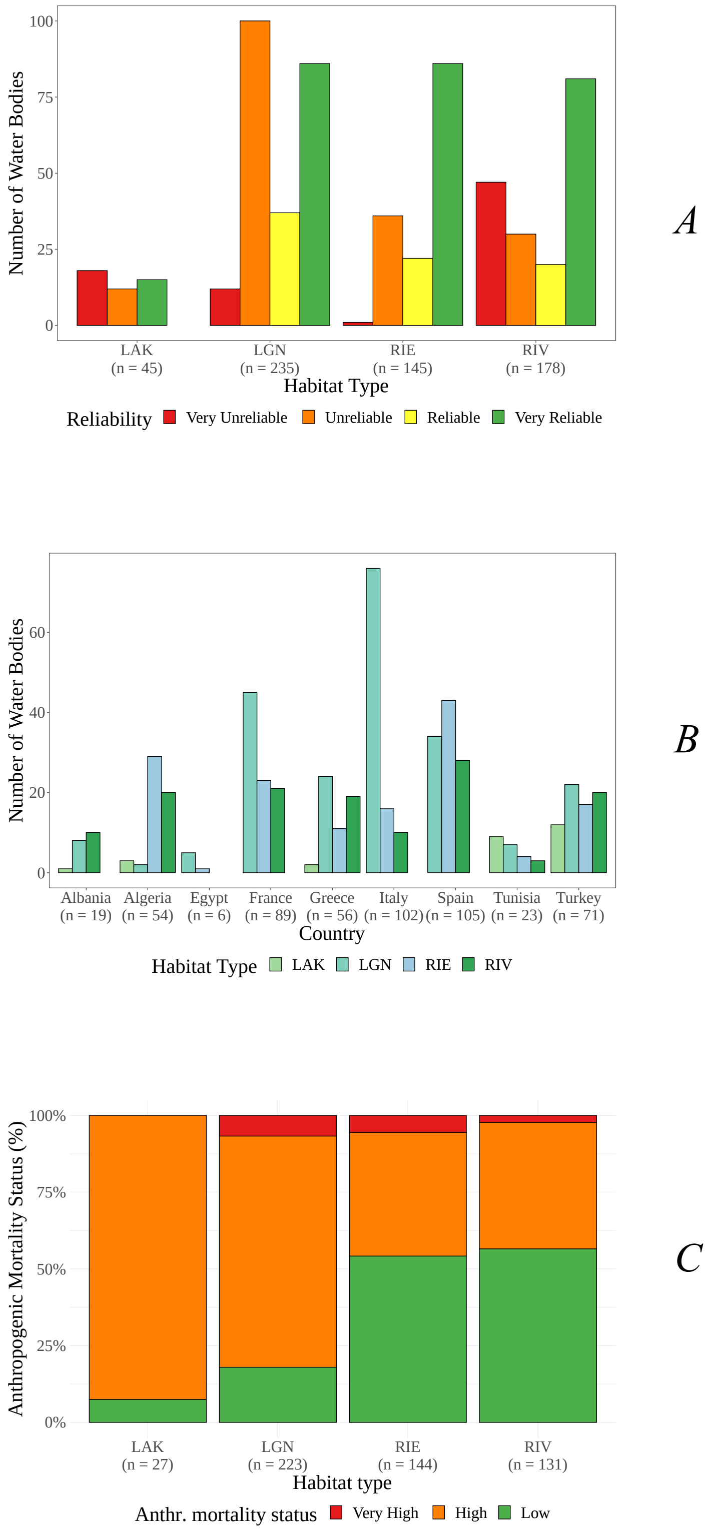


Figure 4.7. Anthropogenic Mortality: A) Number of water bodies where data was assessed to be very reliable, reliable and very unreliable by habitat type (LAK = lake, LGN = lagoon, RIE = estuary, RIV = river). B) Number of water bodies by habitat type and country selected for subsequent analysis. C) Proportion of sites (percent) assessed as very high mortality, high mortality and low mortality by habitat type.

4.3.3. Correspondence analysis of habitats and habitat quality status

Estuaries

A total of 370 conservation status scores (degraded, highly degraded and strongly degraded) were analysed, distributed by habitat variable as follows; habitat overview = 30, migration = 146, pollutants = 44, natural mortality = 6 and anthropogenic mortality = 144.

Analysis using χ^2 tests showed a significant relationship between different habitat quality variables and their conservation status classification (χ^2 = 128.3; $p < 0.05$). A subsequent correspondence analysis retained 93.3 percent of the variance in the first dimension and 6.7 percent in the second dimension (Figure 4.8, Table 4.4). Dimension 1 was defined by habitat overview (absolute contribution to axis inertia, AC = 0.41), pollutants (AC = 0.25) and strongly degraded status (AC = 0.64) on the negative side of the axis and migration (AC =0.27) and degraded status (AC = 0.29) on the positive side. Dimension 2 was defined by the variables anthropogenic mortality (AC = 0.39) and highly degraded (AC = 0.59) on the negative side and migration (AC = 0.0.21 and strongly degraded (AC = 0.25) on the positive side.

Migration was associated with the degraded level, while pollutants, and especially, habitat overview were associated with strongly degraded. Natural mortality was also associated with this status, although the small number of cases meant that it carried little weight in the analysis. Anthropogenic mortality had an intermediate position in the sector formed by the degraded and highly degraded states, at an equal distance between both states on Dimension 1, which retained the highest percentage of variance.

In general, the results were associated with the total variance retained by the variables habitat overview, pollutants and migration and the strongly degraded and degraded states.

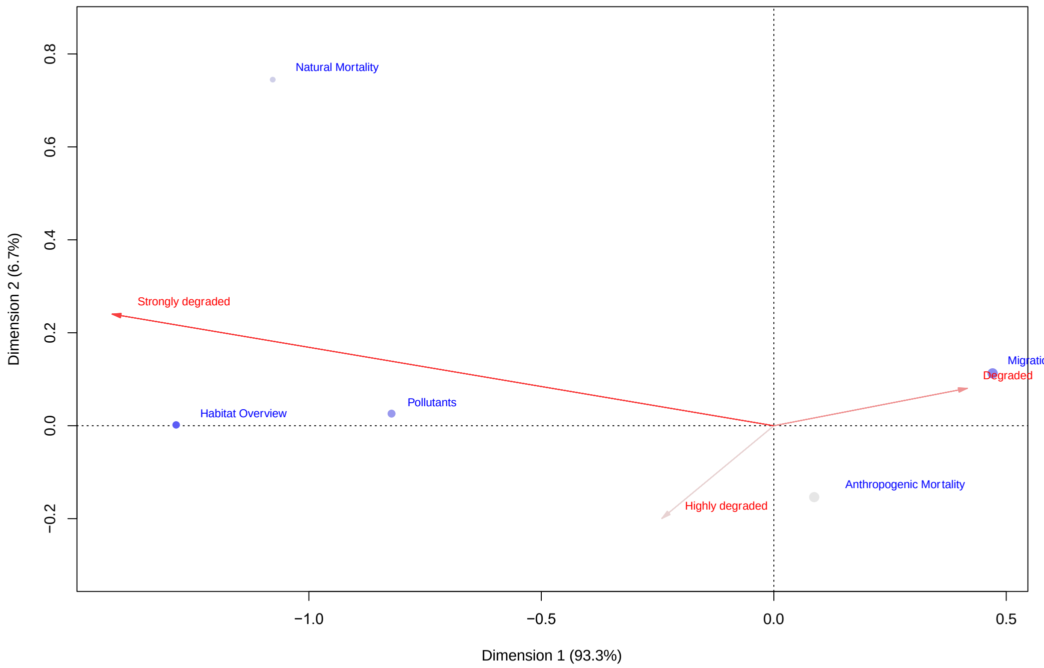


Figure 4.8. Results of correspondence analysis on the conservation status of Mediterranean estuaries. The size of the dots is proportional to the relative frequency of the variable considered. The intensity of the colour in dots and arrows is proportional to their absolute contribution to the total variance (inertia).

Rivers

A total of 413 scores were analysed with the sample sizes; habitat overview = 30, migration = 182, pollutants = 61, natural mortality = 9 and anthropogenic mortality = 131.

The χ^2 test showed a significant relationship between different quality variables and their conservation status classification ($\chi2 = 175.6$; $p < 0.05$).

Correspondence analysis retained 90.7 percent of the variance in the first dimension and 9.3 percent in the second dimension (Figure 4.9, Table 4.4). Dimension 1 was defined by the variables habitat overview (AC = 0.63), pollutants (AC = 0.11) and strongly degraded status (AC = 0.79) on the negative side of the axis and by migration (AC = 0.18) and degraded status (AC = 0.20) on the positive side. Dimension 2 was defined by migration (AC = 0.31 and degraded status (AC = 0.23) on the positive side of the axis and by pollutants (AC = 0.27), anthropogenic mortality (AC = 0.24) and highly degraded status (AC = 0.64) on the negative side.

Habitat overview was associated with strongly degraded status, as was, albeit to a lesser extent, natural mortality, although the small sample size meant that it carried little weight in the analysis. Degraded status was strongly associated with migration, while pollutants was associated with highly degraded status. The position of anthropogenic mortality was intermediate between the highly degraded and degraded states, although the distance on dimension 1 (which retained a larger percentage of variance) was smaller for the degraded state.

In summary, a high percentage of the total variance was retained by the variables, habitat overview, migration and pollutants (in that order) on one hand, and the strongly degraded and degraded states (also in that order) on the other.

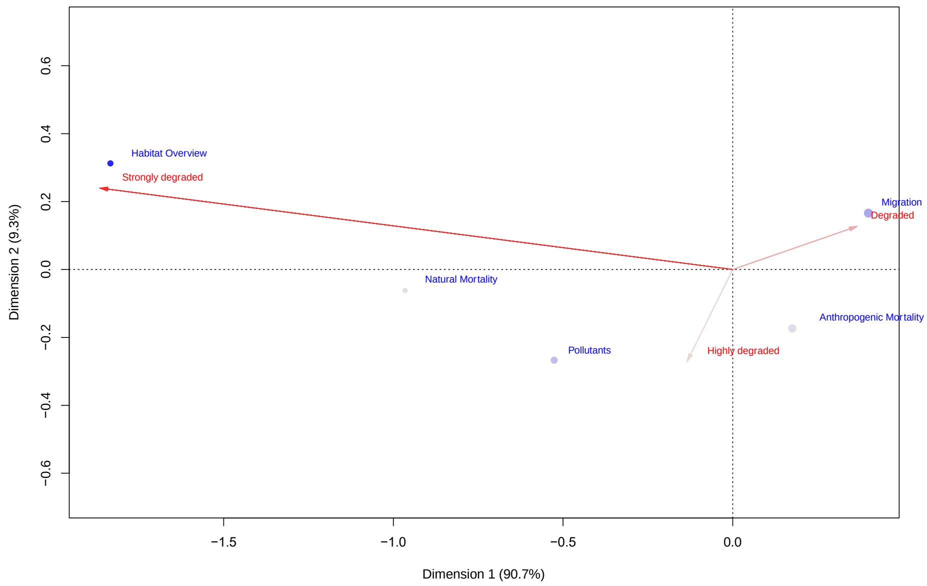


Figure 4.9. Results of the correspondence analysis on the conservation status of Mediterranean rivers. The size of the dots is proportional to the relative frequency of the variable considered. The intensity of the colour in dots and arrows is proportional to their absolute contribution to the total variance (inertia).

Lagoons

The sample size for the lagoon habitat category, was considerably larger than for other habitats (n = 663): habitat overview = 74 sites, migration = 256, pollutants = 70, natural mortality = 40 and anthropogenic mortality = 223.

Using χ^2 tests revealed a significant relationship between different habitat quality variables and their conservation status classification ($\chi2 = 128.16$; $p < 0.05$). Subsequent correspondence analysis retained 59.4 percent of the variance in the first dimension and 40.1 percent in the second dimension (Figure 4.10, Table 4.4). Dimension 1 was defined by anthropogenic mortality (AC = 0.57) and the highly degraded state (AC = 0.38) on the negative side of the axis and migration (AC = 0.24) and the degraded state (AC = 0.60) on the positive side. Dimension 2 was defined by pollutants (AC = 0.58), natural mortality (AC = 0.13) and strongly degraded (AC = 0.92) on the positive side of the axis and by migration (AC = 0.26) on the negative side.

The group of variables related to habitat overview was associated with degraded status, and anthropogenic mortality with highly degraded. Both pollutants and natural mortality were associated with the strongly degraded state. Pollutants was located in the sector marked by the strongly degraded and degraded states, due to the presence of a large number of degraded states, however the weight of the strongly degraded states was greater. Natural mortality was in the opposite sector due to the higher frequency of strongly degraded compared to highly degraded states.

In summary, the results were associated with the large inertias of anthropogenic mortality on one hand, and pollutants, migration and degraded status on the other.

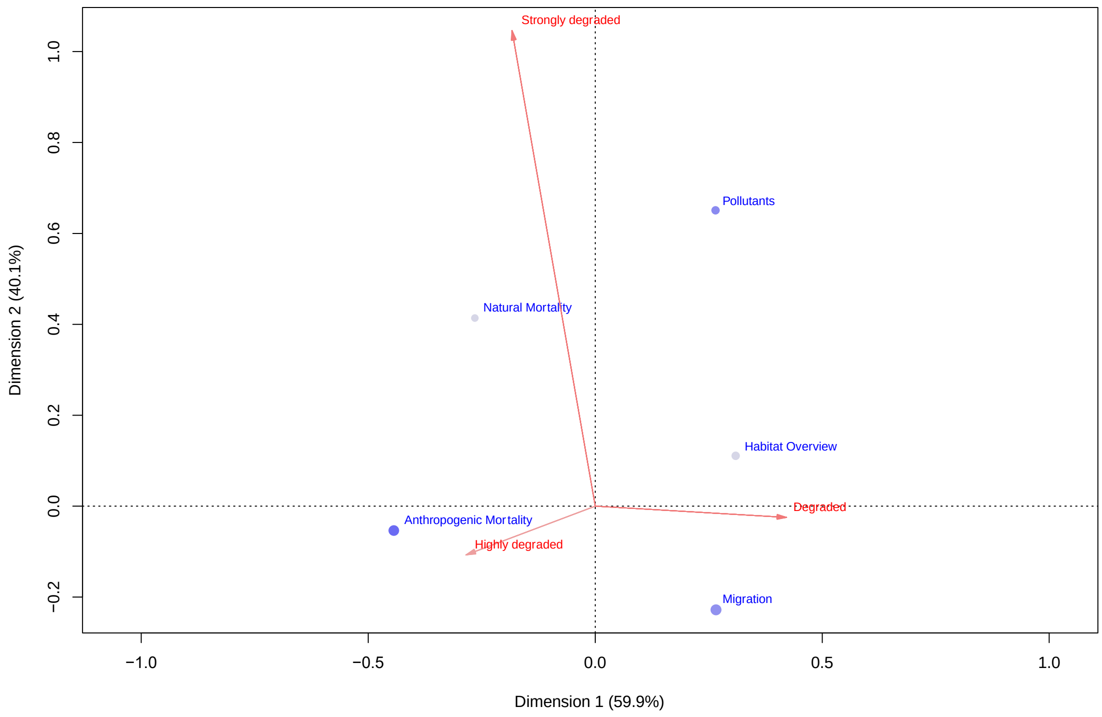


Figure 4.10. Results of correspondence analysis on the conservation status of Mediterranean lagoons. The size of the dots is proportional to the relative frequency of the variable considered. The intensity of the colour in dots and arrows is proportional to their absolute contribution to the total variance (inertia).

Lakes

Using χ^2 testing showed a significant relationship between different habitat quality variables and their conservation status classification for sites belonging to the lake habitat type ($\chi2 = 82.224$; $p < 0.05$).

Correspondence analysis retained 59.7 percent of the variance in the first dimension, and 40.9 percent in the second dimension (Figure 4.11, Table 4.4). Dimension 1 was defined by the variable pollutants (AC = 0.939) and the state strongly degraded (AC = 0.96). The weight of both in the analysis was probably due to the fact that pollutants was the only variable where the strongly degraded state was present. Dimension 2 was defined by the variable anthropogenic mortality (AC = 0.48) and the state highly degraded (AC = 0.456) on the positive side of the axis, and on the negative side by migration (AC = 0.418) and the state degraded (AC = 0.54).

However, the scarcity of data on habitat overview (n = 3), pollutants (n = 5) and natural mortality (n = 3) meant that the results could not be consider as reliable. Associations were more reliable when analysing migration (n = 45) and anthropogenic mortality (n = 27), clearly associated to the degraded and highly degraded states respectively.

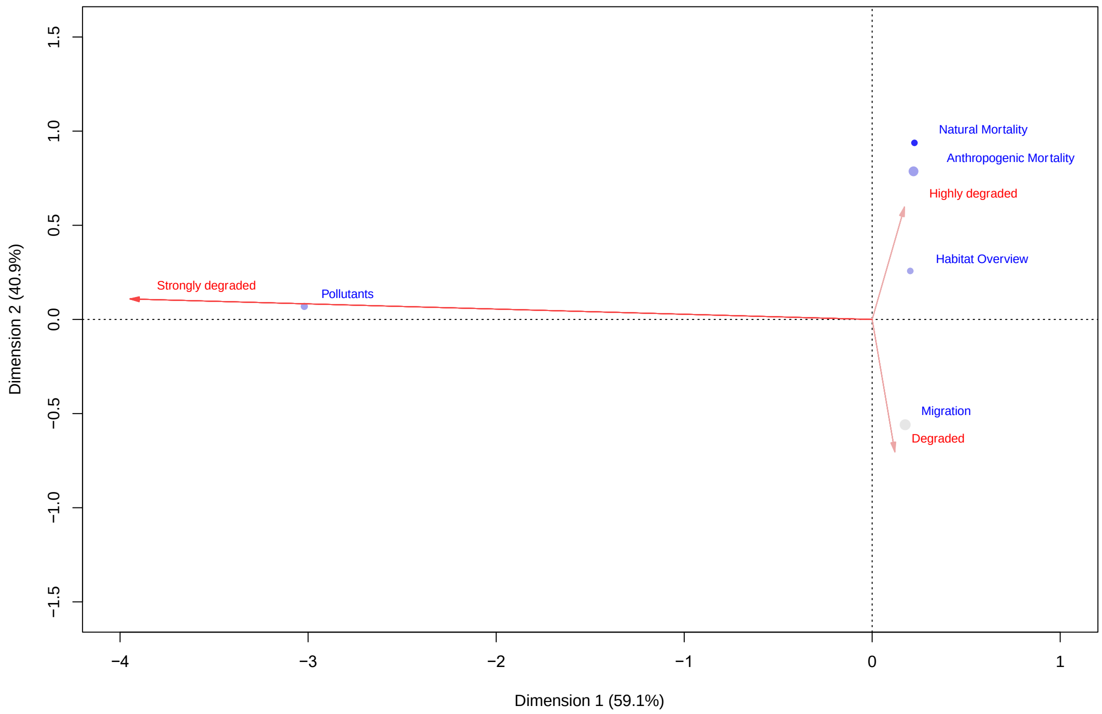


Figure 4.11. Results of correspondence analysis on the conservation status of Mediterranean lakes. The size of the dots is proportional to the relative frequency of the variable considered. The intensity of the colour in dots and arrows is proportional to their absolute contribution to the total variance (inertia).

Anthropogenic Mortality, caused by fishing, was listed as the main pressure on eel populations in lakes and lagoons while the impact of pollutants on lagoons was also relevant (Table 4.4).

In estuaries and rivers, the highest level of impact was the overall conservation status of the habitat. In estuaries this was probably related to highly modified land use, the presence of NIS and the occurrence of dystrophic crises. In rivers, poor habitat quality was probably due to habitat loss (in terms of lost surface area), the presence of NIS and the absence of protected areas. In both habitat types, the impacts of pollutants were also relevant (Table 4.4).

Table 4.4. Summary of correspondence analysis results of habitat quality status by habitat type. Each cell contains the variables associated with each status. The last column contains the variables with the highest inertia associated with *Highly* and *Strongly degraded* status. * results based on a low amount of data.

	Habitat Quality Status			
	Degraded	**Highly degraded**	**Strongly degraded**	**Variables associated with the two worst quality states**
Lakes	Migration	Anthropogenic Mortality Natural Mortality* Habitat Overview*	Pollutants*	Anthropogenic Mortality
Lagoons	Habitat Overview Migration	Anthropogenic Mortality	Pollutants Natural Mortality	Anthropogenic Mortality Pollutants
Estuaries	Migration Anthropogenic Mortality		Habitat Overview Natural Mortality* Pollutants	Pollutants Habitat Overview
Rivers	Migration Anthropogenic Mortality	Pollutants	Habitat Overview Natural Mortality*	Pollutants Habitat Overview

4.4. DISCUSSION AND CONCLUSIONS

4.4.1. Availability of data

The WP3-habitat database was originally designed to be very complete and exhaustive, as it was intended to collect information on many variables with very different characteristics, ranging from habitat descriptors to those related to the causes of eel mortality in the Mediterranean. This enormous task, together with the lack of time to complete it and the final scarcity of data on some of the variables foreseen in the database, particularly on contamination by POPs and heavy metals, as well as in natural mortality due to the presence of parasites or pathogens, led to the need for a literature search for new data to improve the quantity and quality of the information.

Because of the lack of data, a high percentage of the 3 870 possible evaluations in the 645 selected sites could not be carried out and had to be rated as not assessed in the database. The quality of the available data varied widely, with some being highly reliable, while others were incomplete or could not be assessed at all. For example, in some cases the pollutant data were very reliable while in other cases the number of compounds analysed was very low or the concentrations were calculated in matrices that did not allow their evaluation.

To award each score, a system for evaluation of the reliability of data was used which was inseparable from the score awarded in each evaluation. This made it possible to interpret the presence of low scores that did not correspond to good quality but to the existence of partial or non-assessable data. However, in some cases, even using the joint scores and reliability assessment system, it was not possible to fully compensate for differences in quantity and quality of data between sites. Despite this, the use of this system had the advantage of avoiding the loss of already scarce data, by allowing a larger number of variables to be scored (without losing sight of the reliability of that score) while also identifying gaps in the information or quality of information available on the 645 selected sites.

For the subsequent grouping of the variables, the most acceptable reliability categories were selected in each case, discarding the rest. As a result, the information used was not evenly distributed across variables, countries or habitat types. For example, assessment of the habitat overview group of variables could only be carried out in six countries because the reliability of data from some countries was very low. The analysis of pollution by POPs was carried out with 87.1 percent of the data from Italy and Spain, while lakes were the habitat with the least information available.

The scarcity of information in the analysis of the variables could result in a lack of statistical significance, detracting from the validity of some results and even producing a bias by giving greater or lesser weight to some variables, or habitat types, as opposed to others, which did not conform to reality. Also, the results could not be extrapolated to the whole of the Mediterranean basin, as they were obtained from specific geographical areas.

This meant that some results should be carefully evaluated, and conclusions be drawn with caution. However, this was a first comprehensive evaluation of eel habitats in the Mediterranean, that proposed a methodology for such an assessment and whose results allowed the identification of information gaps while highlighting the major conservation problems for eel in the Mediterranean region.

4.4.2. Quality of the environment for eels in the Mediterranean (Habitat Overview)

Habitat overview variables were provided by six of the nine partner countries and related to three of the habitat categories, as lakes were discarded due to insufficient data (n = 3).

In rivers, loss of habitat has been caused by the massive construction of dams that, in the absence of fish passes or other remediation strategies, prevent upstream migration of eels. Since the mid-20th century, dam construction has increased (Lehner *et al*., 2011; van Looy, Tormos and Souchon, 2014), resulting in the loss of 50 percent to 90 percent of available habitat in Europe by the end of the century (Feunteun, 2002). The same phenomenon has occurred in the Mediterranean region (Kettle, Vøllestad and Wibig, 2011), in some parts of which the historical loss of eel habitat has been quantified (Mateo *et al*., 2021), profoundly affecting its natural distribution.

Similarly, in estuarine and coastal wetlands, there has been a significant loss of habitat, although in this case it is not due to dam construction but caused by dewatering and land reclamation with wetland loss rates of 60 percent to 80 percent in some cases (Cataudella, Crossetti and Massa eds, 2015). By comparison, the analysis of lost surface area by habitat provided in Chapter 2, highlighted that rivers were the most inaccessible habitats (65 percent of surface area lost), followed by estuaries (25 percent), lagoons (20 percent) and lakes (10 percent)

Habitat loss causes changes in eel population dynamics by artificially raising local densities, leading to effects such as increased intraspecific competition for space and food, higher social interactions leading to increased aggression and transmission of infectious diseases, all leading to increased mortality rates (Vøllestad and Jonsson, 1988; Bevacqua *et al*., 2011). An increase in local density also alters eel physiology, producing more males (Tesch, 2003; Kettle, Vøllestad and Wibig, 2011), also facilitating natural predation (Agostinho *et al*., 2012; Drouineau, *et al*., 2015) and overfishing (Briand *et al*., 2005).

Results indicate that habitat loss is greatest in rivers and occurs, not only because of the factors indicated above, but also because the area available is subject to numerous structural and hydrological alterations that lead to ecological fragmentation. Given the difficulty in quantifying these alterations, this information was not included in the habitat database, but it would be interesting to consider these factors in future assessments.

Freshwater and other wetland ecosystems have suffered other anthropogenic pressures such as deforestation and the establishment of agricultural land, resulting in excessive sediment inputs to rivers and streams (Wilkinson and McElroy, 2007). For this variable, the worst situations were found in the sites closest to the coast, estuaries and coastal lagoons, habitats in which 88.5 percent and 51.85 percent, respectively, of the sites assessed had more than two thirds of their drainage area with unnatural use.

Because of land use change, and especially with agricultural and urban development, there is an increased input of fertilisers and organic matter, leading to extensive eutrophication (de Jonge, Elliott and Orive, 2002; Smith, 2003). Hypereutrophication has been reported for many sites, affecting 84.4 percent of estuaries and 65.9 percent of rivers. These alterations can give rise to an increasing frequency of severe degradation and crises, such as that experienced in the Mar Menor (Spain), with dramatic fish mortalities (Ruiz *et al*., 2020). Increased agricultural and industrial land use in drainage basins can also lead to the release of organic pollutants and heavy metals.

The presence of non-indigenous species was reported for all the sites evaluated within all habitat categories, with 100 percent prevalence in all reliable assessments. While their presence gives a general idea of the state of habitat degradation, from the point of view of eel stocks, their presence is not always harmful. For example, the red swamp crayfish, *Procambarus clarkii*, is a very important trophic resource for eel leading to eels being proposed as a suitable species for its biological control (Aquiloni *et al*., 2010; Musseau *et al*., 2015).

However, in most cases the presence of NIS poses a threat, either through predation by species such as catfish or pike, competition, or the spread of parasites. For example, the cyprinid

Pseudorasbora parva, is a non-indigenous species that is an intermediate host of *A. crassus* (Gozlan, *et al*., 2010; Cesco, Lambert and Crivelli, 2001).

4.4.3. Eel migratory processes (Migration)

To complete their biological cycle, eels undertake two migrations, to and from their spawning grounds (Tesch, 2003). The first migration to inland waters is the glass eel ascent and colonisation of growth habitats by which glass eels enter lagoons or estuaries (Tesch, 2003) and, in the latter case, continue the migration to colonise upstream areas of rivers, adapting to a wide range of environmental conditions (Feunteun *et al*., 2003). The second migration is the downstream movement in rivers and escapement that takes silver eels from growth habitats to the open sea, for the oceanic journey to the spawning site. This migration takes place during specific periods (autumn-winter) and is triggered in narrow time frames linked to environmental conditions that create very specific migration windows (Durif *et al*., 2003; Bruijis and Durif, 2009).

Therefore, the existence of obstacles in upstream and downstream routes such as gates, locks and dams can alter both the colonisation process and delay or interrupt escapement, especially when the environmental window is limited in time (Bruijis and Durif, 2009; Verbiest *et al*., 2012; Drouineau *et al*., 2017).

To study the migration process, data were collected for each route separately and then merged into a single variable for analysis. Sites where migrations were not naturally possible were removed from the assessment as they were not considered eel habitats. Therefore, the study of the migratory process concerned exclusively the habitat currently available to eel, that is, only areas in rivers below the first impassable dam were considered. Only totally free, or partially obstructed routes were considered.

Results showed that the frequency of occurrence of the category "Both migrations partially obstructed" was not significantly different between habitats, indicating that no habitats were better than others in terms of connectivity. The status "Both migrations not obstructed”, included in the "Degraded" level for the analysis, had a lower frequency of occurrence in coastal lagoons than in the other three habitat types, together with a higher frequency of the "One partially obstructed" category. Thus, lagoons were the habitat with the worst conservation status with respect to migration. As there were no significant differences between the different habitat types with respect to the category "Both migrations partially obstructed", this poor overall quality (as the sum of the two categories implying that migration is not completely free) was due to the presence of a high frequency of the "One partially obstructed" category. The joint analysis of these data with fishing mortality data at the sites where the "One partially obstructed" category was present in lagoons indicated that these were the sites with fishing barriers. The fact that there are periods of time when such barriers do not obstruct migration does not imply that the overall poor quality of migration states in lagoons is associated with, or also has consequences for, the impact of fishing mortality in these areas.

Irrespective of the above, a possible reason for the poorer quality of migration pathways being found in lagoons and not, for example, in rivers was related to the way the variables were calculated. That is, a priori rivers could be expected to have a worse overall quality as it is a habitat type where obstacles to free migration are very frequent. However, if the analysis was constrained to migration routes in the area below the first impassable obstacle, the result was that connectivity was better, for example, in rivers than in lagoons.

4.4.4. Analysis of pollution status (POPs + Heavy Metals)

The presence of contaminants in the environment has been considered as one of the key elements in the decline of the European eel population (Robinet and Feunteun, 2002; Geeraerts and

Belpaire, 2010). Therefore, it has been an issue of ongoing and particular concern to the WGEEL, which has consistently recommended requesting more information on this issue since 2004. In 2007, the Eel Quality Database (EQD) was established to compile quality parameters (Belpaire *et al*., 2011). Among the pollutants it prioritises are PCBs, flame retardants, pesticides and heavy metals. More recently, two monographic workshops have taken place, Workshop of a Planning Group on the Monitoring of Eel Quality (ICES, 2015) and Workshop of the Working Group on Eel and the Working Group on Biological Effects of Contaminants (ICES, 2016).

Eels are particularly vulnerable to contaminants due to their high body lipid content, their position in the food chain, longevity and benthic life habits (ICES, 2016). During the continental phase, most contaminants are concentrated in lipid deposits depending on the degree of habitat contamination (Robinet and Feunteun, 2002; ICES, 2015). Subsequently, during migration, eels subsist by using their fat reserves, which puts accumulated pollutants into circulation. This marks the onset of the effects at subcellular, cellular, tissue and organ level (Robinet and Feunteun, 2002; van Ginneken *et al*., 2009, ICES, 2015, 2016). The most prominent effects include impaired lipid metabolism and decreased fat deposition (Corsi *et al*., 2005; Fernández-Vega *et al*.,1999; Pierron *et al*., 2007; Oliver *et al*, 2015); altered gonadal maturation and oocyte production (Palstra *et al*., 2006; Baillon *et al*., 2015; ICES, 2016; Pierron *et al*., 2014); altered osmoregulatory capacity, behavioural and hormonal disruptions as well as genotoxicity (Couillard, Hodson and Castonguay, 1997; Geeraerts and Belpaire, 2010).

These compounds can, in addition, be transmitted to offspring causing malformations in larvae and compromising their survival (Byer *et al*., 2013; Foekema, *et al.*, 2016; Robinet and Feunteun, 2002; Sühring *et al*., 2015; Freese *et al*., 2017; Freese *et al*., 2019). They seriously compromise migration, reproductive success (Geeraerts and Belpaire, 2010; Pierron, *et al*., 2008; Robinet and Feunteun, 2002) and reduce genetic diversity (Maes *et al*., 2013). Thus, the analysis of pollution status and quality assessment of escaping silver eel from inland waters can also be considered as a useful tool to support management and conservation strategies for eel in the Mediterranean (Capoccioni *et al*., 2020).

Pollutants, both POPs and heavy metals, are two of the variables (together with natural mortality) with the lowest amount of data provided by partner countries. Data for POPs were only available for 101 sites, and for heavy metals for 152 sites. Most of the information came from the calculation of concentrations in water. Therefore, the general rule of assessment was to follow the standards of Directive 2008/105/EC of the European Parliament and of the Council of 16 December 2008 on environmental quality standards in the field of water policy and, in the eel samples, to use the ICES (2015) standards for the calculation of EQI_{cont}. However, this was only possible in 22 sites for POPs and 20 sites for Heavy Metals.

Assessments based on concentrations on pollutants in water are not equivalent to assessments in eels. Therefore, the use of this methodology, which combines concentrations from different sources in the same assessment, has its risks, as it could be biased. This is particularly so as the concentrations of pollutants in the environment do not reflect the real level of contamination in the eels, which, due to their position in the food chain and fat content, are extremely prone to bioaccumulation (Maes *et al*, 2005; Sühring *et al*., 2013; Robinet and Feunteun, 2002; van Ginneken, 2009; ICES, 2013). Another factor to consider is that contaminants accumulate throughout the continental lifespan of eels, so that age or maturation stage will also influence the level of contamination in individual eels (ICES, 2015).

To try to mitigate the deviation that occurs when data calculated on different matrices are combined in the same analysis, a precautionary approach was applied, considering that a certain degree of contamination was already present when a pollutant was detectable in the environment, even if its concentration was below the quality standards of Directive 2008/105/EC. A more correct methodology would have been to scale the concentrations, both in water and sediment, using the frequency distribution of the concentrations to establish levels with respect to the statistics of the distribution itself, but this was a task that was beyond the time limits of this programme.

All the above indicates that the results obtained must be interpreted in context, although they may provide indications of the magnitude of the impact of pollutants. The results on pollution by POPs were based on the analysis of 77 sites, but it should be noted that 87.1 percent of these were from Italy and Spain, so they can hardly be extrapolated to the whole of the Mediterranean. Furthermore, the lack of data meant that it was not possible to study the effect of these pollutants in lakes.

The lowest degree of contamination was detected in lagoons, followed by estuaries and finally rivers. The fact that, for all habitats, the "Polluted" status was the most frequent would indicate that organic pollutants are a major potential threat to eel populations. More exhaustive and reliable data should be a priority to determine the extent of this threat.

Data on heavy metal concentrations were more abundant than those available for POPs, and results were obtained from 103 sites with wider geographical distribution. The analysis showed no significant differences between habitats or degrees of contamination. The absence of differences does not imply that they should not be a matter of concern for the conservation of the species. On the contrary, if the results appear to indicate that heavy metal contamination was homogeneously distributed between habitat types, this should be an issue for future attention.

4.4.5. Analysis of mortality due to natural causes (Natural Mortality)

Natural mortality was studied using two variables, the presence of predators and the presence of parasites or pathogens. Predators were considered to be the greater cause of mortality, since parasites mainly generate sub-lethal effects, more evident in the migratory life stage than during the continental phase. Predation is a source of natural mortality, if it is not exerted by NIS (in which case it would be an anthropogenic impact), that acts throughout the biological cycle, including reproductive migration (Tesch, 2003; Wahlberg *et al*., 2014). The most important natural predators of eels are otters (*Lutra spp.*) and cormorants (*Phalacrocorax carbo*) (Kindermann, 2008; Carpentier *et al*., 2009; ICES, 2011).

Parasites and pathogens are important for the overall life cycle of eels, mainly regarding the parasite *Anguillicola crassus* and the EVEX and AngHV-1 viruses. This led to great interest and demand for information from ICES, leading to recommendations to expand studies and the organisation of the Workshop of a Planning Group on the Monitoring of Eel Quality (ICES, 2015), to lay the foundations for study of the health status of eels.

Anguillicola crassus, is an exotic nematode that was introduced into European waters in the early 1980s and has continued to spread throughout the range of the Europesan eel (Kirk, 2003; Jakob *et al*., 2009; Marohn, Jakob and Hanel, 2013). In addition to causing various afflictions (Kirk, 2003; Lefebvre *et al*., 2013), the greatest damage focuses on the functionality of the swim bladder, altering its gaseous composition (Kirk, Lewis and Kennedy, 2000; Lefebvre *et al*., 2013) or necrotising its tissues (Würtz and Taraschewski, 2000). This leads to a decrease in swimming ability and performance (Székely *et al*., 2009) which, in turn, threatens the success of the reproductive migration (Sjöberg *et al*., 2009; Clevestam *et al*., 2011; Palstra *et al*., 2007) by requiring a higher energetic cost (Marohn, Jakob and Hanel, 2013). Infection has also been reported to negatively impact the silvering process (Fazio *et al*., 2012).

In the case of viruses, AngHV-1 may have lethal effects, while EVEX may, like *A. crassus*, lead to decreased swimming ability (van Ginneken *et al*., 2004; van Ginneken *et al*., 2005).

Both types of parasites and pathogens were included in the assessment of natural mortality, as recommended by ICES (2015). Initially, and due to the paucity of information on the Swimbladder Degenerative Index (SDI), the assessment was performed not through the calculation of the EQI_{dis} as recommended by ICES (2015), but through a modified Infection Index. Instead of the SDI, the prevalence of *A. crassus* as well as the presence of bacteria and other parasites was used, as reported in the European Eel Quality Database (Belpaire *et al*., 2011). This was done because other parasites such as *Pseudodactylogyrus spp*. can cause stock damage (Buchmann, Mellergaard and Køie, 1987; Buchmann 1993; Saraiva 1995; Kennedy, 2007) and bacterial infections often accompany swim bladder damage caused by *A. crassus* (Kirk, 2003).

The validity of the parasite and pathogen assessment with the Infection Index was tested with SDI data from literature with the result that the assessment of *A. crassus* as well as EVEX and AngHV-1 viruses was consistent between the Infection Index and EQI_{dis}.

Results were based on data from 58 sites, with reliable information on parasites and pathogens along with variable reliability on predator presence. There were no significant differences between habitat types or between the frequency of occurrence of different levels of natural mortality.

Undoubtedly, the scarcity of data and their dispersion between habitat types and degrees of natural mortality influenced this lack of significance. But it may also be the case that there are no real differences between habitats or mortality rates when predator, parasite and pathogen presence is assessed together. Independently assessed, the degree of infection of *A. crassus* is lower in brackish waters (Jakob *et al*., 2009; ICES, 2013; Amilhat *et al*., 2014). However, in this study, the circumstances were very different as all three factors were included. Therefore, it is possible that the salinity gradient observed when studying the degree of infection by *A. crassus* was masked by the other variables considered in this study.

4.4.6. Analysis of anthropogenic causes of mortality (Anthropogenic Mortality)

In 2001, ICES warned that the eel stock is outside safe biological limits and that the fishery, as it is developing, is not sustainable (ICES, 2001). Since 2003, ICES has recommended in its annual advice that "all anthropogenic mortalities must be reduced as close to zero as possible". while in November 2021 it recommended that all catches in all habitat types should be reduced to zero by 2022, and that "all other anthropogenic mortalities should be minimized and eliminated where possible" (ICES, 2021b).

Fishing is one of the most clearly recognised drivers of eel stock decline, as all stages of the life cycle are commercially exploited throughout its range, both in commercial and recreational fisheries (Tesch, 2003; Hanel *et al*., 2019). Glass eel fisheries take advantage of the natural concentration of individuals in time and space, both in estuaries and at the entrances of coastal lagoons or in front of dams, resulting in overfishing (Dekker, 2003a; Briand *et al*., 2005). Yellow and silver eel fisheries are also mostly carried out in estuaries and coastal lagoons (Pérez-Ruzafa and Marcos, 2012), with permanent barriers often installed along the channels connecting lagoons to the sea to exploit the migration of silver eels (Cataudella, Crosetti and Massa eds, 2015). Landings declined prior to the recruitment decline observed in the 1980s, indicating that the fishery was a decisive factor due to lack of spawners (Dekker, 2003b).

Eel aquaculture, since it relies on wild-caught animals for fattening and subsequent consumption, is still a fishery with deferred mortality, as captive breeding is, for the time being, unfeasible (Palstra and van den Thillart, 2009).

In addition to legally established fisheries, there is a market for IUU (Illegal, Unreported and Unregulated) catches. Prior to the inclusion of eel in CITES Appendix II, imposing export restrictions and the setting of a zero-export quota by the EU in 2011, it was estimated that 20 percent to 40 percent of the total trade in glass eels came from unlicensed fishers and poachers, while there were also warnings of future increases due to the decreasing availability of glass eels for farming (mainly destined for the Asian market), high prices and the restrictions imposed by CITES and the EU itself (Briand *et al*., 2008). Indeed, the illegal trade in glass eels continued to increase, reaching 100 tonnes in the 2017–2018 fishing season (Europol, 2021). Despite these figures, it is not easy to quantify illegal fishing and trade due to the lack of a traceability system at both national and international levels (Hanel *et al*., 2019). For the sake of completeness, it is worth noting that habitat databases have collected information from 22 sites with illegal fishing, in this case for yellow or silver eels.

When silver eels migrate downstream, they are vulnerable to the effects of hydropower installations. These effects can act in two ways: firstly, they temporarily slow down migration by generating exploratory behaviour that compromises reproductive success by exposing them to increased predation and increased risk of disease (Acou *et al*., 2008; Verhelst *et al*., 2018). Secondly, passage through turbines generates a high number of fatalities and injuries. Because of their body shape, eels are particularly vulnerable to turbine injuries (Larinier and Travade, 2002). In severe cases mortality can be as high as 100 percent (Boubée, Jellyman and Sinclair, 2008; Carr and Whoriskey, 2008), although mortality rates of 10 percent to 50 percent are more frequent (Jansen *et al*., 2007; Larinier, 2008). In addition, the presence of pump stations can lead to up to 100 percent mortality in the most modern models, thus having a similar effect to that of turbines, both in migration delays and induced mortality (Hanel *et al*., 2019).

Anthropogenic mortality was second only to migration in terms of the number of sites analysed (93.4 percent of assessments). Analysis of the results showed that fishing mortality contributed the most weight in the final score.

The medium category was not considered in the assessment of anthropogenic mortality. Following repeated advice from ICES on the reduction to zero of anthropogenic mortalities including fishing mortality, as well as the species being considered outside safe biological limits since 2001 (ICES, 2001), any degree of anthropogenic mortality that was not considered as "Low" should be understood as poor quality and detrimental to the conservation of the species. Indeed, any site may have optimal environmental conditions for the species, but if anthropogenic mortality exceeds a certain level, the site itself cannot be considered a good habitat for the species.

The highest anthropogenic mortality was detected in lakes and lagoons, mainly due to fishing mortality rather than the presence of turbines or pump stations. This was particularly striking in rivers, where the latter type of mortality might theoretically accumulate. This could indicate that, as is the case on the Mediterranean slope in Spain, turbine mortality would be negligible compared to other anthropogenic mortalities, since there are no eels above the turbine dams (Hanel *et al*., 2019). According to this, the presence of large dams with hydroelectric power plants would create more of a problem with the loss of colonisable habitat area than eel mortality.

4.4.7. Conservation status of eel in the Mediterranean

The results indicated that all habitat types presented one or more variables associated with highly degraded and strongly degraded states while joint study of the worst quality statuses in each variable made it possible to identify the issues of crucial interest for the conservation of eels in each of the habitat types.

Migration was the variable with the lowest impact in almost all habitat types, with a higher frequency of the category "Both migrations not obstructed". As discussed in 5.4.3, this was a consequence of the way it was calculated. Although lack of connectivity is a typical problem in rivers, the results indicated that where the analysis was limited to "current area", the possibility of free migration was just as high as in other habitat types. The presence of the state "One migration partially obstructed", was more frequent in coastal lagoons and associated with the presence of fishing lagoon barriers. In this case, partial obstruction was not only a problem of connectivity, but also of anthropogenic mortality and escapement of silver eels.

Anthropogenic mortality is strongly influenced by fishing mortality, while also associated with obstacles to migration, highlighting that many environmental problems do not act on a single pathway. It is therefore necessary to reduce fishing mortality to zero quotas, as ICES has been warning since 2001. This is not an easy task to achieve due to the economic and social implications for eel fisheries, but in the meantime strict measures must be implemented to drastically reduce fishing mortality. These measures should be based on knowledge of eel biology to avoid, as much as possible, the creation of inappropriate rules. An example is the temporal closures of silver eel and glass eel fisheries that have recently been implemented in many Mediterranean countries, that allow the arbitrary choice of a three-month no-fishing period over an extended period of time (for example, between 1 August and the last day of February in the EU), rather than one based on observed migration periods (Hanel *et al*., 2019).

In estuaries and rivers, the main conservation problem was related to habitat. River basins, over their entire length, are subject to greater environmental pressures than the other habitat types. The presence of non-indigenous species was one of main indicators of poor quality, (Gozlan *et al*., 2010), while in estuaries, there were also problems connected with land use and trophic status as a consequence of draining wetlands in estuarine areas for conversion to agricultural land (Wilkinson and Mc Elroy, 2007; Moreno-Mateos *et al*., 2012), and the use of fertilisers in estuarine agricultural environments. Together with the concentration of organic pollutants coming from entire river basins, these are the main factors causing eutrophication problems (de Jonge, Elliott and Orive, 2002; Smith, 2003).

In rivers, lost surface area is largely responsible for the poor quality assessment in the habitat overview, resulting from the construction of obstacles that are usually impassable to eels (Feunteun, 2002: Kettle, Vøllestad and Wibig, 2011).

All the above problems were among those identified as the five interacting categories that threaten biodiversity in river basins (Dudgeon, 2013; Dudgeon *et al*., 2006).

Pollutants were associated with highly and strongly degraded states in three of the four habitats, while their role was more doubtful in lakes due to the scarcity of data. Considering the dispersed availability of information and methodological difficulties in standardising data as well as ensuring its reliability, along with the importance of pollution levels in eels, it is essential to have a broader and better geographically distributed knowledge of pollution in a wider network of sites in all types of habitats, both for POPs and heavy metals.

Natural mortality appeared in the poor-quality ratings for all four habitat types, despite the lack of data. Predation is a natural process that can even indicate a good state of health of an ecosystem, for example, in terms of biodiversity. However, the problem arises when the mortality rate due to predation is very high, while the parasites and pathogens component of natural mortality should be viewed with concern, especially considering its relative importance (of *A. crassus* in particular). As was the case with contaminants, it is necessary to seek new information and to monitor populations to assess the exact dimension of this problem and its real impact on the possibilities of eel recovery.

If all the factors discussed above are analysed objectively, all except predation by native species, have a common component; they are of anthropogenic origin and acting synergistically, have been recognised as causes of eel population decline (Miller, Feunteun and Tsukamoto, 2016; Drouineau *et al*., 2018; ICES, 2019; ICES, 2020; ICES, 2021a). They have also been recognised and documented as important factors affecting eel populations in the Mediterranean, on the basis of the data collected and analysed within the eel research programme. While oceanic factors are extremely difficult to control, most of the key factors exert pressure on the inland phase of the eel life cycle and can be acted upon. It should be an ethical obligation to make a firm commitment to take steps for the effective control, and as far as possible, remediation, of the anthropogenic factors affecting eel populations in the Mediterranean.

4.4.8. Conclusions

- Individual habitat quality was assessed and categorised for the first time at 645 sites with respect to six groups of variables: habitat overview, migration routes, organic pollutants, heavy metals, natural mortality and anthropogenic mortality.
- There was great heterogeneity of the information available for the assessments both by variables and by habitat types. Sometimes the information did not really exist, but in other cases it was evident that it could not be collected by the partner countries. However, very reliable data were also available. The result was a high frequency of records with no data together with the presence of incomplete or non-assessable data. The groups of variables with the least reliable information available were, in order: natural mortality, followed by organic pollutants, heavy metals and habitat overview. The habitat with the least reliable information was lakes, while the other habitats reported similar amounts of information.
- An ad-hoc evaluation system was created, in order to avoid discarding any further data from the scarce information available, based on the assignment of quality scores and reliability scores for each record. In this way, both scores became inseparable, as reliability measured the degree of uncertainty with which each quality score was awarded giving it a specific meaning within the context of the evaluation of each variable.
- Mediterranean eel habitats face serious conservation problems due to the development of catchment areas, the presence of non-indigenous species and the existence of hypereutrophic states due to poor water quality.
- Although only the current area for Mediterranean eel was analysed, it can be affirmed that migratory routes are in a good state of conservation, except in coastal lagoons where fishing barriers affect migration to a great extent.
- The level of contamination by organic pollutants was high, while heavy metals showed a greater range of results, from areas where contamination was very high to others with low levels of contamination.
- High levels of natural mortality were detected, although the scarcity of data prevented clear conclusions. Mortality due to anthropogenic factors was very high and strongly associated with fishing mortality.
- In Mediterranean rivers and estuaries, the main conservation problems for European eel were pollution by pesticides and heavy metals, the presence of non-indigenous species, development of catchment areas, loss of surface area and poor water quality causing frequent states of hypereutrophication. In Mediterranean lakes and lagoons, the main problem was fishing pressure and pollution by heavy metals and pesticides.

4.5. RECOMMENDATIONS

- A programme for the generation of information is needed, especially in relation to parasites, pathogens, heavy metals and organic pollutants.
- It is also necessary to promote the search for information on different variables included in the Habitat Database, especially in the sites already catalogued.
- There should be a drastic reduction in fishing pressure in all habitats, but especially in coastal lagoons and lakes.
- Habitat enhancement programmes need to be developed for eel growth habitats, especially related to increased water quality and connectivity.
- Strict control of emissions of organic pollutants and heavy metals needs to be ensured as well as the development of long-term monitoring programmes for these compounds.

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Additional Results Part I - Final scores and reliability levels of variables relative to eel habitats by country and by habitat typology

ALBANIA SCORES					ALBANIA RELIABILITY				
	LAK	LGN	RIE	RIV		LAK	LGN	RIE	RIV
Habitat overview Scores					**Habitat overview reliability**				
Not assessed				6	Not Assessed				6
Slightly altered	1	6		2	Very reliable	1	2		1
Altered		2			Reliable		4		1
Strongly altered				2	Very unreliable		2		2
Migration Scores					**Migration reliability**				
Not assessed					Not Assessed				
Both migration not obstructed				9	Very reliable				
One migration partially obstructed	1				Reliable	1	8		10
Both migrations partially obstructed		8		1	Very unreliable				
POPs Scores					**POP reliability**				
Not Assessed		3		2	Not Assessed		3		2
Low/Slightly polluted		3		1	Very reliable		2		
Polluted	1			5	Reliable				3
Strongly polluted		2		2	Unreliable	1	2		5
					Very unreliable		1		
Heavy metals scores					**Heavy metals reliability**				
Not Assessed				1	Not Assessed				1
Low/Slightly polluted		4		1	Very reliable	1			2
Polluted		3		4	Reliable		6		5
Strongly polluted	1	1		4	Unreliable				2
					Very unreliable		2		
Natural mortality Scores					**Natural mortality reliability**				
Not Assessed					Not Assessed				
Low		1		7	Very reliable				
Medium		7		1	Reliable				
High	1			2	Unreliable				
					Very unreliable	1	8		10
Anthropogenic mortality Scores					**Anthropogenic mortality reliability**				
Not Assessed					Not Assessed				
Low				8	Very reliable	1	8		10
High	1	3		2	Reliable				
Very High		5			Unreliable				
					Very unreliable				

ALGERIA SCORES	LAK	LGN	RIE	RIV	ALGERIA RELIABILITY	LAK	LGN	RIE	RIV
Habitat overview Scores					**Habitat overview reliability**				
Not assessed		1	23	15	Not Assessed		1	23	15
Slightly altered	2	1	3	1	Very reliable				
Altered	1		3	2	Reliable	1		1	
Strongly altered				2	Very unreliable	2	1	5	5
Migration Scores					**Migration reliability**				
Not Assessed					Not Assessed				
Both migration not obstructed	3	2	29	20	Very reliable				
One migration partially obstructed					Reliable	3	2	29	20
Both migrations partially obstructed					Very unreliable				
POPs Scores					**POP reliability**				
Not Assessed	3	2	29	20	Not Assessed	3	2	29	20
Low/Slightly polluted					Very reliable				
Polluted					Reliable				
Strongly polluted					Unreliable				
					Very unreliable				
Heavy metals scores					**Heavy metals reliability**				
Not Assessed		1	22	13	Not Assessed		1	22	14
Low/Slightly polluted	1		1	1	Very reliable	3	1	1	
Polluted			4	2	Reliable			1	1
Strongly polluted	2	1	2	4	Unreliable			3	2
					Very unreliable			2	3
Natural mortality Scores					**Natural mortality reliability**				
Not Assessed		1	26	19	Not Assessed		1	26	19
Low	1		2	1	Very reliable				
Medium	2	1	1		Reliable	2	1	1	
High					Unreliable				
					Very unreliable	1		2	1
Anthropogenic mortality Scores					**Anthropogenic mortality reliability**				
Not Assessed					Not Assessed				
Low	1	1	27	20	Very reliable	3	2	29	20
High	2	1	2		Reliable				
Very High					Unreliable				
					Very unreliable				

EGYPT SCORES	LAK	LGN	RIE	RIV
Habitat overview Scores				
Not assessed				
Slightly altered				
Altered			1	
Strongly altered		5		
Migration Scores				
Not assessed				
Both migration not obstructed		5		
One migration partially obstructed				
Both migrations partially obstructed			1	
POPs Scores				
Not Assessed				
Low/Slightly polluted		4	1	
Polluted		1		
Strongly polluted				
Heavy metals scores				
Not Assessed				
Low/Slightly polluted				
Polluted		4	1	
Strongly polluted		1		
Natural mortality Scores				
Not Assessed				
Low			1	
Medium		5		
High				
Anthropogenic mortality Scores				
Not Assessed				
Low				
High		3	1	
Very High		2		

EGYPT RELIABILITY	LAK	LGN	RIE	RIV
Habitat overview reliability				
Not Assessed				
Very reliable				
Reliable		4	1	
Very unreliable		1		
Migration reliability				
Not Assessed				
Very reliable				
Reliable		5	1	
Very unreliable				
POP reliability				
Not Assessed				
Very reliable				
Reliable		1		
Unreliable		1		
Very unreliable		3	1	
Heavy metals reliability				
Not Assessed				
Very reliable		3		
Reliable		2		
Unreliable				1
Very unreliable				
Natural mortality reliability				
Not Assessed				
Very reliable				
Reliable		1	1	
Unreliable				
Very unreliable		4		
Anthropogenic mortality reliability				
Not Assessed				
Very reliable		5		
Reliable				
Unreliable			1	
Very unreliable				

FRANCE SCORES	LAK	LGN	RIE	RIV
Habitat overview Scores				
Not assessed		50	28	22
Slightly altered				
Altered				
Strongly altered				
Migration Scores				
Not assessed		6	4	
Both migration not obstructed		28	22	20
One migration partially obstructed				
Both migrations partially obstructed		16	2	2
POPs Scores				
Not Assessed		46	28	16
Low/Slightly polluted		4		
Polluted				6
Strongly polluted				
Heavy metals scores				
Not Assessed		46	28	16
Low/Slightly polluted		4		6
Polluted				
Strongly polluted				
Natural mortality Scores				
Not Assessed		5	4	
Low		1		
Medium		40	18	16
High		4	6	6
Anthropogenic mortality Scores				
Not Assessed		5	4	
Low		5	1	1
High		40	20	18
Very High			3	3

FRANCE RELIABILITY	LAK	LGN	RIE	RIV
Habitat overview reliability				
Not Assessed		50	28	22
Very reliable				
Reliable				
Very unreliable				
Migration reliability				
Not Assessed		6	4	
Very reliable				
Reliable		44	24	22
Very unreliable				
POP reliability				
Not Assessed		46	28	16
Very reliable		4		
Reliable				6
Unreliable				
Very unreliable				
Heavy metals reliability				
Not Assessed		46	28	16
Very reliable		4		6
Reliable				
Unreliable				
Very unreliable				
Natural mortality reliability				
Not Assessed		5	4	
Very reliable		4		
Reliable		8		
Unreliable		2		
Very unreliable		31	24	22
Anthropogenic mortality reliability				
Not Assessed		5	4	
Very reliable		6	1	1
Reliable		37	22	20
Unreliable		2		
Very unreliable			1	1

GREECE SCORES					GREECE RELIABILITY				
	LAK	LGN	RIE	RIV		LAK	LGN	RIE	RIV
Habitat overview Scores					**Habitat overview reliability**				
Not assessed	1	17	7	6	Not Assessed	1	17	7	6
Slightly altered		6	3	1	Very reliable				
Altered	1	1	1	3	Reliable	1	1		6
Strongly altered				9	Very unreliable		6	4	7
Migration Scores					**Migration reliability**				
Not assessed					Not Assessed				
Both migration not obstructed	2	2	11	19	Very reliable				
One migration partially obstructed		22			Reliable	2	24	11	19
Both migrations partially obstructed					Very unreliable				
POPs Scores					**POP reliability**				
Not Assessed	2	24	11	18	Not Assessed	2	24	11	18
Low/Slightly polluted					Very reliable				
Polluted				1	Reliable				
Strongly polluted					Unreliable				
					Very unreliable				1
Heavy metals scores					**Heavy metals reliability**				
Not Assessed	2	18	9	14	Not Assessed	2	18	9	14
Low/Slightly polluted		5			Very reliable				
Polluted				3	Reliable		1	2	3
Strongly polluted		1	2	2	Unreliable				2
					Very unreliable		5		
Natural mortality Scores					**Natural mortality reliability**				
Not Assessed					Not Assessed				
Low	2	1	11	18	Very reliable				
Medium		23		1	Reliable		6		
High					Unreliable			1	
					Very unreliable	2	18	10	19
Anthropogenic mortality Scores					**Anthropogenic mortality reliability**				
Not Assessed					Not Assessed				
Low	1	3	10	15	Very reliable	2	24	11	19
High	1	21	1	4	Reliable				
Very High					Unreliable				
					Very unreliable				

ITALY SCORES					ITALY RELIABILITY				
	LAK	LGN	RIE	RIV		LAK	LGN	RIE	RIV
Habitat overview Scores					**Habitat overview reliability**				
Not assessed	1	34		8	Not Assessed	1	34		8
Slightly altered		47	3	2	Very reliable				
Altered		20	12	3	Reliable		45	2	3
Strongly altered		1	2	3	Very unreliable		23	15	5
Migration Scores					**Migration reliability**				
Not assessed		3			Not Assessed		3		
Both migration not obstructed	1	49	14		Very reliable				
One migration partially obstructed		50	3		Reliable	1	99	17	16
Both migrations partially obstructed				16	Very unreliable				
POPs Scores					**POP reliability**				
Not Assessed	1	88	14	8	Not Assessed	1	88	14	8
Low/Slightly polluted		12	1		Very reliable		5	2	1
Polluted		2	1	8	Reliable		2	1	7
Strongly polluted			1		Unreliable		5		
					Very unreliable		2		
Heavy metals scores					**Heavy metals reliability**				
Not Assessed	1	81	16	7	Not Assessed	1	81	16	7
Low/Slightly polluted		11		3	Very reliable		15	1	9
Polluted		7	1	6	Reliable		1		
Strongly polluted		3			Unreliable		2		
					Very unreliable		3		
Natural mortality Scores					**Natural mortality reliability**				
Not Assessed	1	76	16	13	Not Assessed	1	76	16	13
Low		21	1	2	Very reliable		2		
Medium		3			Reliable		1		
High		2		1	Unreliable		6		1
					Very unreliable		17	1	2
Anthropogenic mortality Scores					**Anthropogenic mortality reliability**				
Not Assessed	1	25	1	6	Not Assessed	1	25	1	6
Low		11	1	2	Very reliable				
High		65	11	8	Reliable				
Very High		1	4		Unreliable		76	16	10
					Very unreliable		1		

SPAIN SCORES	LAK	LGN	RIE	RIV	SPAIN RELIABILITY	LAK	LGN	RIE	RIV
Habitat overview Scores					**Habitat overview reliability**				
Not assessed					Not Assessed				
Slightly altered		20	8	2	Very reliable		2	8	4
Altered		13	22	15	Reliable		16	18	15
Strongly altered		1	13	11	Very unreliable		16	17	9
Migration Scores					**Migration reliability**				
Not assessed					Not Assessed				
Both migration not obstructed		21	26	20	Very reliable				
One migration partially obstructed					Reliable		34	43	28
Both migrations partially obstructed		13	17	8	Very unreliable				
POPs Scores					**POP reliability**				
Not Assessed		23	18	19	Not Assessed		23	18	19
Low/Slightly polluted		5	7	3	Very reliable		5	13	8
Polluted		5	10	4	Reliable		5	11	1
Strongly polluted		1	8	2	Unreliable		1	1	
					Very unreliable				
Heavy metals scores					**Heavy metals reliability**				
Not Assessed		23	21	20	Not Assessed		23	21	20
Low/Slightly polluted		2	5	3	Very reliable		10	9	5
Polluted		1	15	4	Reliable			2	
Strongly polluted		8	2	1	Unreliable		1	11	3
					Very unreliable				
Natural mortality Scores					**Natural mortality reliability**				
Not Assessed					Not Assessed				
Low		10	1	18	Very reliable		1	3	
Medium		23	39	10	Reliable		4		1
High		1	3		Unreliable				
					Very unreliable		29	40	27
Anthropogenic mortality Scores					**Anthropogenic mortality reliability**				
Not Assessed					Not Assessed				
Low		21	38	28	Very reliable		34	43	28
High		6	4		Reliable				
Very High		7	1		Unreliable				
					Very unreliable				

TUNISIA SCORES	LAK	LGN	RIE	RIV
Habitat overview Scores				
Not assessed	27	17	4	49
Slightly altered		1		
Altered				
Strongly altered				
Migration Scores				
Not Assessed				
Both migration not obstructed	27	18	4	49
One migration partially obstructed				
Both migrations partially obstructed				
POPs Scores				
Not Assessed	27	18	4	49
Low/Slightly polluted				
Polluted				
Strongly polluted				
Heavy metals scores				
Not Assessed	27	15	4	44
Low/Slightly polluted		3		5
Polluted				
Strongly polluted				
Natural mortality Scores				
Not Assessed	27	14	4	43
Low		4		6
Medium				
High				
Anthropogenic mortality Scores				
Not Assessed				
Low	18	11	2	47
High	9	7	2	2
Very high				

TUNISIA RELIABILITY	LAK	LGN	RIE	RIV
Habitat overview reliability				
Not Assessed	27	17	4	49
Very reliable				
Reliable				
Very unreliable		1		
Migration reliability				
Not Assessed				
Very reliable	27	18	4	49
Reliable				
Very unreliable				
POP reliability				
Not Assessed	27	18	4	49
Very reliable				
Reliable				
Unreliable				
Very unreliable				
Heavy metals reliability				
Not Assessed	27	15	4	44
Very reliable		3		
Reliable				1
Unreliable				
Very unreliable				4
Natural mortality reliability				
Not Assessed	27	14	4	43
Very reliable				
Reliable				
Unreliable		4		2
Very unreliable				4
Anthropogenic mortality reliability				
Not Assessed				
Very reliable	9	7	2	3
Reliable				
Unreliable			2	
Very unreliable	18	11		46

Additional Results Part II – List of sites with best assessment results (data-rich sites)

Country	Site Name	Area/River basin	Site coordinates		Habitat type
			Long	Lat	
Albania	Karavasta	Adriatic sea	19.50	40.93	LGN
Algeria	Oubeira	Oubeira	8.39	36.85	LAK
Egypt	Lake Burullus	Northern Nile Delta basin	30.87	31.48	LGN
Egypt	Lake Mariout	Northern Lakes basin	29.90	31.15	LGN
France	Canet	Canet	3.02	42.67	LGN
France	Salses-Leucate	Salses-Leucate	3.00	42.85	LGN
France	Bages-Sigean	Bages-Sigean	3.00	43.08	LGN
Italy	Caprolace coastal lake	Lazio	12.97	41.35	LGN
Italy	Fogliano	Lazio	12.90	41.40	LGN
Italy	Lesina	Puglia	15.43	41.88	LGN
Italy	Monaci	Lazio	12.94	41.38	LGN
Italy	Orbetello	Toscana	11.20	42.43	LGN
Italy	Arno	Toscana	10.28	43.68	RIE
Italy	Tevere	Lazio	12.61	42.18	RIV
Spain	Estany Pudent	Ibiza	1.44	38.73	LGN
Spain	Ses Salines d'Eivissa	Ibiza	1.37	38.86	LGN
Spain	Es Salobrar de Campos	Mallorca	3.00	39.36	LGN
Spain	Albufera de Mallorca	Mallorca	3.10	39.79	LGN
Spain	Albufereta de Pollensa	Mallorca	3.09	39.86	LGN
Spain	Albufera des Grau	Mallorca	4.25	39.95	LGN
Spain	Guadiaro	Guadiaro	-5.31	36.57	RIV
Spain	Guadalhorce	Guadalhorce	-4.68	36.85	RIV
Spain	Ebro	Ebro	-1.04	41.76	RIV
Spain	Turia o Guadalaviar	Turia o Guadalaviar	-1.25	40.10	RIV
Spain	Segura	Segura	-1.73	38.16	RIV
Spain	Palmones	Palmones	-5.45	36.17	RIE
Spain	Verde	Verde	-4.95	36.49	RIE
Spain	Guadalhorce	Guadalhorce	-4.46	36.67	RIE
Spain	Guadalmedina	Guadalmedina	-4.43	36.71	RIE
Spain	Velez	Velez	-4.11	36.73	RIE
Spain	Ebro	Ebro	0.66	40.72	RIE
Spain	Segura	Segura	-0.65	38.11	RIE
Spain	Laguna del Hondo	Bajo Vinalopó	-0.75	37.18	LGN
Spain	Turia o Guadalaviar	Turia o Guadalaviar	-0.34	39.43	RIE
Spain	Mijares	Mijares	-0.01	39.91	RIE
Spain	Guadalfeo	Guadalfeo	-3.57	36.74	RIE
Spain	Mar Menor	Mar Menor	-0.79	37.72	LGN
Spain	L'Albufera de Valencia	El Saler	-0.35	39.34	LGN

CHAPTER 5. ANALYSIS OF EEL RECRUITMENT IN THE MEDITERRANEAN

ABSTRACT

Given the importance of recruitment for the European eel global stock assessment, the aim of the present chapter is to perform a comprehensive investigation of regional-level recruitment in the Mediterranean.

The dynamics of recruitment were explored both in the long-term and in the short-term (intra-annual) using quantitative and qualitative data provided by partner countries. In addition, data based on fishery-dependent sources, were integrated through a systematic literature search. Overall, 23 time-series were gathered, 33 monitoring data sets and data from 130 papers, spanning from 1913 to 2021, providing comprehensive coverage of past and present existing information on eel recruitment in the Mediterranean region. All data were checked for quality, assigned to recruitment season, and eventually transformed for standardization.

Overall, glass eel recruitment in the Mediterranean was documented in 79 sites. The habitat typology of sites included both transitional and inland eel habitats: 20 sites were coastal lagoons, 48 sites were river estuaries and one was a river. Glass eel recruitment was also documented in six sites classified as artificial channels and reported in four coastal areas in the Mediterranean.

Past and present levels of abundance were compared using data for specific sites along with time-series, across four time-frames in the last century. For the pre-1950's period, data highlighted past abundance of recruitment in specific sites around the Mediterranean. Pre-1980's data documented a period of abundance, in which the main fisheries developed mostly in the north-western part of the Mediterranean. Many of these fisheries continued into the 1980–2009 period, with landing trends documenting a wide-spread decline occurring throughout the 1990s and the lowest recruitment levels occurring everywhere in the last years of this time period. Finally, in the period following the implementation of Eel management Plans (EMPs) in European countries, time-series showed further decreases in abundance in all sites, even if some sites showed signs of recovery in the middle of this period. However, no information was available on changes in fishing effort in specific sites and this partial recovery has not been confirmed in more recent years. In this last period, several scientific monitoring actions have been implemented in many sites but data are still too few to evaluate their effectiveness. The overall eel recruitment trend described for the Mediterranean area is consistent with what has been observed in the rest of Europe.

Detailed monthly data on catches or presence from the three information sources (fisheries, monitoring and literature), as well as taking into account three separate stages of eel life history (unpigmented or pigmenting glass eels, pigmented elver and small bootlace eels), allowed an in-depth analysis of the seasonal pattern for glass eel recruitment in the Mediterranean. The arrival of transparent glass eels coincides with the winter months, while in the following months pigmented elvers are more abundant, having already arrived at the coasts in the previous months or at the recruitment sites, along with small bootlace eels in the colonization phase. Some differences in recruitment seasonality were highlighted when comparing data from north-western and eastern sites in the Mediterranean.

HIGHLIGHTS

For research

- European eel recruitment in the Mediterranean was described comprehensively for the first time, based on the exhaustive collection of past and present data.
- Recruitment was documented at 79 sites across the Mediterranean, including all transitional eel habitats.
- There are definite seasonal recruitment patterns in the different parts of the Mediterranean region. Specific environmental features of sites influence glass eel behaviour to define intra-seasonal migration dynamics and thus overall seasonal abundance at the local level.
- There were high levels of recruitment in the twentieth century, before the 1950s and through the 1980s, when most of the glass eel fisheries developed. A consistent decline followed in the 1990s, across all of the Mediterranean region, with the lowest recruitment levels occurring in the early 2010s. Some signs of recovery, in some sites, were observed around 2015, but these were not sustained in more recent years.
- Recruitment remains at its lowest level and the overall trend is consistent with the trend observed in Europe on the Atlantic and North Sea coasts.

For management

- The results of the study highlight that glass eels need full protection in the Mediterranean, with specific measures to guarantee migration and colonization in all habitats.
- Many countries are already protecting recruitment with total glass eel fisheries bans, while others have implemented fishing closure periods, although these are presently not fully consistent with established seasonal patterns of recruitment.
- Given the low level of present recruitment, there should be no eel fishery, at any stage, occurring in the Mediterranean. Furthermore, glass eel fisheries for any use (including restocking) do not seem to be justified.
- The results support management options aimed at reducing all glass eel fishing to zero mortality, as well as local management measures aiming at protecting current recruitment, by mitigating all potential impacts on this stage of the eel life cycle.
- There is a need to continue or establish monitoring with a network of key sites, in order to follow the evolution of recruitment in the Mediterranean area in the long term. Such a network needs to include different eel habitats, distributed in such a way as to cover the different areas of the Mediterranean.
- The key sites can be identified based on the results of the comprehensive analysis, using fishery-independent monitoring methods and time-schedules taking into account the local environmental features of sites and specific seasonality patterns.

5.1. INTRODUCTION

5.1.1. Background

Glass eel recruitment is the process sustaining eel local stocks in the countless coastal and continental aquatic habitats across the entire area where eels are distributed. It consists of two steps; firstly, the approach of glass eels from marine open waters to the coasts after metamorphosis and secondly, their entry and ascent into estuaries, lagoons, tidal channels and coastal wetlands. These have been extensively studied and described over the last century for a number of sites across Europe and the Mediterranean, from many of points of view. These include ontogenetic, physiological and behavioural aspects, as well as ecological aspects, such as local factors influencing migration, while quantitative aspects in the short and long-term have also been considered, including temporal dynamics at the intra-seasonal and inter-annual scale.

These aspects have been reviewed in recent papers (Harrison *et al*., 2014; Kara and Quignard, 2019; Cresci, 2020). Kara and Quignard (2019) deals specifically with glass eel recruitment in a comprehensive book chapter dedicated to the European eel in the Mediterranean region. Nevertheless, there is still a common perception that scarce information is available, specifically for the Mediterranean.

Recruitment studies in Mediterranean sites have mainly addressed glass eel presence and behaviour, as well as the dynamics of recruitment. Some of these studies have been revised and used to describe temporal patterns of recruitment in the Mediterranean (ICES, 2020a). The migration patterns are thought to be more complex than in Atlantic estuaries, probably because of the different role of local drivers on migration. The influence of the tide in driving migration by selective tidal stream transport (Wippelhauser and McCleave, 1987; Harrison *et al*., 2014) is less important in the Mediterranean than in Atlantic estuaries, because of reduced tidal excursion. Hence, other factors probably play a stronger role including attraction due to outflow of a river or channel, temperature differences between the sea and an inland water body as well as lagoon connectivity with the sea. These differences are also reflected in the different locations of glass eel fisheries in the Mediterranean compared to large Atlantic estuaries.

An active glass eel ascent typically provides natural recruitment to Mediterranean coastal lagoons and sporadic or erratic fisheries in estuaries and coastal areas. This run is accompanied by fry of other euryhaline fish typically found and harvested in lagoons such as mullets, sea bass and sea bream. Glass eel runs provide seed for lagoon stocking to enhance production through extensive aquaculture, intensive aquaculture or other purposes including glass eel harvesting for direct consumption and exports. However, there have been relatively few organised and officially authorized fisheries on a continuous basis in specific sites and this has hampered the opportunity to collect long time-series data to evaluate recruitment trends in the region.

5.1.2. Recruitment trends and estimates

The most evident and alarming symptom of the decline of the global eel stock was a noticeable reduction in glass eel catches in Europe between the 1980s and 1990s. Recruitment time-series have been gathered by the joint ICES/EIFAAC/GFCM WGEEL since the early 2000s and in time-series that date back to 1910. These, along with the much less complete records of adult eel fisheries landings, have formed the basis for the provision of advice on the status of the eel stock since then. The amount of glass eel arriving in continental waters declined dramatically in the early 1980s, with time-series indices reaching minima in 2011 of less than one percent in the continental North Sea and less than five percent elsewhere in Europe compared to average levels for 1960–1979 (ICES, 2011).

The trend in European eel recruitment is derived from long-term time-series collected in estuaries scattered over all of Europe and are the best indicators of stock status. Owing to the complexity of the eel life history across the continental range and the limited knowledge and data on production and impacts for large parts of this distribution, it is very difficult to apply a classical fisheries stock assessment based on the principles of a stock–recruitment relationship. Considering that the population is fragmented into a myriad of sub-populations distributed at very different latitudes, in highly variable habitats in terms of ecological characteristics and anthropogenic impacts, that are exploited in many ways, there are not enough data available for a global quantitative assessment. The eel is therefore classified as a category three stock: "Stocks for which survey-based assessments indicate trends. Includes stocks for which survey or other indices are available that provide reliable indications of trends in stock metrics, such as total mortality, recruitment, and biomass" (ICES, 2019). Assessments of the global stock and advice has, to date, been based on time-series of recruitment indices, comparing index levels in recent years with those of a past reference periods and expressing the former as a proportion of the latter.

The recruitment time-series data used by WGEEL are derived from fishery-dependent surveys (such as commercial fish landings records) and fishery-independent surveys using similar gears to those used in fisheries along with other gears and science-based survey designs. They are analysed on a yearly basis and summarized in three separate indices (ICES, 2013). Two of these indices report glass eel trends, one for the North Sea, and the other for the rest of Europe (referred to as Elsewhere Europe), on the basis of different time-series trends in the 1980s (ICES, 2010). A third index reports trends for young, yellow eels, mostly in the Baltic Sea (ICES, 2013).

The number of reported and analysed recruitment series varies through time, because new series have started and some have discontinued, due to lack of recruits in some fishery-based surveys or the disruption of fishery-based time-series due to the introduction of quotas. Not all series contribute to the WGEEL recruitment indices, as some series may be discarded by a selection procedure that excludes two or more series from the same location, only one being retained, as well as series with less than ten years and series biased by restocking.

Four series are available from the Mediterranean region and are presently included in WGEEL recruitment assessment. Two fishery-based, long-term series are from Spain. The Albufera de Valencia series, is 73 years long (1949–2021), and the Ebro Delta, is 56 years long, (1966–2021). A third series is from an ongoing trap-based monitoring programme in France, in Vaccares, La Fourcade station in the Camargue lagoons and is 18 years long (2004–2021). The fourth series is from Italy, relying on data from the local glass fishery at the Tevere estuary, but the series stopped in 2006 because of the closure of the fishery as yields were no longer sustainable for the fishers because of small and discontinuous catches. This series covers 32 years (1975–2006) and was kept for assessment of the glass eel recruitment index, even if discontinued. These series are merged with the series "Elsewhere in Europe" to estimate the recruitment index (EE), and therefore no specific information on recruitment trends in the Mediterranean arises from the assessments made by the WGEEL.

Bornarel *et al*. (2018) applied a model, GEREM (Glass Eel Recruitment Estimation Model), originally developed to estimate annual absolute glass eel recruitment at different spatial scales (Drouineau *et al*., 2016), to estimate a recruitment index across the eel distribution range and the four Mediterranean time-series were used for application to the ecoregion corresponding to the Western Mediterranean Sea. Results showed a decrease in recruitment slightly earlier than was seen in other zones and was not completely consistent with the recruitment index trend evaluated for "Elsewhere in Europe" in the decades between 1990 and 2010. The reduced number of series used for estimation, and the scarcity of data for the period prior to 1980, suggested caution in the interpretation of results, and highlights the need to apply this or other models for recruitment to a larger number of time-series, and possibly for longer timescales. A quality check of the other available time-series should also be made, to analyse if catch data could be biased, for instance by changes in fishing effort.

Absolute recruitment estimates are important quantitative tools for glass eel fisheries management to evaluate fishing impacts or setting glass eel quotas and for local assessments at the catchment or EMU scale. Models, such as GEMAC (Beaulaton and Briand, 2007), or a model developed by Bru, Lejeune and Prouzet (2006) and Prouzet *et al*. (2009), have been developed to estimate exploitation rates and recruitment at the site level, but both are suitable only for estimates at the estuarine scale. The GEREM model of Drouineau *et al*. (2016) is, on the other hand, a Bayesian model developed to estimate recruitment at various nested spatial scales, that is, river catchment recruitment, overall recruitment within a specific study area and zonal recruitment in zones within the study area. This model was used to estimate annual absolute glass eel recruitment at different spatial scales in France, and the Vaccares 11-year long time-series was used to estimate recruitment for the French EMU Rhone Mediterranean-Corsica along with the other Atlantic French EMUs (Drouineau *et al*., 2016).

So far, no yellow eel time-series have been considered to be informative about recruitment in the Mediterranean therefore they were never used by WGEEL. This issue might be explored by revising available time-series in specific sites across the region.

Further insights into recruitment might be provided by data from monitoring schemes at specific sites. Following the alarming decline in glass eel recruitment, including in the Mediterranean, specific recruitment monitoring activities were started at the end of the 1990s, and some followed the implementation of eel management plans for the European Union eel regulation (European Union, 2007). Along with the monitoring scheme in Camargue (Vaccares lagoon) mentioned above, based on a trap at a fish-pass on the sea-channel of the lagoon, operated on a continual basis since 2004, other glass-eel specific monitoring programmes on recruitment have been set up at many Mediterranean sites (see Chapter 14 on monitoring). Within the SUDOANG project, a specific task studied recruitment in the Spanish Mediterranean area at the Ter river estuary. Similar sampling schemes are in place in Italy, where at present, glass eel monitoring is ongoing at 12 additional sites (ICES, 2021; Chapter 14). In 2013, monitoring resumed at the Tevere estuary, where there was a glass eel fishery in the past. Other sites include tidal channels of lagoons and river estuaries. Results need to be evaluated on a comparative basis, but preliminary observations confirm that not all sites give good results and that sampling schemes have to take into account the hydro-morphological features of the sites as well as local environmental conditions.

5.1.3. Aims

Within WP3, a specific task focused on reviewing and updating information and data on glass eel recruitment with the aim of broadening and increasing knowledge on recruitment in the Mediterranean focused on long-term, short term (intra-annual) and spatial scale dynamics over the years. In addition, a separate evaluation was performed at the regional level for Mediterranean recruitment trends, working further on existing time-series and eventually trying to integrate them with additional series, including carrying out quality-checks on the available temporal trends.

An important objective, was to contribute towards evaluating the effectiveness of recruitment monitoring across the Mediterranean, both in terms of methodologies employed and the representativeness of sites. This involved a comprehensive analysis of data available from the present network of monitoring sites, that were implemented based on the needs of European Union regulations (eel regulation, Eu-Map), or within national frameworks. This was also designed to evaluate, in collaboration with WP2, the suitability of single sites and protocols for recruitment monitoring, that, although standardized, should take into account the specificity of sites, based on their habitat typology and environmental settings.

5.2. MATERIALS AND METHODS

5.2.1 Data collection and data quality checks

Specific activities aimed at collecting all available information on glass eel recruitment at sites in the Mediterranean, both old and recent, and was based on a thorough literature search, the compilation by scientific partners of a dedicated spreadsheet within WP3 and raising data from any monitoring and surveys carried out in partner countries, within national frameworks. Complementary information on the environmental features of recruitment sites came from the WP3-habitat database, with further web-based and literature searches on specific topics.

The literature search had the objective of collecting all relevant papers, relying for older papers on the comprehensive bibliography compiled by Charlon (1982) on the leptocephalus and glass eel stages between 1829 and 1980, relevant documents in libraries and on-line libraries. For recent papers (after 1980), Web of Science and Google Scholar were used as sources. In total 130 papers were found, dating from 1913 to 2021, including the most relevant documents, providing comprehensive coverage of past and present information in the Mediterranean region. All papers were re-examined in depth to extract useful information for aspects related to site locations and characteristics, abundance of recruitment, seasonality, drivers of migration, biological features of glass eel (size, pigmentation, feeding) and any other relevant points. Data were standardized when necessary and used to build tables and matrices for the descriptive aspects of recruitment, and to perform subsequent analyses.

The data collection within WP3 required partners to provide annual data on glass eel abundance from monitoring and commercial fisheries. The recruitment spreadsheet was also integrated with data obtained from the literature search, when suitable.

All data were checked for quality. Technical quality checks concerned: duplicated rows, site names with spelling errors, inconsistencies between coordinates and sites (for example, the same site with different coordinates, or the same coordinates for different sites), errors in habitat attribution and empty cells.

Time-series were verified with scientific partners and grey literature, while data from reports were cross-checked for consistency. Time-series from scientific estimates giving numbers (n) were transformed to weight (values standardized to kg for abundances) by using individual mean weights (g) for glass eels at the site or the nearest site with available data.

5.2.2 Data analysis

In order to describe how glass eel abundance at the Mediterranean scale changed over time, four time-frames were identified, as follows:

- *pre-1950*: a period when most land reclamation was carried out in the Mediterranean region, including all years from 1909 to 1949, but only scattered data available;
- *pre-1980*: including years from 1950 to 1979, coinciding with the period of known glass eel abundance during which the main fisheries developed and hence time-series of catches are available;
- *pre-2009*: including years from 1980 to 2008, coinciding with the period of documented decline, in which fisheries data and relative time-series are still available; and
- *post-2009:* including years from 2009 to 2021, coinciding with the period following the implementation of eel management plans in European countries, and some new time-series became available.

Mean annual abundances relative to each time frame were calculated. Maps were drawn to highlight the temporal evolution of abundances at specific sites across the Mediterranean region.

Individual time-series trends were plotted on raw data and smoothed with a five-year moving average. Because the series covered varying time intervals and were incomplete, with some years missing for some countries, only those covering more than ten years were selected to describe overall trends. The analysis focused on the period 1999–2020, which provided the largest number of overlapping series: nine time-series from three countries (Spain, France and Italy).

The time-series selected were scaled to each 1999–2020 average and log-transformed to standardise values, and geometric means were calculated. To investigate seasonal recruitment patterns, descriptive analysis was carried out to detect common patterns among time-series, to explore whether spatial patterns emerged and to explore whether changes occurred between periods when past data were available at a specific site.

All quantitative data, that is, relevant data as monthly occurrences over an annual cycle at the same location, were normalised to proportions according to Righton *et al*. (2016).

Studies reporting only qualitative data, such as the start and end of the migration season or peak of occurrence or presence occurring at a specific site and month, were converted into ranks of occurrence per month according to a scale ranging from 0 to 4, from 0 meaning movement was absent, to 4 maximum intensity, the peak of timing (0= no catch; x = ≤ 25% of the total occurrence; xx = <50%; xxx = < 75%; xxxx ≤ 100%, peak of presence).

All data from monitoring, landings and literature were merged and analysed irrespective of source or type, that is, quantitative or qualitative.

Prior to analysis, daily data were grouped per migration season according to eel life history calendars where the glass eel season *y* ranges from September *y*-1 to August *y*. A clear distinction was made between actually reported 0 values, versus "no data available". In this sense, only the actual 0 values were kept, that is, when a measurement had been made and no catch resulted. Time-series were selected according to the number of months with non-0-values available, that is, more than five months per year. Since the matrix contained data for eleven countries from the Mediterranean area and more than 40 percent was qualitative information only, for countries with reduced data availability and to avoid a reduction in spatial coverage, the limit value was reduced to three months per year.

Results are shown separately for each stage of glass eel development, that is, unpigmented glass eel stages VA-VIA2 of Strubberg (1913), pigmented glass eel and elver stages (VIA3-VI B, bootlace), and shown by habitat type (river, estuary and lagoon). A new habitat type category was considered while exploring the data: artificial channels equipped with a pumping station (coded as "CHL").

All the maps were made using the QGIS (2021) software with the ESRI Ocean base map. All the graphs were made through the "ggplot2" package (Wickham, 2016) of the R Core Team software (2021).

5.3. RESULTS

5.3.1 Overview of recruitment sites

Overall, glass eel recruitment in the Mediterranean was documented in 79 sites (Figure 5.1). In the map, four sites on the Atlantic coast have also been included for comparison purposes as they are not too distant from the strait of Gibraltar: the Guadalquivir River in Spain and the Kenitra coast, Sebou and Loukkos rivers in Morocco.

The Mediterranean sites were distributed between 31.15 degrees north (Al Max canal near Alexandria, Egypt) and 45.41 degrees north (lagoon of Venice, Italy) latitude. The Moulouia river in Morocco is the westernmost site where glass eels were present, while the river Asi Samandağ in Türkiye is the easternmost. An unsuccessful search for glass eels was carried out in in rivers near Salonicco, northern Greece, in the 1930s (Athanassoupolos, 1936).

The habitat typology of sites included all transitional eel habitats, as identified by the habitat task in WP3: 20 sites were coastal lagoons and 48 sites have been described as river estuaries. Among rivers and estuaries, the most notable for surface and outflow (mainstream rivers, perennial large rivers) were the river Nile (Egypt), the Tevere river (Central Tyrrhenian, Italy), the Po River (northern Adriatic, Italy) and the Rhone delta (France). There were many perennial medium-sized rivers and some were described as creeks based on their small dimensions and mean annual river flow (perennial stable streams and tributaries). Some rivers in Sardinia (Italy), in Tunisia and the Moulouia on the Mediterranean coast of Morocco, were temporary rivers drying out at some times of the year (seasonal streams and tributaries). Some sites were artificial channels, where glass eel recruitment has been documented in the past or through recent monitoring (Tuscany, Central Italy) or from historical literature (Maccarese, central Italy; Al Max canal, Tolombat and Gibouti, Egypt). Glass eel presence has also been reported in two coastal areas in the Mediterranean, in Greece, in the Eleusis Gulf (Aegean Sea), and in the Tunis Gulf, in the south-eastern part of the bay in front of Tunis Lake. Similarly, glass eel presence has been confirmed in the Rabat-Kenitra coastal area, on the Atlantic coast of Morocco.

This general overview, as explained in the materials and methods section, combined information from past and recent literature, from data collected within WP3database and from monitoring and scientific surveys carried out in various countries. On the whole, eight percent of data collected were from commercial fisheries, 69 percent was derived from past or on-going monitoring in different countries and 23 percent was derived from literature. As a consequence, surveys were very different in terms of content and methods, while also depending on the historical period in which they were carried out. Figure 5.2 shows the survey types that yielded information on glass eel presence and recruitment in the sites, from any source, in the years 1913–2021 (see also Table 5.7).

In the early 1900s, in the wake of Grassi and Calandruccio's findings of leptocephali and glass eels in the Strait of Sicily (Grassi and Calandruccio, 1903a, b) and following Schmidt’s findings on the breeding place of eels and his detection of leptocephali in the Mediterranean in the cruises of 1912-1925 (Schmidt, 1912, 1924), most investigations concerned the search for recruitment sites, and the description of glass eels in different locations and along the ascent season.

Among these old papers, some do not provide specific details about their methodologies (NR – *not reported*), while others said they used sporadic observations and samplings (*anecdotal*). Other information from recruitment sites surveyed in the early 1900s, was from stations where employees of the coast guard or of the fisheries service collected glass eel and other finfish fry attracted by pumping stations in the canals, to be transported to stock lagoons to sustain fisheries or for extensive aquaculture. At these sites, in practice, all glass eels arriving at the station were collected, as the fish were present along the season (*collection*). For two of these (Al Mex canal in Egypt, Maccarese in Italy), data are complete for some years, making it possible to have information on recruitment abundance.

On the other hand, in many of the historical and in some contemporary papers, as well as for many sites, detailed observations and sampling spanned a whole year or season and in some cases were carried out across years (*observations*). These yields scarce information on recruitment abundance levels but provide many details on glass eel morphometrics and pigmentation stages, and sometimes also on seasonality, modalities of ascent and local environmental factors influencing migration. This information was used for a further description of recruitment.

Between 1990 and 2020, monitoring schemes (*monitoring*) were put in place, also focusing on sites already surveyed in older time periods, with varying methodologies and extensively described in Chapter 14. Some of these monitoring methods used, or still use, fishing gears that overlap, or partially overlap, with fishing activities (*fishery-based*).

Longer-term recruitment abundance can only be inferred for sites where fisheries have been maintained over time. These are located in rivers and in the Albufera lagoon in Spain as well as in the river Tevere (*fishery*), a fishing site in Italy. For these sites, time-series are more-or-less complete. Some are already available to the WGEEL, and already used for annual evaluations of recruitment levels at the European scale. Some series are new additions and are used in this project for evaluations of the Mediterranean recruitment trend (see below, Section 5.3.3).

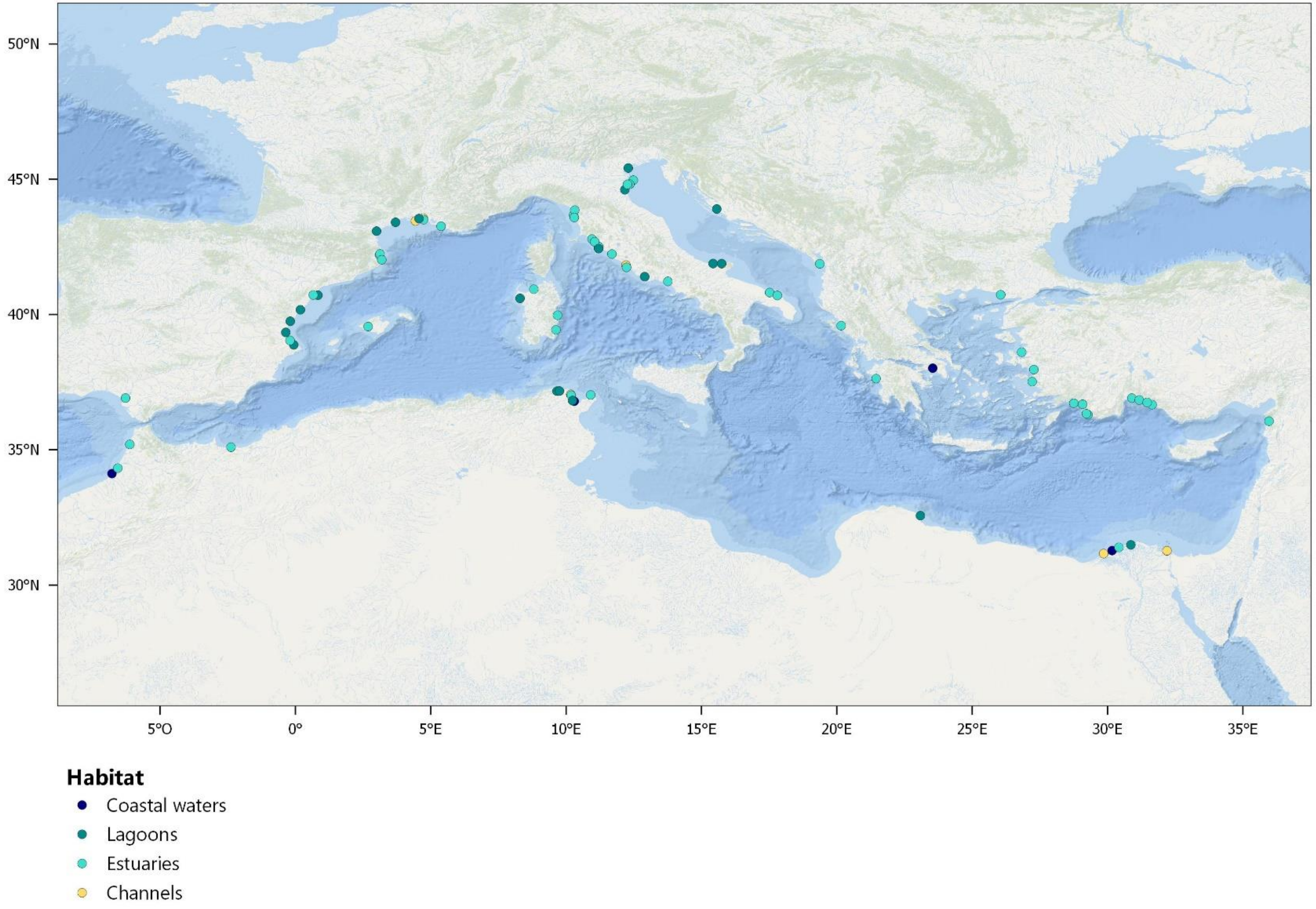


Figure 5.1. Locations of the 79 Mediterranean sites where glass eel presence was documented on the basis of literature, fisheries, scientific surveys and monitoring (reference years 1913-2021) by habitat type.

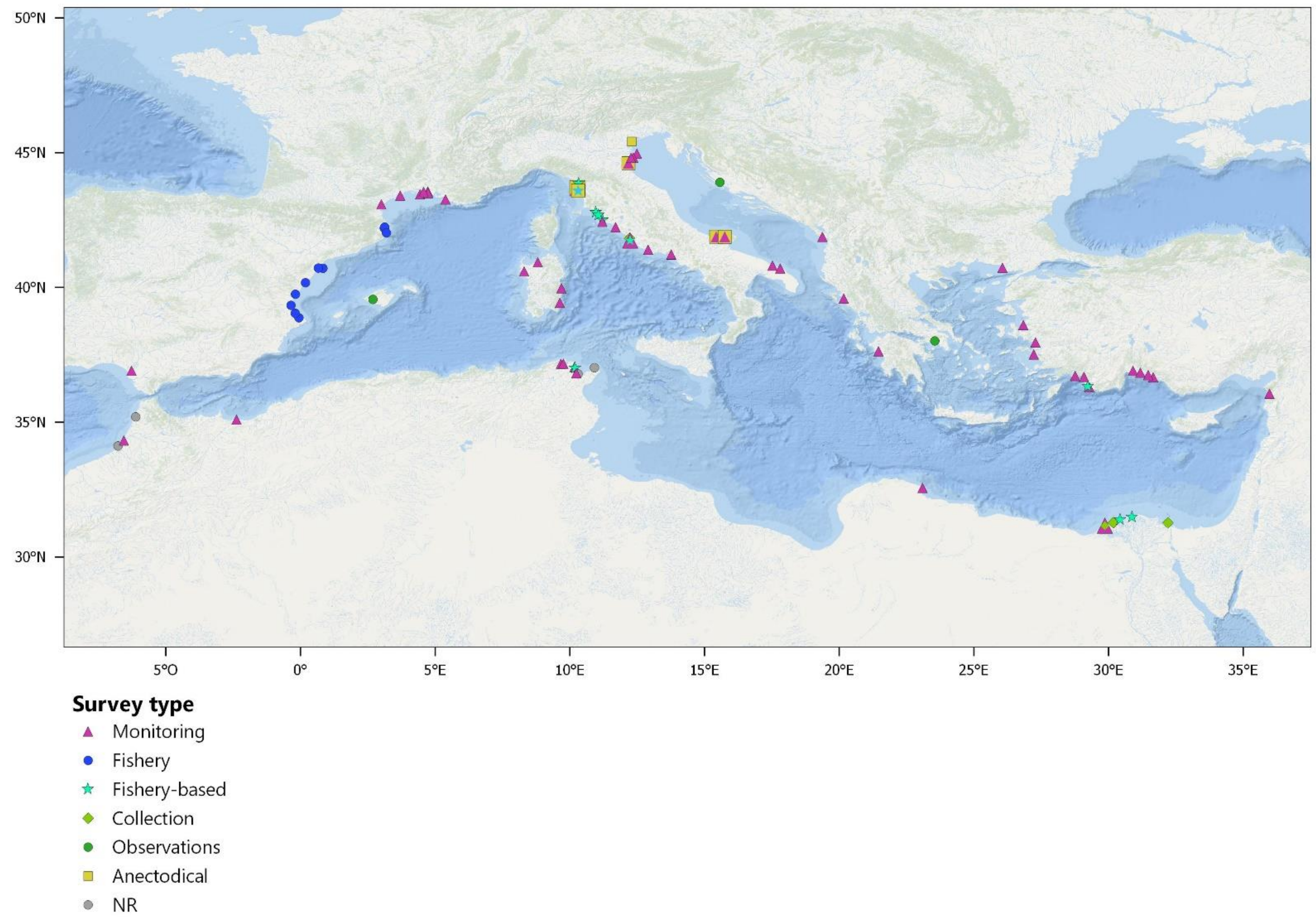


Figure 5.2. Sources of information on glass eel presence in the sites (reference years 1913-2021). Monitoring: data inferred by monitoring with varying methodologies. Fishery: times-series from glass eel fisheries data. Fishery-based: times-series from monitoring using methodologies overlapping with fishing activities. Collection: data from channels with pumping stations. Observations: detailed observations and samplings lasting one year or across several years. Anecdotal: sporadic observations. Not-reported (NR): no detail on data or methodology.

5.3.2 Abundance levels and glass eel fisheries over time

Past and present levels of abundance were compared for the four time-frames (pre-1950, pre-1980, before implementation of the 2007 European Union eel regulation, and since the eel regulation), close to the major breakpoints in the recruitment series identified by WGEEL in the assessment of recruitment trends (ICES, 2020a, b).

Literature for the *pre-1950* period, even if often anecdotal, hints at high recruitment levels at several sites around the Mediterranean. Accurate information on abundance in the first part of the 20th century was only obtained for a few sites; Maccarese near Rome (Central Italy), Al Max canal near Alexandria (Egypt), the Albufera lagoon (Spain) and the Alfeios river, in the Peloponnese region, on the Aegean Sea (Greece).

Maccarese near Rome and Al Max Canal present similar features as they are located at artificial channels with water regulation pumping stations. In Maccarese, reclamation work was carried out during the years for which data were reported (1909-1933) and in Alexandria the pump station was to regulate the water level of Lake Manzala which is located below sea level. The glass eel ascent occurring at these sites can be defined as "*induced*", meaning that the pump stations created an outflow that strongly attracted glass eels, which then concentrated in the channel and below the pump station, where they were collected in large numbers. The peaks of abundance within the season were mostly related to the activity pattern and the flow rates of the pumps, rather than to other local environmental factors. This type of induced ascent was most easily detected at the beginning of the twentieth century when the first installations were made at the same time as land reclamation or other hydrological management and it sustained fry collection schemes, not only for glass eel, but also other finfish juveniles, for stocking. For Maccarese, 18 years of data are available, between 1909 and 1933 (seven years within the period are not reported), with yields averaging 2.4 tonnes per year but fluctuating over the years (range 0.48 tonnes to 6.6 tonnes)., According to Chiappi (1931; 1932; 1934; 1935), the data can be considered to be comprehensive for all glass eel arrivals within the season. At Al Mex, only three years of data are available (1920–1922) with yields ranging between 0.5 tonnes and 1.9 tonnes.

For comparison, Athanassopoulos (1936) described glass eel recruitment in the Alfeios river as a "natural" recruitment, with migration induced only by natural drivers, and reported constantly low levels of recruitment in the years 1933 to 1935, with yields of 50 kg/year to 70 kg/year. On the other hand, the pre-1950 period data for the Albufera lagoon are only for 1949, the first year for which data from this site was available, reporting 9.3 tonnes of yield (Figure 5.3a).

The time-series from the Albufera continues across the later time periods, and in the *pre-1980* period catches averaged 4.7 tonnes/year, ranging from 0.4 tonnes in 1959 to 16.7 tonnes in 1961. Data from a second site in Spain, the Ebro Delta, became available from 1966 onwards, with average yields in this period of 3.5 tonnes/year, a maximum yield of 8.8 tonnes in 1938 of and a minimum of 1.1 tonnes in 1973, but no information is available on fishing effort in this period or for later periods. In Italy, in the 1970s, two fixed fisheries on rivers began, one on the Tevere estuary and the other on the Marta River mouth, both on the Central Tyrrhenian coast. The two sites are less than 100 km apart, but main branch of the Tevere estuary is large, with a salinity wedge that moves upstream for five to six kilometers, depending on the river outflow, while the Marta River flows into the sea with a quite small, narrow river mouth. Fyke-net fisheries were practiced at both sites, with nets installed along the river banks of the lower part of the estuary, in 10-15 stations (one fyke-net per station) stretching for four to five km on the Tevere and in lower numbers (one to three) on the Marta. Yields were not fully documented but were around seven tonnes/year to ten tonnes/year on the Tevere and about four tonnes/year on the Marta. High catches could occur in a single night, and there was strong conflict over the resources between fishers at both sites. In the same period, many other glass eel fisheries developed in Italy, but these were exploited by specialised, itinerant fishermen that moved along the coasts of central Italy, to the mouths of various rivers (Arno in Tuscany, various canals and minor rivers, Garigliano and Sele in Campania) fishing for glass eel with fyke-nets and for other finfish fry with seine nets. They were itinerant for the whole season, moving with trucks equipped for storage and transport of the seed. No data are available for these fisheries, but they were quite well developed in the 1970s in Italy and possibly also in other countries (Figure 5.3b).

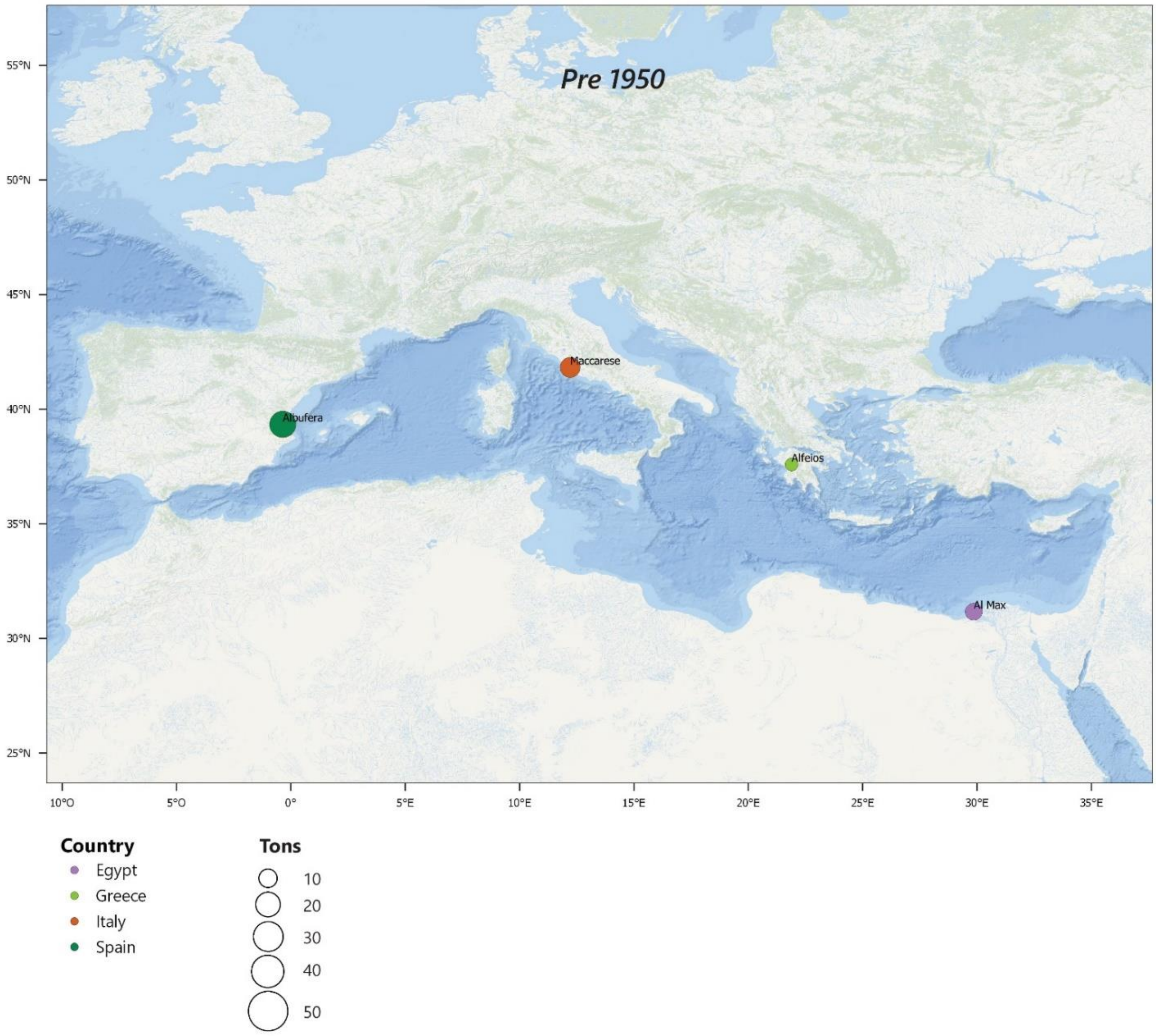


Figure 5.3a. European eel recruitment abundance in the period pre-1950 by country and magnitude (tonnes/year).

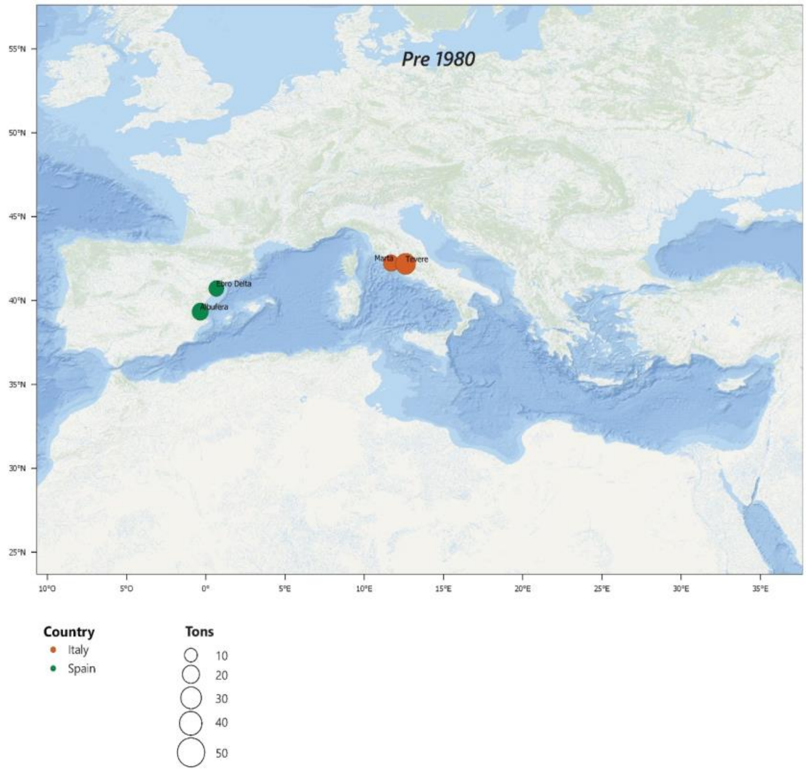


Figure 5.3b. European eel recruitment abundance in the period pre-1980 by country and magnitude (tonnes/year)

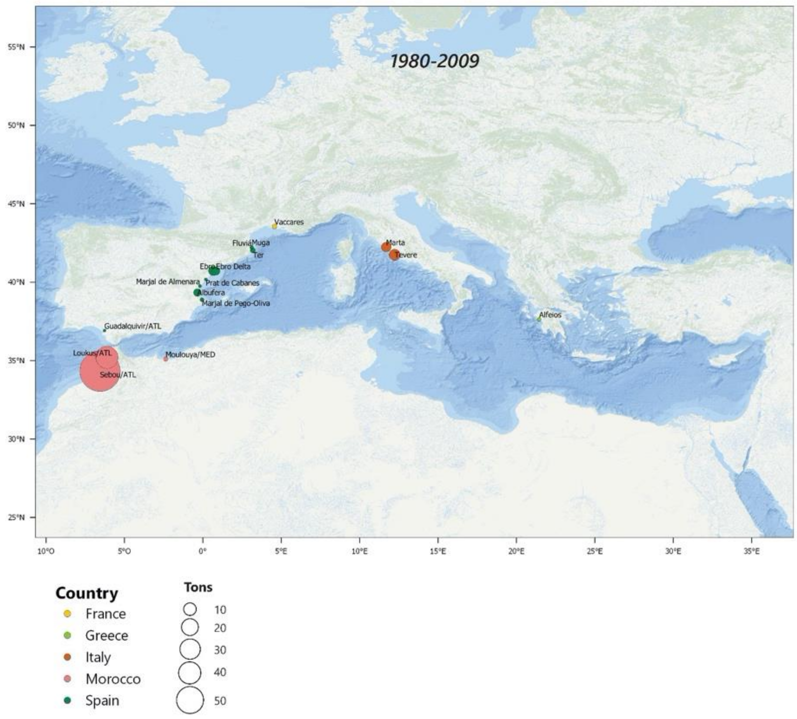


Figure 5.3c. European eel recruitment abundance in the period 1980 to 2009 by country and magnitude (tonnes/year). Data are glass eel catches from fishery-based time-series and monitoring (Guadalquivir/ATL, Vaccares).

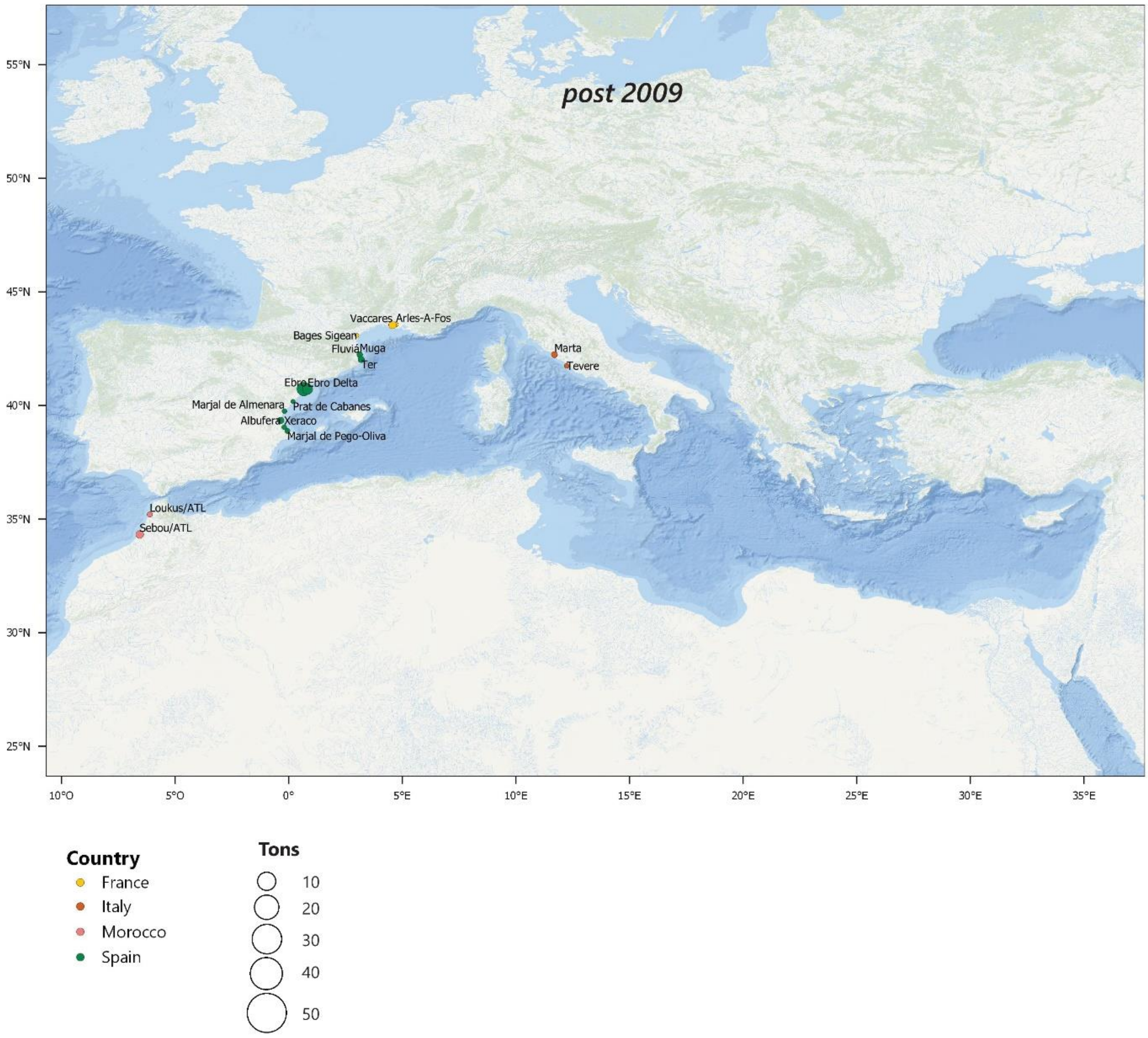


Figure 5.3d. European eel recruitment abundance in the period post 2009 by country and magnitude (tonnes/year). Data are glass eel catches from fishery-based time-series and from monitoring (at Bages Sigean, Vaccares and Arles A Fos).

The time period for which most data were available was *1980-2009* (Figure 5.3c). In Spain, the Albufera and Ebro delta fisheries continued. In the Albufera, yields were as high as 4.2 tonnes in 1988 but dropped to 0.04 tonnes in 2002. In the Ebro Delta the highest yield was 3.8 tonnes in 1981 and the lowest was 0.11 tonnes in 2000. New series were available from seven rivers in Spain, with varying levels of abundance but all showing declining catches. Information on fishing effort was scattered and varied between sites, so analysis did not deliver any clear information about the number of fishers, number of fishing gears per day or number of effective fishing days. Therefore, at present, it is not possible to correlate catches and fishing effort. The same typology of glass eel fisheries described above continued through the 1980s until the early 1990s in Italy. The time-series from the Tevere estuary was available, up to 2006, with annual yields progressively decreasing from about ten tonnes to less than 30 kg. Similarly, in the Marta, catches dropped from about four tonnes/year to about 0.1 tonnes at the end of the period (detailed catch data was only available for the years 2000 to 2005). During this period, data were available also for northern Africa, albeit only for some years. On the Mediterranean side, data were available for fisheries on the Moulouia, a river in Morocco (1989–1990, 1996–1998, 2001–2002). The highest catches were observed in 1990 (233 kg) and the lowest in 2002 (20 kg). By comparison, data from the Atlantic coast of Morocco report catches as high as 150 tonnes on the Sebou river in 1985, dropping to 5 tonnes in 2006, and catches of 40 tonnes on the Loukkos river in 1987, dropping to 0.1 tonnes in 2008. Overall, it is evident that the decline in glass eel recruitment occurred everywhere in the Mediterranean at that time, causing problems for most of the glass eel fisheries. In 2004, the monitoring of recruitment by trapping at Vaccares, Camargue lagoons, France, started on a continual basis.

In the after 2009 time period, the same time-series were available for seven rivers in Spain, and from the Vaccares Fourcade station on the Camargue lagoons, France, while the series for fisheries in Italy stopped. In general the abundances declined at all sites, even if in some locations, signs of recovery were observed. Higher yields were observed in 2014 in Vaccares and in 2015 in the Ebro Delta, as well as in 2017 in the Albufera lagoon, Ebro Delta, Muga, Ter and Xeraco rivers. However, no information is available on changes in fishing effort and this recovery has not been confirmed in more recent years. In France, one new station at Port La Nouvelle channel (Bages Sigean lagoon) was set up in 2018 to monitor recruitment using fishery-independent monitoring methods. In Italy, between 2013 and 2021, scientific monitoring was initiated on the Tevere estuary and the Marta River mouth, at the same sites where fisheries had been practiced in previous years.

Table 5.1 shows the mean yields for the four time periods, for the major sites in the Mediterranean.

Table 5.1. Average annual European eel recruitment by time period in the main Mediterranean sites (kg/year)

			Time period			
Country	**Habitat**	**Site**	**pre 1950**	**pre 1980**	**1981-2009**	**post 2009**
Morocco	RIE	Sebou/ATL			51 700.00	285.00
Morocco	RIE	Loukus/ATL			13 726.83	40.00
Morocco	RIE	Moulouya/MED			111.00	
Spain	RIE	Guadalquivir/ATL*			2.36	
Spain	LGN	Albufera	6 573.50	4 748.81	877.43	141.23

			Time period			
Country	**Habitat**	**Site**	**pre 1950**	**pre 1980**	**1981-2009**	**post 2009**
Spain	RIE	Ebro Delta		3 490.43	1 052.77	681.59
Spain	RIV	Ebro			2 243.50	1 234.30
Spain	RIE	Fluviá			26.42	6.90
Spain	LGN	Marjal de Almenara			9.23	19.74
Spain	LGN	Marjal de Pego-Oliva			59.43	35.63
Spain	RIE	Muga			6.56	64.52
Spain	LGN	Prat de Cabanes			7.25	5.50
Spain	RIE	Ter			219.09	118.04
Spain	RIE	Xeraco				23.34
France	LGN	Bages Sigean*				0.18
France	LGN	Vaccares*			138.72	244.75
France	CHL	Arles-A-Fos*				7.91
Italy	RIE	Marta		4 000.00	1 726.55	100.00
Italy	CHL	Maccarese	2 383.89			
Italy	RIE	Tevere		8 870.00	2 544.81	14.90
Greece	RIE	Alfeios	60.00		60.00	
Egypt	CHL	Al Max	1 054.19			

*Data from scientific surveys

5.3.3 Long-term trends in recruitment (time-series)

Twenty-three recruitment times-series from seven countries in the Mediterranean area were reconstructed and covered varying time intervals from 1910 to 2020. Out of these, nine have data in the period, 1999–2020 (Table 5.2). The time-series data were derived from fishery-dependent sources (that is, catch records) and fishery-independent surveys. Each series was classified according to source (official statistics, monitoring) and type of data: commercial catch-per-unit effort (cpue; kg/net), total commercial catch (kg) and scientific estimates (n).

The longest time-series relied on fishery data from "sedentary" fisheries and fishery-based monitoring in eight Spanish river estuaries (including the Guadalquivir), the Tevere river (Italy), and the Albufera lagoon (Spain). Of the three series available from France, one was from trap-based data collection at La Fourcade, in the Vaccares lagoon (this data series consists originally of numbers, but numbers were converted to kg using the mean annual weight values for glass eels, regularly sampled), while the two additional series from France were still short. The same applies to the two Spanish series from the Xeraco and the Prat de Cabanes rivers, while the data series from Italy (Marta) and Morocco (Moulouia) were too discontinuous to allow further analyses to determine temporal trends. Therefore, only series covering more than ten years were selected for further trend analysis (Table 5.3, Figure 5.1 and Figure 5.4) and others were discarded. The selected series cover varying time intervals, with the Albufera and Ebro Delta being the longest. Eight series were updated to 2020.

A summary of the features of all the data series is presented in Table 5.2, and in the map in Figure 5.4, while a summary of the characteristics of the 12 time-series retained for analysis are shown in Table 5.3.

Table 5.2. Recruitment data series from Mediterranean sites. Min and max indicate the first year and last year in the records; N values indicate the number of years with records (N+) and without (N-). Life stages: GY = glass eel and yellow eel, G = glass eel, Y = yellow eel. Sampling type: ND = not determined, N = net, C = commercial catch, T = trap, P = pump station. Unit for the data originally collected is given. Habitat: CMW= coastal marine water, LGN = lagoon, RIE = river estuary, RIV = river. CHL = Channel with pumping station. Kept: the data series was used (1) or discarded (0) in recruitment analyses.

Country	Code	Site	Min year	Max year	N+	N-	Life Stage	Sampling Type	Unit	Habitat	Source	Kept	Reference
Morocco (ATL)	Sebo	Sebou/ATL	1987	2011	5	20	G	ND	kg	RIE	Literature	0	Yahyaoui, 1988
Morocco (ATL)	Louk	Loukus/ATL	1987	2011	8	17	G	ND	kg	RIE	Literature	0	Yahyaoui, 1988
Morocco (MED)	Moul	Mouloya/MED	1989	2002	7	7	G	ND	kg	RIE	Literature	0	Yahyaoui, Aguesse and Beaubrun, 1983, Yahahoui *et al*., 1996
Spain (ATL)	Guad	Guadalquivir/ATL	1997	2006	10	0	G	N	n	RIE	Literature	1	Arribas *et al*., 2012
Spain	Albu	Albufera	1949	2020	66	5	G	C	kg	LGN	Fisheries statistics	1	WP3 DB
Spain	Ebro	Ebro Delta	1966	2020	46	8	G	C	kg	RIE	Fisheries statistics	1	WP3 DB
Spain	Ebrr	Ebro	1997	2020	17	6	G	C	kg	RIV	Fisheries statistics	1	WP3 DB
Spain	Flu	Fluviá	1999	2019	13	7	G	C	kg	RIE	Fisheries statistics	1	WP3 DB
Spain	Mada	Marjal de Almenara	2000	2017	17	0	G	C	kg	RIE	Fisheries statistics	1	WP3 DB
Spain	Mapo	Marjal de Pego-Oliva	2001	2019	18	1	G	C	kg	RIE	Fisheries statistics	1	WP3 DB

Country	Code	Site	Min year	Max year	N+	N-	Life Stage	Sampling Type	Unit	Habitat	Source	Kept	Reference
Spain	Muga	Muga	1999	2020	14	8	G	C	kg	RIE	Fisheries statistics	1	WP3 DB
Spain	Pcab	Prat de Cabanes	2007	2016	9	1	G	C	kg	RIE	Fisheries statistics	0	WP3 DB
Spain	Ter	Ter	1999	2020	16	6	G	C	kg	RIE	Fisheries statistics	1	WP3 DB
Spain	Xer	Xeraco	2012	2019	5	3	G	C	kg	RIE	Fisheries statistics	0	WP3 DB
France	Bage	Bages Sigean	2018	2020	3	0	G	T	n	LGN	Official scientific project	0	WP3 DB
France	Afos	Arles-à-Fos	2014	2020	6	1	G	T	n	CHL	Official scientific project	0	WP3 DB
France	Vac	Vaccares	2004	2020	17	0	G	T	n	LGN	Official website	1	WP3 DB
Italy	Mac	Maccarese	1909	1933	18	7	G	P	kg	CHL	Literature	1	Chiappi, 1931, 1932, 1934, 1935
Italy	Tibe	Tevere	1975	2006	32	0	G	C	kg	RIE	Fisheries statistics	1	WP3 DB
Italy	Mart	Marta	1972	2014	31	12	G	C	kg	RIE	Fisheries statistics	0	WP3 DB
Greece	Alfe	Alfeios	1933	2000	4	63	G	N	cpue	RIE	Literature	0	Athanassopolos, 1936; Zompola *et al*, 2008

Country	Code	Site	Min year	Max year	N+	N-	Life Stage	Sampling Type	Unit	Habitat	Source	Kept	Reference
Egypt	AlMa	Al Max	1920	1923	3	1	G	P	n	CHL	Literature	0	Paget, 1923; Schmidt 1923

Table 5.3. Recruitment data series from Mediterranean sites selected for recruitment analysis

Country	Code	Name	Survey Type	Stage	Original Unit
Spain	Guad	Guadalquivir/ATL	Scientific	G	cpue
Spain	Albu	Albufera	Commercial	G	kg
Spain	EbrD	Ebro Delta	Commercial	G	kg
Spain	Ebro	Ebro	Commercial	G	kg
Spain	Flu	Fluviá	Commercial	G	kg
Spain	Mada	Marjal de Almenara	Commercial	G	kg
Spain	Mapo	Marjal de Pego-Oliva	Commercial	G	kg
Spain	Muga	Muga	Commercial	G	kg
Spain	Ter	Ter	Commercial	G	kg
France	Vac	Vaccares	Scientific	G	number
Italy	Mac	Maccarese	Pump station	G	kg
Italy	Tev	Tevere	Commercial	G	kg

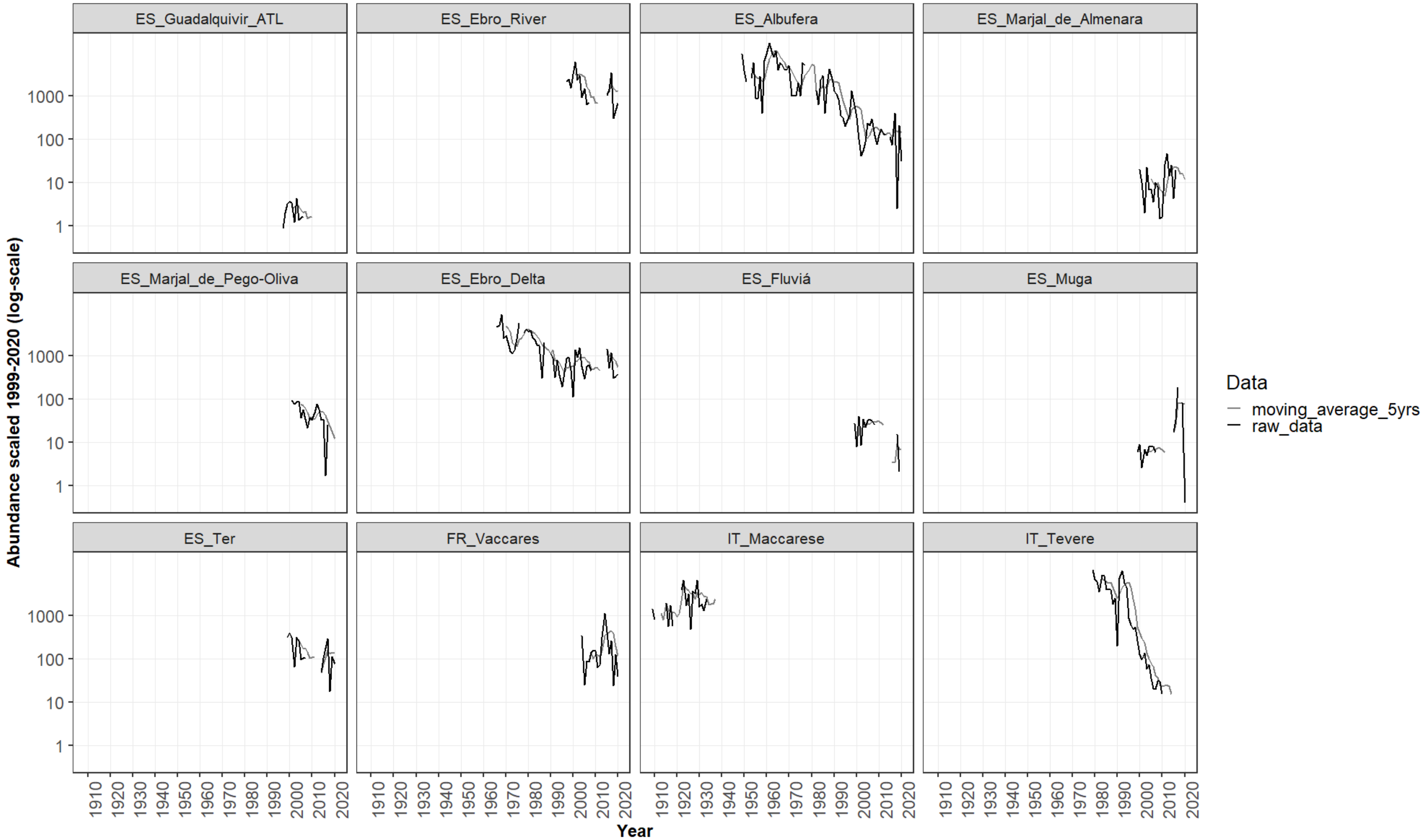


Figure 5.4. Individual time-series of glass eel recruitment with more than ten years data over the period 1949 to 2020 in Mediterranean rivers and coastal lagoons (Spain: Guadalquivir/ATL, Ebro River, Albufera, Marjial de Almenara, Marjial de Pego-Oliva, Ebro Delta, Fluvia, Muga and Ter; France: Vaccares; Italy: Maccarese and Tevere). Note the logarithmic scale on the y axis.

Up to 2021, the joint EIFAAC/ICES/GFCM considered that the available time-series for European eels were too inconsistent and insufficient to carry out a specific recruitment assessment in the Mediterranean. For this reason, available Mediterranean time-series were categorised “Elsewhere Europe” (ICES, 2010). Table 5.4 shows the Atlantic and Mediterranean glass eel series currently used by joint EIFAAC/ICES/GFCM WGEEL for the Recruitment index (ICES, 2021).

Table 5.4. Atlantic and Mediterranean glass eel recruitment time-series currently used by the joint EIFAAC/ICES/GFCM WGEEL in the ICES Annual Stock Advice

Country	Series	ICES Code	Start year	End year	Type
Spain	Guadalquivir/ATL	GuadG	1998	2007	scientific monitoring
Spain	Albufera de Valencia	AicpG	1982	2020	commercial catch
Spain	Ebro Delta	EbroG	1966	2020	commercial catch
France	Vaccares	VacG	2004	2020	scientific monitoring
Italy	Tevere	TibeG	1975	2006	commercial catch

Table 5.5 and Figure 5.5 show the new times series collected within this study that are worthy of note for evaluation of the recruitment index used for trend analysis in the ICES Eel Annual Stock Advice.

Table 5.5 New Mediterranean glass eel recruitment time-series collected within the GFCM European eel Research Programme. N values indicate the number of years with records (N+) and without (N-). Sampling type: C = commercial catch, P = pump station. Habitat: LGN = lagoon, RIE = river estuary, CHL = Channel with pumping station

Country	**Series**	**Code**	**Start year**	**End year**	**N+**	**N-**	**Sampling type**	**Unit**	**Habitat**
Spain	Albufera de Valencia*	Albu	1949	2020	66	5	C	kg	LGN
Spain	Fluviá	Flu	1999	2019	13	7	C	kg	RIE
Spain	Marjal de Almenara	Mada	2000	2017	17	0	C	kg	RIE
Spain	Marjal de Pego-Oliva	Mapo	2001	2019	18	1	C	kg	RIE
Spain	Muga	Muga	1999	2020	14	8	C	kg	RIE
Spain	Ter	Ter	1999	2020	16	6	C	kg	RIE
Italy	Maccarese	Mac	1909	1933	18	7	P	kg	CHL

* Albufera de Valencia time-series with new data available, that is, start year: 1949

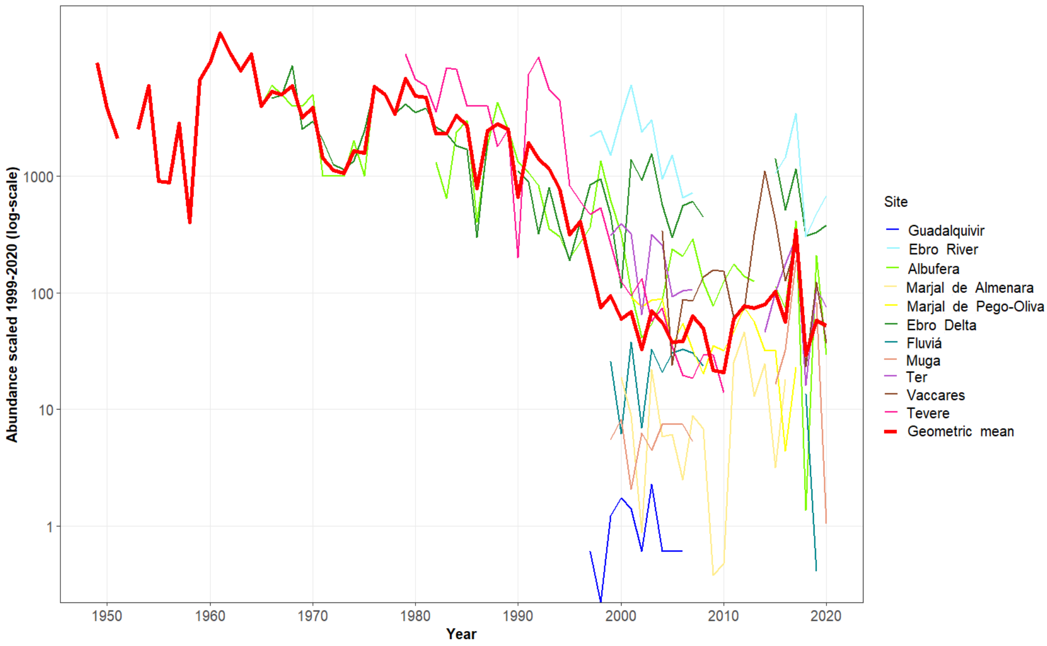


Figure 5.5. Time-series of glass eel recruitment in 11 European river and coastal lagoon sites over the period, 1949–2020. (Each time-series scaled to its 1999–2020 average. Geometric means are presented as a red line.)

The overall picture emerging from the available time-series confirms that for these European eel fisheries in the Mediterranean, landings in the period 1980 to 2009 documented a marked decline across the 1990s with the lowest recruitment occurring at all sites in the most recent years of this time frame. In the period following the implementation of eel management plans in European countries, the time-series show a further decrease in abundance at all sites, even if for some sites (for example, the Spanish rivers, and the French site on the Camargue lagoon) signs of recovery were observed in the middle of this period.

However, no information is available or has been validated on changes in fishing effort in specific sites and this partial recovery has not been confirmed in the most recent years. Therefore, the trend in recruitment described for the Mediterranean area seems consistent with the trend described for the rest of Europe. It would be interesting to consider these new series in recalculations of recruitment indices, while also performing trend analysis to separate the “Mediterranean area” from the ‘North Sea’ and ’Elsewhere Europe’ area (ICES, 2010).

5.3.4 Towards an index for recruitment: a case study from the river Tevere (Italy)

Establishing long-term monitoring of recruitment in future years in the Mediterranean is a crucial issue, that will rely on effective monitoring programmes and in particular, fishery-independent monitoring, being established. The very low levels of recruitment and the closure of many fisheries, either spontaneously given the inconsistent catches or due to closures imposed by new regulations, highlight the need to identify and implement effective, representative monitoring methods and sampling schemes. Chapter 14 of this report includes a complete review of monitoring arrangements for recruitment, covering past, ongoing and future monitoring, while also taking into account methodological issues, such as site location, gear used and monitoring frequency. The review highlights the complexities in identifying the most suitable designs at local level, taking into consideration specific environmental factors while also allowing comparisons with historic monitoring systems.

The possibility of deriving a monitoring-based recruitment index was considered, based on existing data from the Tevere river mouth in Italy. A long-term fishery data-series was available (commercial catches 1975–2006, operated by two fisher cooperatives), complemented for several years by daily monitoring across the recruitment season based on fisheries (1990–2006, fishers along with scientific personnel), until the spontaneous closure of the activity. Starting from 2013, a new fishery-independent monitoring system was set up in the same stretch of river as part of the actions implemented for the EMP, particularly by the EMU-Lazio, using fyke-nets for sampling, with a reduced time scale (daily for one week per month, coinciding with the new moon, instead of daily for the whole season) over five months (November-March).

The data available for this site offer the opportunity to reconstruct a recruitment index, based on fishery data, for comparison with the monitoring series, to evaluate their consistency, over a period of 16 years (1990–2006). This, in turn, could allow appraisal of the effectiveness of fishery-independent scientific monitoring in the last eight years (2013–2021).

Review of the historical time-series

The time-series for glass eel fishery landings at the Tevere river mouth, 1975–2006, is shown in Figure 5.6. Reported catches are from the two cooperatives fishing at the site, which operated for an average of five months (November-March) each year, except for in 1978 and 1979 when fishing was suspended due to market saturation. No specific details on real fishing effort are available for the period 1975–1989, such as a tally of fishing days and the number of fyke-nets used. However, for the 1970s, fishers reported that there were two fisher cooperatives made up of two groups of at least four fishers, fishing at night, alternately at eleven stations along the river with one glass eel fishing gear per station. Moreover, sporadic information on daily catches is available for the seasons 1976–1980, which allows comparison of the average CPUEs with a long-term perspective (Figure 5.9).

This series is one of very few recruitment series available for the Mediterranean and is currently being used by the joint EIFAAC/ICES/GFCM WGEEL in global stock assessments, as well as in the different analyses in this Chapter.

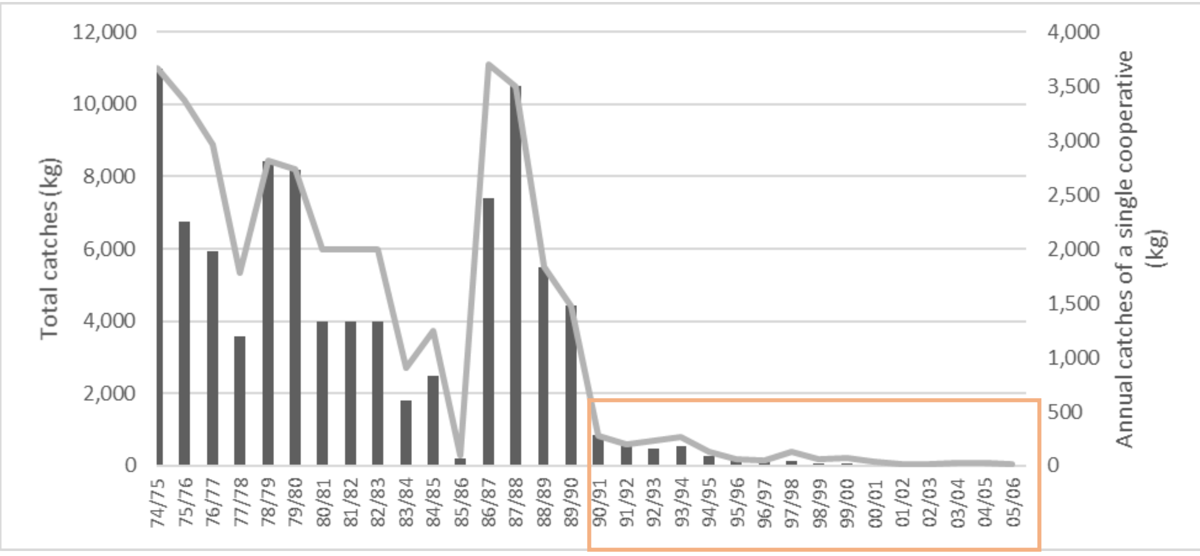


Figure 5.6 Glass eel fishery landings at the Tevere river mouth, 1975–2006. The left axis and bar plots show the total annual landings (kg). The right axis and grey line represents the catch trend based on on catches reported by a single cooperative.

From 1990 onwards, the Tevere glass eel fishery was practiced by only one cooperative and surveyed with detailed monitoring of daily catches and fishing effort, implemented within specific research projects. This fishery-based monitoring continued for 16 years, until termination of fishing due to insufficient catches (Figure 5.7).

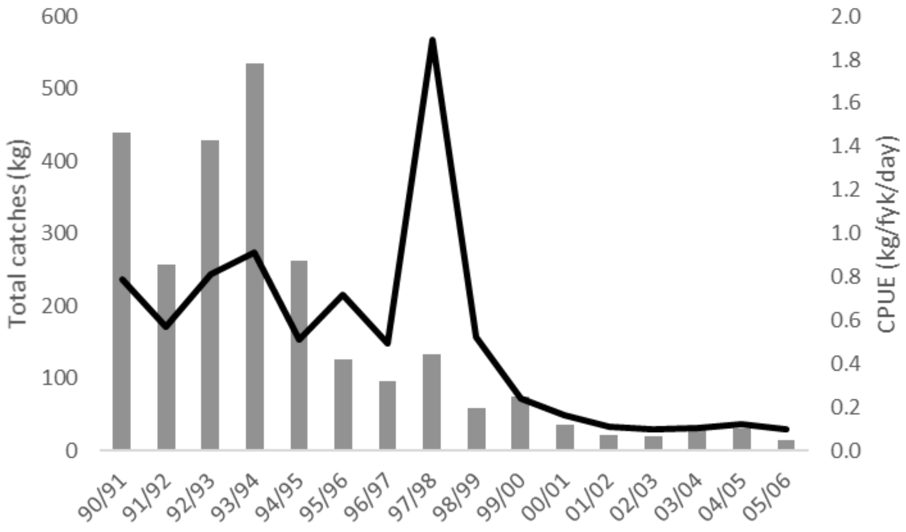


Figure 5.7 Glass eel fishery landings at the Tevere river mouth, 1990–2006. The left axis and bar plots show the total annual landings (kg). The right axis and black line represent the daily CPUE calculated as kg per single fyke net per day.

Within this period, the most dramatic change occurred in the season 1998–99, with catches dropping below 60 kg for the whole season, without any signs of recovery in the following years. This occurred despite an attempt to increase fishing effort, not by increasing number of nets deployed each day but by increasing the duration of daily fishing and the number of fishing days.

Table 5.6. Glass eel fishing activities in the Tevere river mouth (1990-2006)

Year	**Length of season (days)**	**Effective fishing days**	**Days off**	**Mean daily catch (Kg)**	**Number of nets**	**Mean number of nets/day**	**Fishing hours per day**	**Seasonal CPUE (kg/net/yr)**	**Mean daily CPUE (kg/net/day)**
1990–91	116	89	27	4.88	543	6	15	72.0	0.79
1991–92	133	72	61	3.57	417	6	15	44.3	0.57
1992–93	118	93	25	4.61	558	6	15	71.5	0.81
1993–94	120	78	42	6.85	537	7	15	77.6	0.91
1994–95	92	77	15	3.40	452	6	15	44.6	0.51
1995–96	92	39	53	3.24	168	4	15	29.3	0.72

Year	Length of season (days)	Effective fishing days	Days off	Mean daily catch (Kg)	Number of nets	Mean number of nets/day	Fishing hours per day	Seasonal CPUE (kg/net/yr)	Mean daily CPUE (kg/net/day)
1996–97	69	28	41	3.40	204	7	15	13.1	0.49
1997–98	26	14	12	9.50	72	5	15	25.9	1.89
1998–99	57	20	37	2.90	114	6	15	10.2	0.52
1999–00	63	48	15	1.69	219	5	15	16.3	0.24
2000–01	115	79	36	0.45	229	3	23	12.2	0.16
2001–02	121	90	31	0.23	180	2	22	10.3	0.11
2002–03	139	98	41	0.20	196	2	16	9.8	0.10
2003–04	143	102	41	0.30	284	3	23	10.8	0.10
2004–05	139	89	50	0.34	257	3	20	10.6	0.12
2005–06	109	51	58	0.29	153	3	24	5.0	0.10

CPUE: catch per unit effort

The mean daily fishing effort calculated over the season for the 16 seasons is shown in Table 5.6. This shows the conspicuous change in daily CPUE, in the period 1990–1998, compared to the following period (1999–2006), with the lowest record being observed in 2005–2006, which marked the end of this fishery. In Figure 5.8, the average daily fishing effort for all 16 seasons is shown, as well as separately for the periods 1990–1998 and 1999–2006.

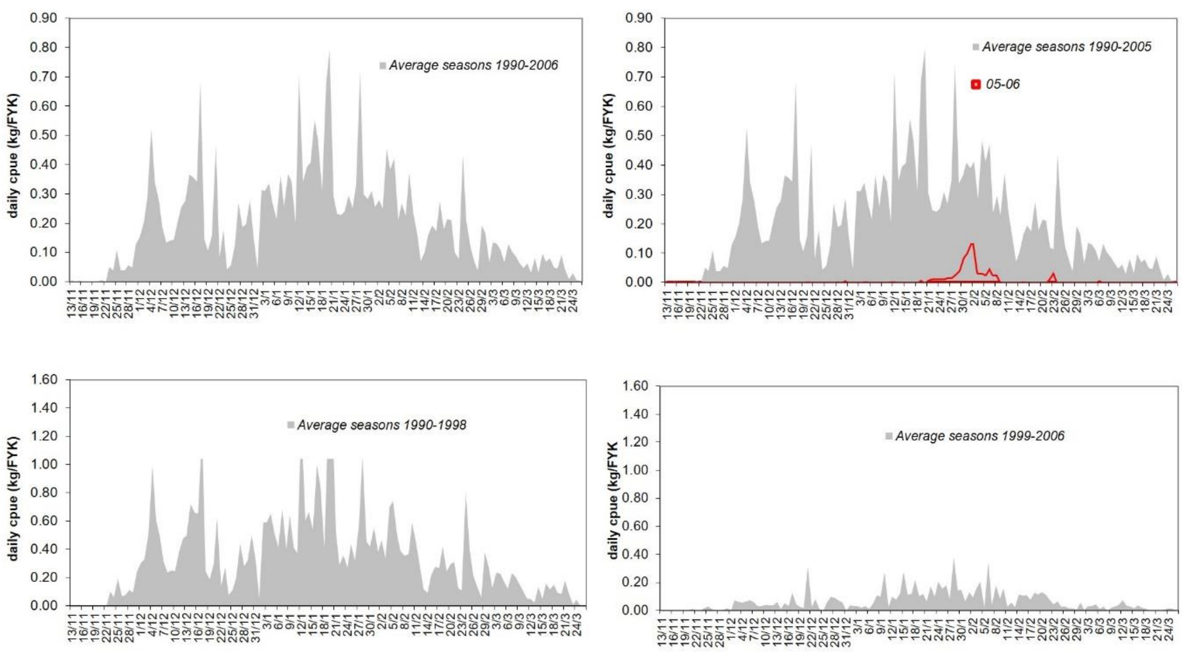


Figure 5.8. Average CPUE (kg/net/day) in the Tevere river mouth, 1990–2006. Top left: average CPUE for 15 years (1990-2005). Top right: Average CPUE for last fishing season (2005–2006) superimposed in red. Bottom left: average CPUE, 1990–1998. Bottom right: average CPUE, 1999–2006.

Derivation of the Tevere recruitment index series 1990–2006

A recruitment index was developed based on data for the 16-year period, 1990–2006, for each month, based on the average CPUE in new moon weeks, for a total of at least four weeks of new moons (w1-w4) for each year of monitoring (Figure 5.9). For comparison, Figure 5.9 also shows CPUEs from new moon the weeks during fishing seasons from 1976 to 1980.

The recruitment index was calculated as average CPUE for each year (daily CPUE over the four new moon weeks) in the 16 years of fishery-based monitoring (1990–2006), and is reported along with catches in Figure 5.10 and in logarithmic scale in Figure 5.11.

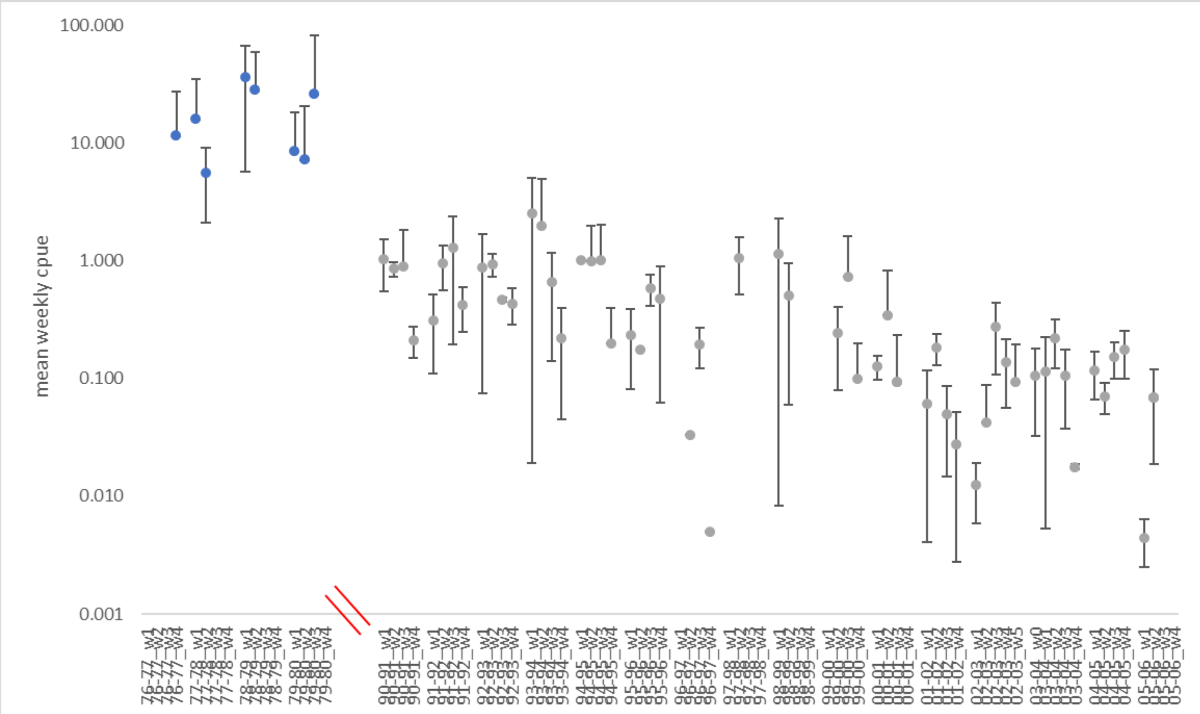


Figure 5.9. Average CPUE (kg/fyke net/week, logarithmic scale) during new moon weeks in the Tevere river mouth. Grey dots: average weekly CPUE (weeks coincident with new moon, w1-w4) over the 16 years of fishery-based monitoring (1990–2006). Blue dots: average weekly CPUE for 1976–1980 when only sporadic daily catches were available. Red lines: daily catches not available (1980–1990).

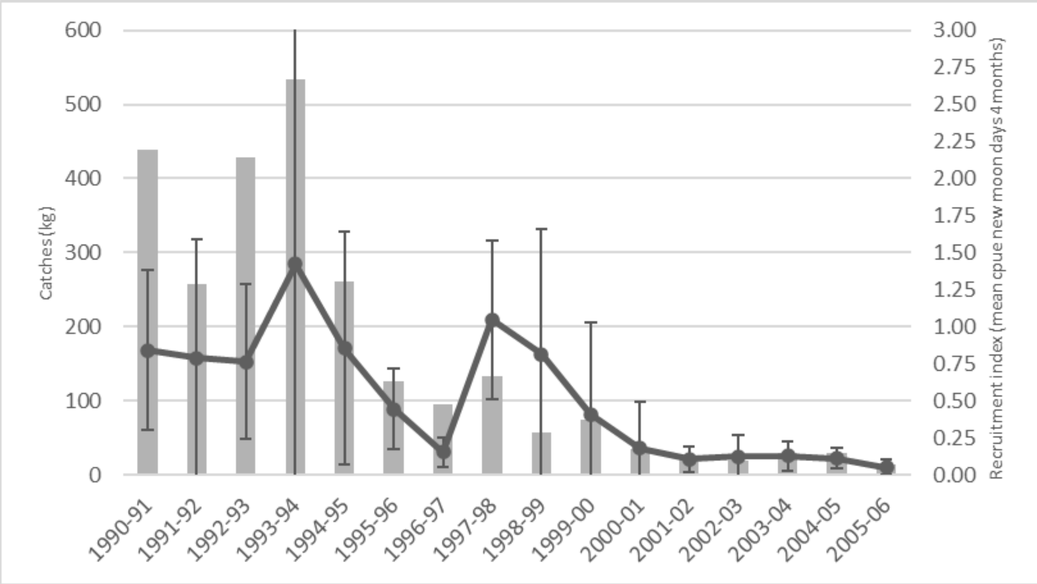


Figure 5.10. Total catches (grey bars, kg/yr) and recruitment index (black line, average daily CPUE over the four new moon weeks) over the period, 1990–2006.

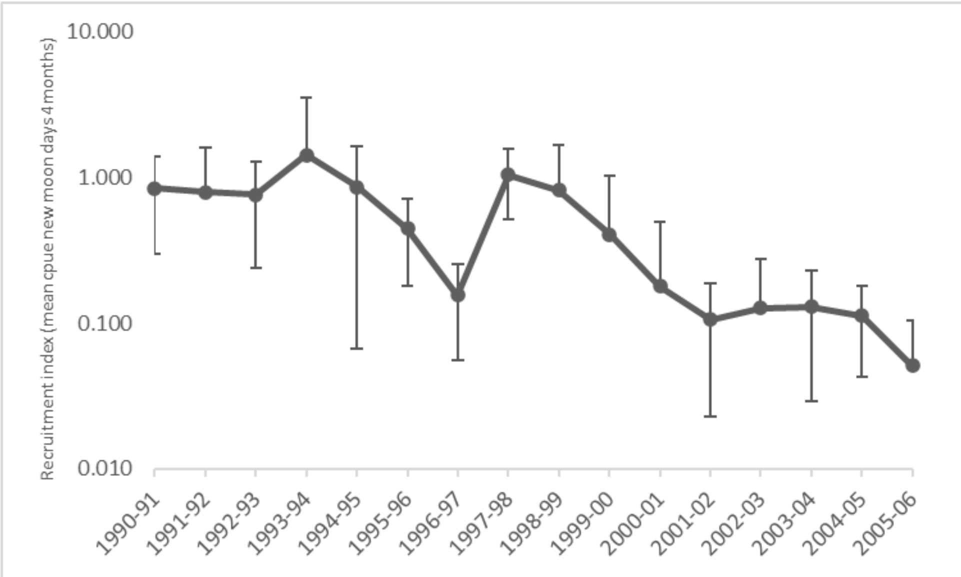


Figure 5.11. Recruitment index over the period, 1990–2006 (Logarithmic scale, daily CPUE over the 4 new moon weeks).

Tevere recruitment index series 1990–2021

The average new moon CPUE for each year, that is, the recruitment index based on daily CPUEs over the new moon weeks across the four weeks monitoring in the year, were calculated for the period 2013–2021, based on data from the new fishery-independent monitoring implemented on the Tevere, and reported in Figure 5.12 and Figure 5.13, along with the trend for the fishery-based index, 1990–2006.

The recruitment index values seem consistent with those in the previous 16-year period, and in line with overall long-term recruitment trends in the Mediterranean (Section 5.3.4).

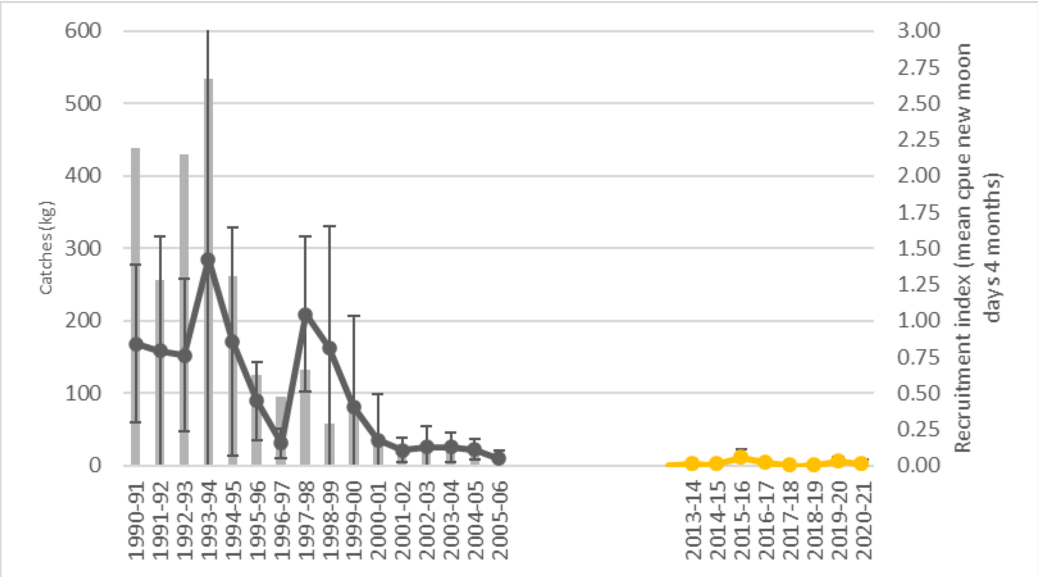


Figure 5.12. Fish catches (grey bars, kg/yr) and recruitment index (average daily CPUE over the four new moon weeks) for 1990–2006 (grey line) and for 2013–2021 (yellow line).

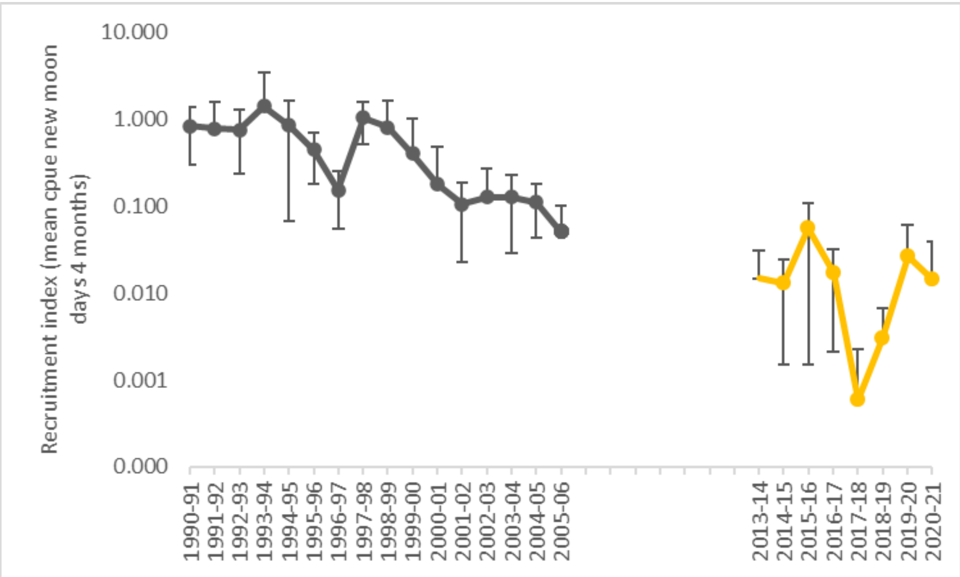
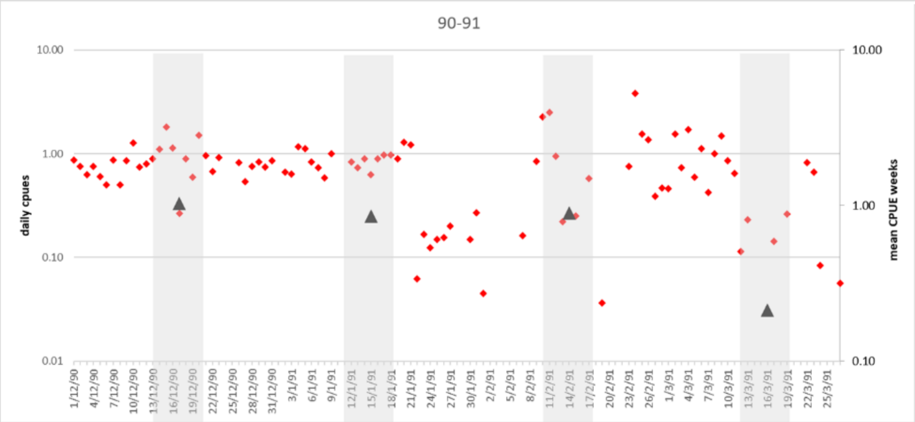


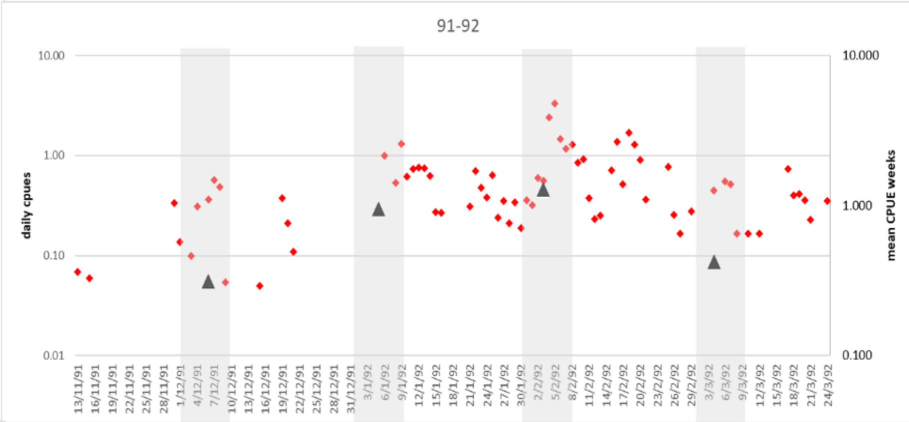
Figure 5.13. Recruitment index (average daily CPUE over the four new moon weeks) for 1990–2006 (grey line) and 2013–2021(yellow line), on a logarithmic scale.

However, some details of the sampling scheme for the new fishery-independent method need to be considered. In some months of some years of monitoring, sampling did not take place under a new moon but had to be postponed owing to operational constraints related to the river (e.g. floods), coinciding with a full moon. On occasions where catches were low, numbers were recorded instead of catch weight and data were converted to weight using a fixed average value, possibly leading to underestimates or overestimates of CPUE. This meant that sampling results were not always adequate for calculation of the recruitment index. Therefore, further analysis was carried out on the data from the fishery-dependent monitoring (1990–2006), comparing daily CPUE with the mean weekly CPUE of the new moon week, in order to better understand intra-seasonal trends.

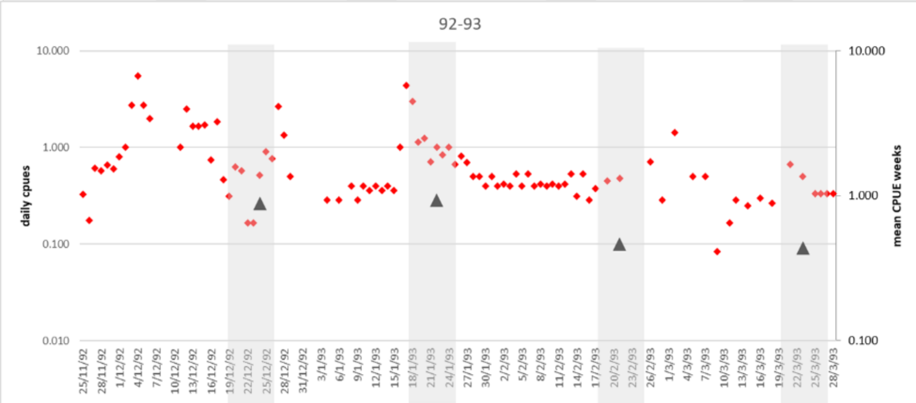
Figure 5.14 shows the mean weekly CPUE (logarithmic scale, average over seven days, including three days before and three days following the new moon and delineated by grey bands in the graphs) over the 16-year period of fishery-dependent monitoring (1990–2006), along with the daily CPUE in the season. The results show that when sampling is limited to days coinciding with the new moon it does not always coincide with the effective peak of ascent, because daily CPUE fluctuates within a longer period of 14 days before and after the new moon. This means that sampling at the turn of the new moon week (7 days total, 3 days before and 3 days after the new moon) will not necessarily record the peak of abundance. Weather conditions or the state of the river (floods or low levels) may make it difficult to install fyke-nets or may affect their efficacy in intercepting glass eels and consequently affect the final number of actual usable fishing days for the calculation of CPUE over the entire monitoring season. Future monitoring programmes for this site should plan for extended monitoring, including waning and waxing crescent moon days, over a period of two weeks, in all recruitment season months.



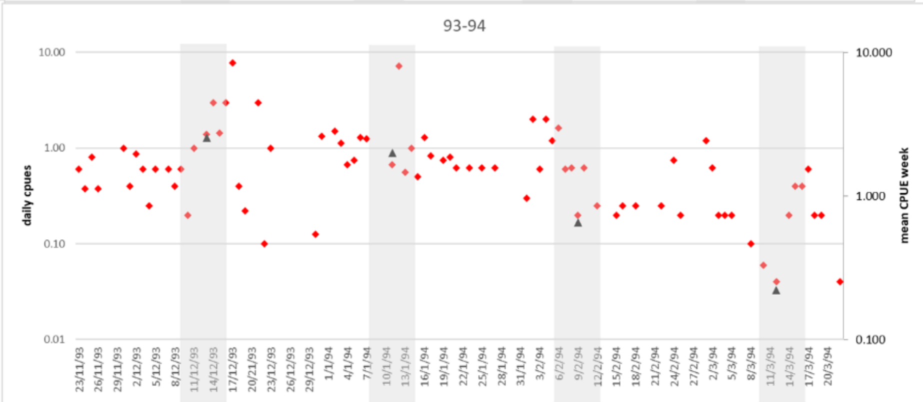
90-91
daily cpues
mean CPUE weeks
10.00
1.00
0.10
0.01
10.00
1.00
0.10



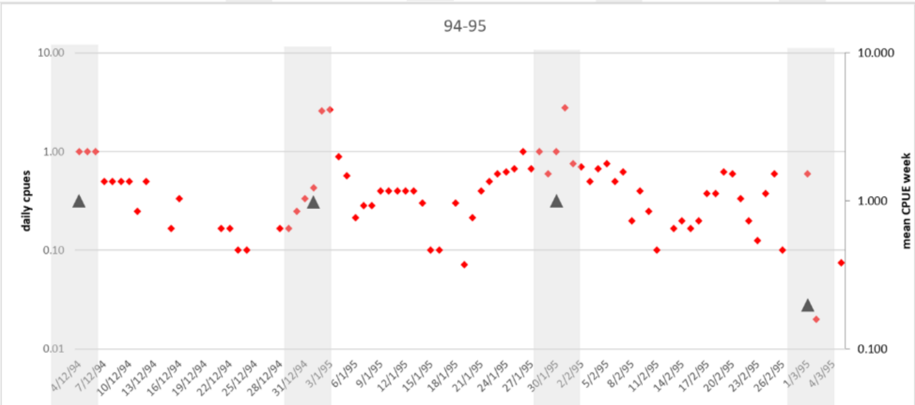
91-92
daily cpues
mean CPUE weeks
10.00
1.00
0.10
0.01
10.000
1.000
0.100



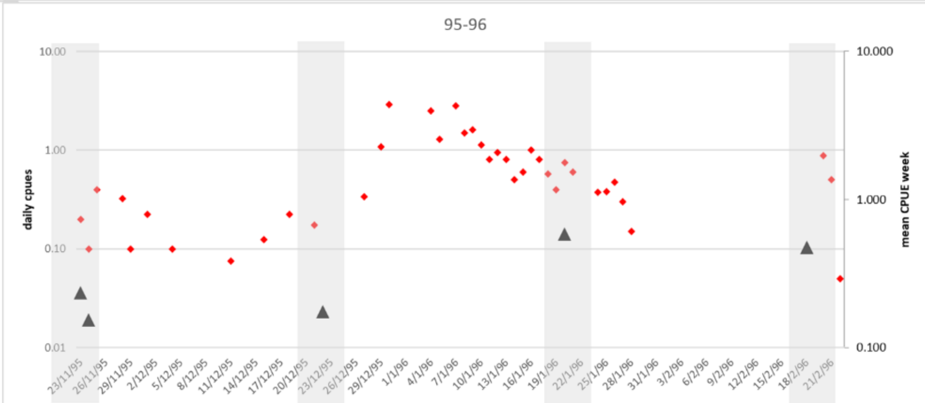
92-93
daily cpues
mean CPUE weeks
10.000
1.000
0.100
0.010
10.000
1.000
0.100



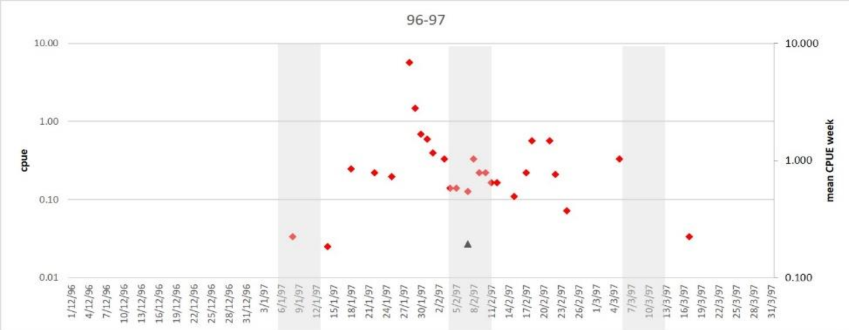
93-94
daily cpues
mean CPUE week
10.00
1.00
0.10
0.01
10.000
1.000
0.100

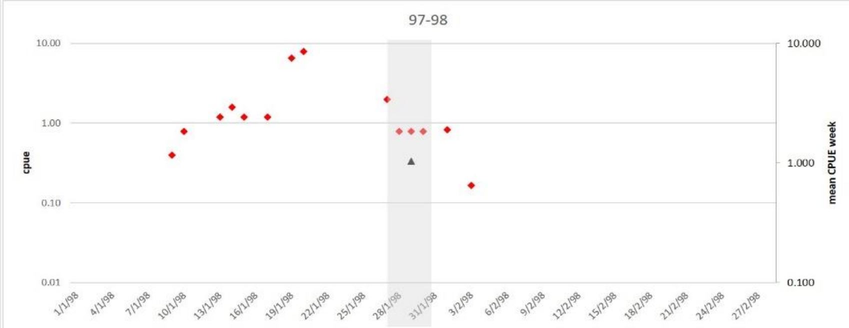


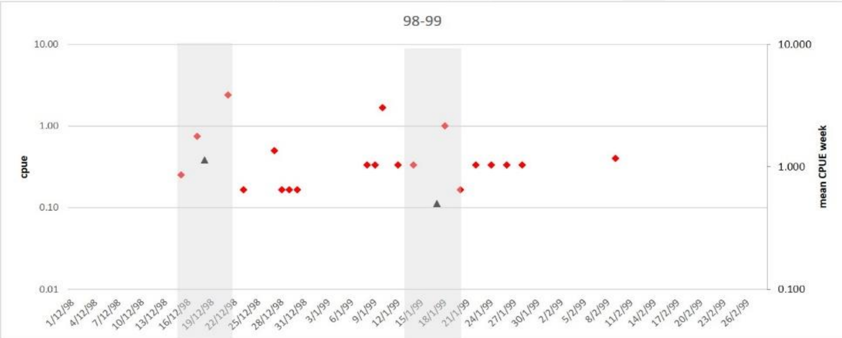
94-95
daily cpues
mean CPUE week
10.00
1.00
0.10
0.01
10.000
1.000
0.100

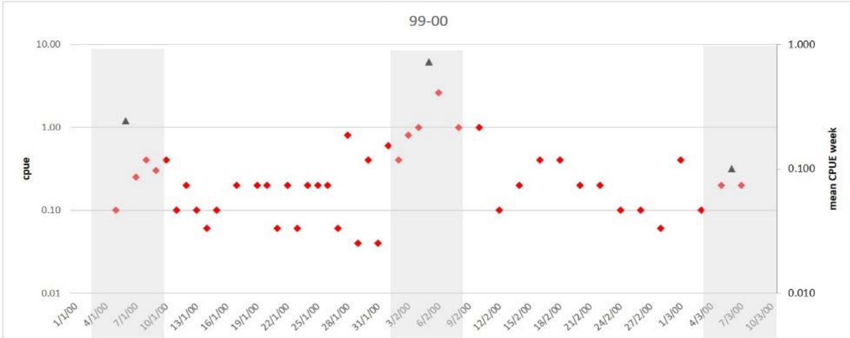


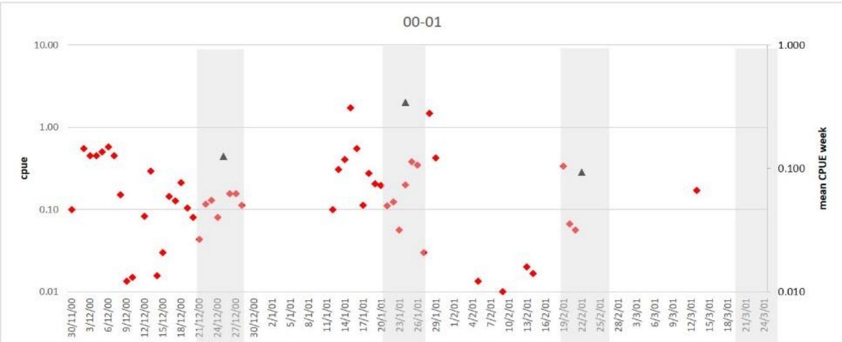
95-96
daily cpues
mean CPUE week
10.00
1.00
0.10
0.01
10.000
1.000
0.100

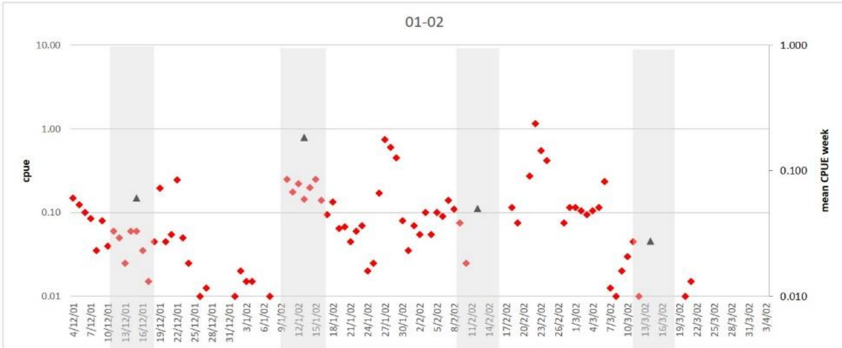

96-97
cpue
mean CPUE week


97-98
cpue
mean CPUE week


98-99
cpue
mean CPUE week


99-00
cpue
mean CPUE week


00-01
cpue
mean CPUE week


01-02
cpue
mean CPUE week

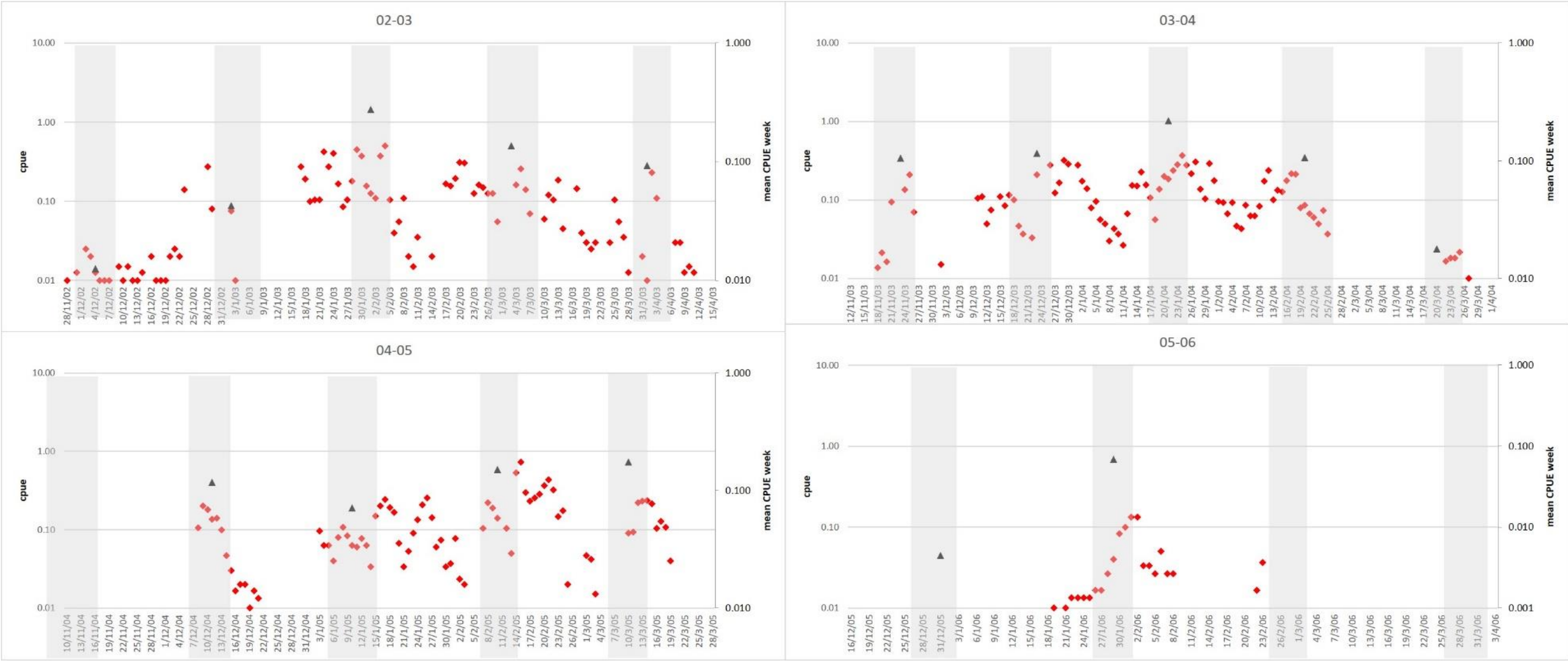


Figure 5.14. Recruitment index trends, 1990–2006. Daily CPUE (red dots, kg/net/day, logarithmic scale) and mean weekly CPUE (black triangles, kg/net/seven days, logarithmic scale), including three days before and after the dark period for the moon, indicated by a grey band in the graphs.

5.3.5 Short term trends in recruitment: seasonality

The data gathered from three information sources (fisheries and monitoring data from WP3 database and from literature) were used to infer the seasonal pattern of glass eel recruitment in the Mediterranean. An overview of the presence and relative abundance of recruitment in each month from these data for 11 countries is presented in Table 5.7, with respect to single sites and habitat typology, along with data sources and years when data was collected. Where possible, if the paper or the monitoring activity reported information on pigmentation and size, relative monthly abundances were split per recruit stage (glass eel/pigmented glass eel/elver and bootlace). When the information was not available, abundances refer generically to “glass eel”. Relative abundances were allotted to recruitment seasons, running from October in the previous year to September in the year that is recorded in the table.

Table 5.7. Seasonal appearance of glass eel at sites on the Mediterranean coastline. Empty cell = no monitoring; 0 = no catch; x = ≤ 25% of the total occurrence; xx = <50%; xxx = < 75%; xxxx ≤ 100%, peak of presence; P= presence, anectodal. Data for year from October in previous year to September in the year recorded. In the case of several years monitoring at a site, data have been averaged per month. Data available before and after the eel regulation implementation are reported separately. Habitat: CMW= coastal marine water, LGN = lagoon, RIE = river estuary, RIV = river. CHL = Channel with pumping station. Source and type: SL = Scientific literature, M = monitoring, O = observation, FB = fishery based, C = collection, NR = not recorded. Stage: G = glass eel; E = elver; B = bootlace; NR = eel stage not reported

Country	**Habitat**	**Site**	**Source**	**Type**	**Year**	**Stage**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**Reference**
Morocco	CMW	Rabat-Kenitra	SL	NR	1980	G/E								P	P	P			Yahyaoui, Aguesse and Beaubrun,1983
Morocco	RIE	Moulouya/MED	SL	M	1983	G	xxx	0	xx	0							xxx	xxxx	Yahyaoui 1988
Morocco	RIE	Moulouya/MED	SL	M	1983	E	x	xxx	xx	xxx									Yahyaoui 1988
Morocco	RIE	Moulouya/MED	SL	NR	1995	G/E											P	P	Yahahoui *et al*., 1996
Morocco	RIE	Sebou/ATL	SL	M	1982-83	E	xx	xx	xx	xx	xx								Yahyaoui 1988
Morocco	RIE	Sebou/ATL	SL	NR	1982-95	G									xx	xx	xx	xx	Yahyaoui 1988; Yahahoui *et al*., 1996
Spain	RIE	Guadalquivir/ATL	SL	M	2012	G/E	xxx	xxx	xxxx	xxxx	xx	x	x	x	x	xx	xxxx	xxxx	Arribas *et al*., 2012
Spain	RIE	Guadalquivir/ATL	SL	M	1997-2006	G	x	x	x	x	x	x	x	x	x	x	x	x	Arribas *et al*., 2012
Spain	RIE	Gros - Palma de Mallorca	SL	O	ND	G	P	P	P	P	P								D'Ancona, 1958
France	CHL	Arles-A-Fos	M	M	2014-20	G	xx	x	xx	x	x	x	x	x	x	x	x	x	WP3 DB (Nation. Monit.)
France	LGN	Vaccares	SL	M	2001	G	xxx	x	x	x	x						x	x	WP3 DB (MRM project, 2022)
France	LGN	Vaccares	M	M	2004-9	G	xx	xx	xx	x	0					x	x	x	WP3 DB (MRM project, 2022)

Country	Habitat	Site	Source	Type	Year	Stage	J	F	M	A	M	J	J	A	S	O	N	D	Reference
France	LGN	Vaccares	M	M	2010-20	G	x	xx	xx	x						x	x	x	WP3 DB (MRM project, 2022)
France	LGN	Bages Sigean	SL	M	1982/1983	G	x		x	0		x			x	x	x	x	Lecomte-Finiger, 1983
France	LGN	Bages Sigean	SL	M	1982/1983	E	0		x	x		0			0	0	0	0	Lecomte-Finiger, 1983
France	LGN	Bages Sigean	M	M	2019-21	G	xx	x	x	x	x	x	0	x	x	x	x	xx	WP3 DB (FLUX Project 2019, 2020, 2021)
France	RIE	Huveaune	SL	M	1940	G	P	P	P	P	P	P	P	P	P	P	P	P	Petit and Vilter, 1944
France	RIE	Rhone	SL	M	2004-5	G	x	xx	xx	x									Crivelli *et al*., 2008; Maes *et al*., 2009
France	RIE	Rhone	SL	M	2008-2020	G	x	x	x	x	x	x	x	x		x	x	x	Bouchard *et al*., in press.
France	LGN	Bages-Sigean	SL	M	1975	G	x	x	x	0	x	0	0	x	x	x	x	xx	Lecomte-Finiger, 1976
France	LGN	Sète -Thau	SL	M	1934-35	G	xx	xx	xx								x	xx	Gandolfi-Hornyold, 1931, 1936
Tunisia	CHL	Kalaat El Andalous	M	M	2007	G		xx	x	x	xx	x							WP3 DB (Nation. Monit.)
Tunisia	CMW	Tunis Gulf	SL	NR	1989	G/E	x	x	xxx	xx	xx	x	x	x	x	x	x	x	N/A
Tunisia	LGN	Ichkeul	M	M	2000-2007	G	xx	xx	xx	x	x	x	x	0					WP3 DB (Nation. Monit.)
Tunisia	LGN	Tinja	M	M	2004	G					x	x							WP3 DB (Nation. Monit.)
Tunisia	LGN	Tunis lake	SL	NR	1928	G/E	P	P	P	P	P	P							Heldt and Heldt 1928
Tunisia	LGN	Tunis lake	SL	NR	1929	G	xx	xx	xx	x	x	xx					0	0	Heldt and Heldt 1929a
Tunisia	LGN	Tunis lake	SL	NR	1929	E	0	0	xx	xx	xx	x							Heldt and Heldt 1929a
Tunisia	LGN	Tunis lake	SL	NR	1930	G/E	xx	xx	x										Heldt and Heldt 1930
Tunisia	LGN	Tunis lake	SL	M	1928-30	G	x	x	x	x	x	x	x						Heldt, 1929
Tunisia	RIE	Sidi Daoud	SL	NR	1930	G/E	x	x	xx	x	x	x							Heldt and Heldt 1929b

Country	Habitat	Site	Source	Type	Year	Stage	J	F	M	A	M	J	J	A	S	O	N	D	Reference
Italy	CHL	Maccarese	SL	C	1922-33	G	xx	x	x	0					0	x	x	xx	Chiappi, 1931, 1932, 1934, 1935
Italy	CMW	Livorno	SL	A	1912-23	G	P	P	P	P	P				P	P	P	P	Grassi, 1914
Italy	LGN	Calich	M	M	2018	G	xx	xx											WP3 DB (AGRIS – LAORE 2019)
Italy	LGN	Comacchio	SL	A	1940	G		P	P	P									D'Ancona 1940, 1958
Italy	LGN	Comacchio	M	M	2011	G	x	xx	xx	x									Lanzoni *et al*., 2022
Italy	LGN	Fogliano	SL	M	2013	E		xxx		x								x	Leone *et al*., 2016
Italy	LGN	Fogliano	SL	M	2013	B		x		xxx								x	Leone *et al*., 2016
Italy	LGN	Fogliano	M	M	2017	B	0	0	xxx									0	WP3 DB (ARSIAL 2021)
Italy	LGN	Fogliano	M	M	2013-19	G	xx	xx	x							x	x	xx	Leone *et al*., 2016; WP3 DB (ARSIAL 2021)
Italy	LGN	Fogliano	M	M	2017-19	E	xx	xx	x							0	0	x	WP3 DB (ARSIAL 2021)
Italy	LGN	Lesina	SL	A	1914	G										P	P	P	D'Ancona, 1958
Italy	LGN	Lesina	SL	M	1980	G	x	x	x	x	xx	xx							Villani, Pesaro and Gandolfi, 1981
Italy	LGN	Lesina	SL	M	1980	E	0	0	0	x	xx	xx	x						Villani, Pesaro and Gandolfi, 1981
Italy	LGN	Lesina	SL	M	1980	B	0	x	0	0	0	xx	x						Villani, Pesaro and Gandolfi, 1981
Italy	LGN	Lesina	M	M	2014-19	G	x	xxx	0							x	xx	xx	WP3 DB (Nation. Monit.)
Italy	LGN	Orbetello	M	M	2020-21	G										0	0	xxx	WP3 DB (UNIMAR, 2019, 2020, 2021)
Italy	LGN	Varano	SL	A	1914	G										P	P	P	D'Ancona, 1958
Italy	LGN	Varano	M	M	2014-15	G	xx	xxx	0							0	0	0	WP3 DB (Nation. Monit.)

Country	Habitat	Site	Source	Type	Year	Stage	J	F	M	A	M	J	J	A	S	O	N	D	Reference
Italy	LGN	Venezia	SL	A	1890	G		P	P										Bullo, 1891
Italy	LGN	Venezia	SL	A	1940	G				P	P								D'Ancona 1940, 1958
Italy	RIE	Arno	SL	M	1979	G	x	xx	xx	x	x						x		Gandolfi *et al*., 1979
Italy	RIE	Arno	SL	M	1979	E	x	x	xx	x	xx	x	x	0			x		Gandolfi *et al*., 1979
Italy	RIE	Arno	SL	A	1912-14	G	P	P	P	P							P	P	Grassi, 1914
Italy	RIE	Coghinas	SL	M	1983-84	G		0	0	xx	x				0	0	x	xxx	Chessa *et al*., 1985
Italy	RIE	Coghinas	SL	M	1983-84	E		x	x	xxx	xx	x	x		x	x	x		Chessa *et al*., 1985
Italy	RIE	Coghinas	M	M	2018-19	G	x	xxx	x	x						x	x	x	WP3 DB (AGRIS - LAORE, 2019)
Italy	RIE	Flumendosa	M	M	2018	G			x	x	x						x	x	WP3 DB (AGRIS - LAORE, 2019)
Italy	RIE	Po	SL	M	1979-80	G			xx	xx	xx	0							Villani, Pesaro and Gandolfi, 1981
Italy	RIE	Po	SL	M	1979-80	E			x	x	xx	xxx							Villani, Pesaro and Gandolfi, 1981
Italy	RIE	Po	SL	M	1979-80	B			x	x	xx	xx							Villani, Pesaro and Gandolfi, 1981
Italy	RIE	Pramaera	SL	M	2017-18	E	x	x	x	x	xx	xx	0	x	xx	xx			Podda *et al*., 2020
Italy	RIE	Pramaera	M	M	2017-19	G	xx	xx	x	x	x	x	x	x	x	x	x	xx	Podda *et al*., 2020
Italy	RIE	Reale-Torre Guaceto	M	M	2014-15	G	xxx	xx	x							0	0	x	WP3 DB (Nation. Monit.)
Italy	RIE	Tevere	SL	FB	1920	G/E	xxx	xx	xxx	0					0	0	x	xxx	Chiappi, 1931
Italy	RIE	Tevere	M	M	1991-05	G	xx	xx	x	x							x	x	Ciccotti *et al*., 1995
Italy	RIE	Tevere	M	M	2014-19	G	xx	x	x							x	x	xx	ARSIAL, 2013, 2014, 2015, 2018, 2021

Country	Habitat	Site	Source	Type	Year	Stage	J	F	M	A	M	J	J	A	S	O	N	D	Reference
Italy	RIV	Albegna	M	FB	2012-13	G	xxxx											x	ARPAT, 2014
Italy	RIV	Arno	M	FB	2013-14	G	xx	xxx	xx										ARPAT, 2014
Italy	RIV	Bruna	M	FB	2012-13	G	xxxx											x	ARPAT, 2014
Italy	RIV	Burlavacca	M	FB	2013	G	0	xxxx										0	ARPAT, 2014
Italy	RIV	Garigliano	M	M	2018-19	G	xx	xx								x	x	xxx	UNIMAR, 2019, 2020, 2021
Italy	RIV	Marta	M	M	2000-05	G	xx	x	x	0							x	xx	WP3 DB (Nation. Monit.)
Italy	RIV	Marta	M.	M	2014-20	G	xx	x	0							0	xx	xx	ARSIAL, 2013, 2014, 2015, 2018, 2021
Italy	RIV	Morelli	M	M	2014-15	G	xx	x	x							0	x	x	WP3 DB (Nation. Monit.)
Italy	RIV	Ombrone	M	FB	2012-14	G	xxx											xx	WP3 DB (ARPAT, 2014)
Italy	RIV	Po di Goro	M	M	2020-21	G	xx	xxx									0	0	UNIMAR, 2019, 2020, 2021
Italy	RIV	Po di Volano	M	M	2020-21	G	xx	xxx									0	0	UNIMAR, 2019, 2020, 2021
Italy	RIV	Scolmatore	M	FB	2013-14	G	xx	xx	xxx									0	WP3 DB (ARPAT, 2014)
Croatia	LGN	Vrana	SL	O	1900	G			p										Strubberg, 1913
Montenegro	RIE	Bojana	SL	M	2005	G		xxx	xxx	xxxx	x								Hegediš *et al*., 2005
Libya	LGN	Umm Hufayan	SL	M	2018	B				x	xxxx	xxxx	xxxx	x	x				Abdalhamid *et al*., 2018
Greece	CMW	Eleusis	SL	O	1936-37	G	x	xxx	x	x	0	0	0			0	0	x	Athanassopoulos, 1936
Greece	CMW	Eleusis	SL	O	1936-37	E	x	x	xxxx	x	0	0	0			0	0	0	Athanassopoulos, 1936
Greece	CMW	Eleusis	SL	O	1936-37	B	0	0	xx	x	xxx	x	x			x	x	x	Athanassopoulos, 1936
Greece	RIE	Alfeios	SL	M	1999-00	G	xx	xxx	xxx	xx						0	0	x	Zompola *et al*., 2008
Greece	RIE	Alfios	SL	M	2008	G/E	xx	xxxx	xxx	x						0	0	xx	Zompola *et al*., 2008
Greece	RIE	Salgiada	SL	M	1999-00	G	xxx	xxx	xx	x						0	x	xxxx	Zompola *et al*., 2008

Country	Habitat	Site	Source	Type	Year	Stage	J	F	M	A	M	J	J	A	S	O	N	D	Reference
Greece	RIE	Salgiada	SL	M	2008	G/E	xxx	xxx	xx	0						x	xx	xxxx	Zompola *et al*., 2008
Egypt	CHL	Abukir - Tolombat	SL	C	1927	G/E												xx	Wimpenny, 1929
Egypt	CHL	Abukir - Tolombat	SL	C	1928-29	G	xxx	xx	xxx	xxx	xx	x					x	x	Wimpenny, 1929
Egypt	CHL	Abukir - Tolombat	SL	C	1928-29	E	x	x	x	xx	xx								Wimpenny, 1929
Egypt	CHL	Al Max	SL	C	1927	G/E												xx	Wimpenny, 1929
Egypt	CHL	Al Max	SL	C	1919-22	E				xx	xx	xx							Paget, 1923; Schmidt, 1923
Egypt	CHL	Al Max	SL	C	1919-23	G	x	xx	x	xxx	x	xx				x	x	x	Paget, 1923
Egypt	CHL	Al Max	SL	C	1928-29	G	xxx	xxx	xxx	x								x	Wimpenny, 1929
Egypt	CHL	Al Max	SL	C	1928-29	E	x	x	x	xx								xx	Wimpenny, 1929
Egypt	CHL	Al Max	SL	M	1971-73	G/E/ B		x	x	xx	xx	x							Ezzat and El Serafy, 1977
Egypt	CHL	Al Max	SL	M	1972-73	G		x	x	xx	xx	x							Ezzat and El Serafy, 1977
Egypt	CHL	Al Max	SL	M	1972-73	E		0	x	xx	xx	x							Ezzat and El Serafy, 1977
Egypt	CHL	Al Max	SL	M	1972-73	B		0	x	x	xx	xxx							Ezzat and El Serafy, 1977
Egypt	CHL	Manzala-Gabouti	SL	C	1928-29	G	x	x	x	xx								x	Wimpenny, 1929
Egypt	CHL	Manzala-Gabouti	SL	C	1928-29	E	x	xx	xx	x								x	Wimpenny, 1929
Egypt	LGN	Burullus	SL	FB	2015	E/B					P								El Nabi, El Desoky and Mohammed-Geba, 2017
Egypt	RIE	Rosetta-Nile	SL	FB	2015	E/B					P								El Nabi, El Desoky and Mohammed-Geba, 2017

Country	Habitat	Site	Source	Type	Year	Stage	J	F	M	A	M	J	J	A	S	O	N	D	Reference
Türkiye	RIE	Dalaman - Aegean	SL	M	1996	NR			P	P	P	P							Geldiay and Balõk, 1996; Küçük, Gümüş and Gülle, 2005
Türkiye	RIE	Gediz - Aegean	SL	M	1996	NR			P	P	P	P							Geldiay and Balõk, 1996; Küçük, Gümüş and Gülle, 2005
Türkiye	RIE	Aksu - Antalya	SL	M	1998	G			x	xx	x								Geldiay and Balõk, 1996; Ikiz *et al*., 1998; Küçük, Gümüş and Gülle, 2005
Türkiye	RIE	Aksu - Antalya	SL	M	1998	E			x	xx	xxx	xx							Geldiay and Balõk, 1996; Ikiz *et al*., 1998; Küçük, Gümüş and Gülle, 2005
Türkiye	RIE	Aksu - Antalya	SL	M	1998	B						x							Geldiay and Balõk, 1996; Ikiz *et al*., 1998; Küçük, Gümüş and Gülle, 2005
Türkiye	RIE	Alara - Antalya	SL	M	1998	G			x	xx	x								Geldiay and Balõk, 1996; Ikiz *et al*., 1998; Küçük, Gümüş and Gülle, 2005
Türkiye	RIE	Alara - Antalya	SL	M	1998	E			x	xx	xxx	xx							Geldiay and Balõk, 1996; Ikiz *et al*., 1998; Küçük, Gümüş and Gülle, 2005
Türkiye	RIE	Alara - Antalya	SL	M	1998	B						x							Geldiay and Balõk, 1996; Ikiz *et al*., 1998; Küçük, Gümüş and Gülle, 2005
Türkiye	RIE	Asi- Antalya	SL	M	1998	G			x	xx	x								Geldiay and Balõk, 1996; Ikiz *et al*., 1998; Küçük, Gümüş and Gülle, 2005
Türkiye	RIE	Asi- Antalya	SL	M	1998	E			x	xx	xxx	xx							Geldiay and Balõk, 1996; Ikiz *et al*., 1998; Küçük, Gümüş and Gülle, 2005

Country	Habitat	Site	Source	Type	Year	Stage	J	F	M	A	M	J	J	A	S	O	N	D	Reference
Türkiye	RIE	Asi- Antalya	SL	M	1998	B						x							Geldiay and Balõk, 1996; Ikiz *et al*., 1998; Küçük, Gümüş and Gülle, 2005
Türkiye	RIE	Büyük Menderes	SL	M	1996	NR			P	P	P	P							Geldiay and Balõk, 1996; Küçük, Gümüş and Gülle, 2005
Türkiye	RIE	Eşen	SL	M	1996	NR			P	P	P								Geldiay and Balõk, 1996; Küçük, Gümüş and Gülle, 2005
Türkiye	RIE	Fethiye-Karadere	SL	FB	1989-90	G					X								Özdilek, 2016
Türkiye	RIE	Gozlen	SL	M	1998-99	G		0	x	xx	xx	x	x						Küçük, Gümüş and Gülle, 2005
Türkiye	RIE	Gozlen	SL	M	1998-99	E		0	x	xx	xx	x	x						Küçük, Gümüş and Gülle, 2005
Türkiye	RIE	Gozlen	SL	M	1998-99	B		0	x	x	xx	x	x						Küçük, Gümüş and Gülle, 2005
Türkiye	RIE	Köprüçay - Antalya	SL	M	1998	G			x	xx	x								Geldiay and Balõk, 1996; Ikiz *et al*., 1998; Küçük, Gümüş and Gülle, 2005
Türkiye	RIE	Köprüçay - Antalya	SL	M	1998	E			x	xx	xxx	xx							Geldiay and Balõk, 1996; Ikiz *et al*., 1998; Küçük, Gümüş and Gülle, 2005
Türkiye	RIE	Köprüçay - Antalya	SL	M	1998	B						x							Geldiay and Balõk, 1996; Ikiz *et al*., 1998; Küçük, Gümüş and Gülle, 2005
Türkiye	RIE	Kucuk Menderes - Aegean	SL	M	1996	NR			P	P	P	P							Geldiay and Balõk, 1996; Küçük, Gümüş and Gülle, 2005

Country	Habitat	Site	Source	Type	Year	Stage	J	F	M	A	M	J	J	A	S	O	N	D	Reference
Türkiye	RIE	Manavgat-Antalya	SL	M	1998	G			x	xx	x								Geldiay and Balõk, 1996; Ikiz *et al*., 1998; Küçük, Gümüş and Gülle, 2005
Türkiye	RIE	Manavgat-Antalya	SL	M	1998	E			x	xx	xxx	xx							Geldiay and Balõk, 1996; Ikiz *et al*., 1998; Küçük, Gümüş and Gülle, 2005
Türkiye	RIE	Manavgat-Antalya	SL	M	1998	B						x							Geldiay and Balõk, 1996; Ikiz *et al*., 1998; Küçük, Gümüş and Gülle, 2005
Türkiye	RIE	Meriç	SL	M	1996	NR			P	P	P	P							Geldiay and Balõk, 1996; Küçük, Gümüş and Gülle, 2005

The data in Table 5.7 suggests that there are differences in the seasonality of recruitment between different parts of the Mediterranean region. While recruits are present all year round in some sites, albeit with very low abundance in the summer months, there is a definite pattern of seasonal migration of glass eels, that represents the true recruitment. The main peaks occur in the winter months (December-March), but a second minor peak can occur in May-June (Figure 5.15). The distribution of elvers over the months follows a similar pattern, with a peak in January, and an earlier peak at the start of the season, but the most evident peak of abundance is in April and May. Meanwhile, bootlace eels (9-10 cm) are present from March onwards.

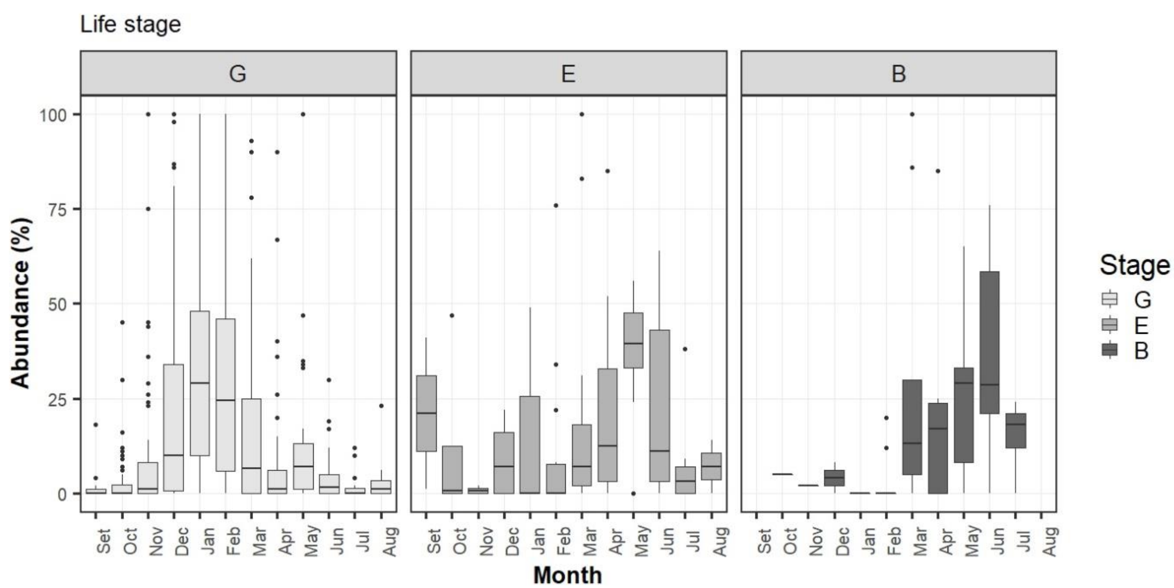


Figure 5.15. Monthly relative abundance (percent) for glass eels (G), elvers (E) and bootlace eels (B) across all sites and countries.

Considering the seasonal pattern in different habitats (Figure 5.16a-c), in river estuaries, the peak is in winter, based on data from Italy, and in coastal waters the peak is towards late winter (March), based mainly on data from Greece (Eleusis Gulf). Recruitment seasonality on CHL channel stations is based essentially on data from the two pumping stations in Italy (early 1900s) and Egypt (1920s and 1970s), both referring to glass eels, and there is an obvious difference in the seasonal main peak between them. Two seasonal peaks are evident in lagoons and estuaries, for which higher numbers of observations are available, from many countries. This observation might be due to the presence of advanced stages in the late season when all years and all stages are considered together.

Therefore, the overall relative abundance over the months, clearly shows how the actual recruitment of transparent glass eels, coincides with the winter months, and precedes the recruitment of pigmented glass eel and the recruitment of small bootlace eels in the colonization phase.

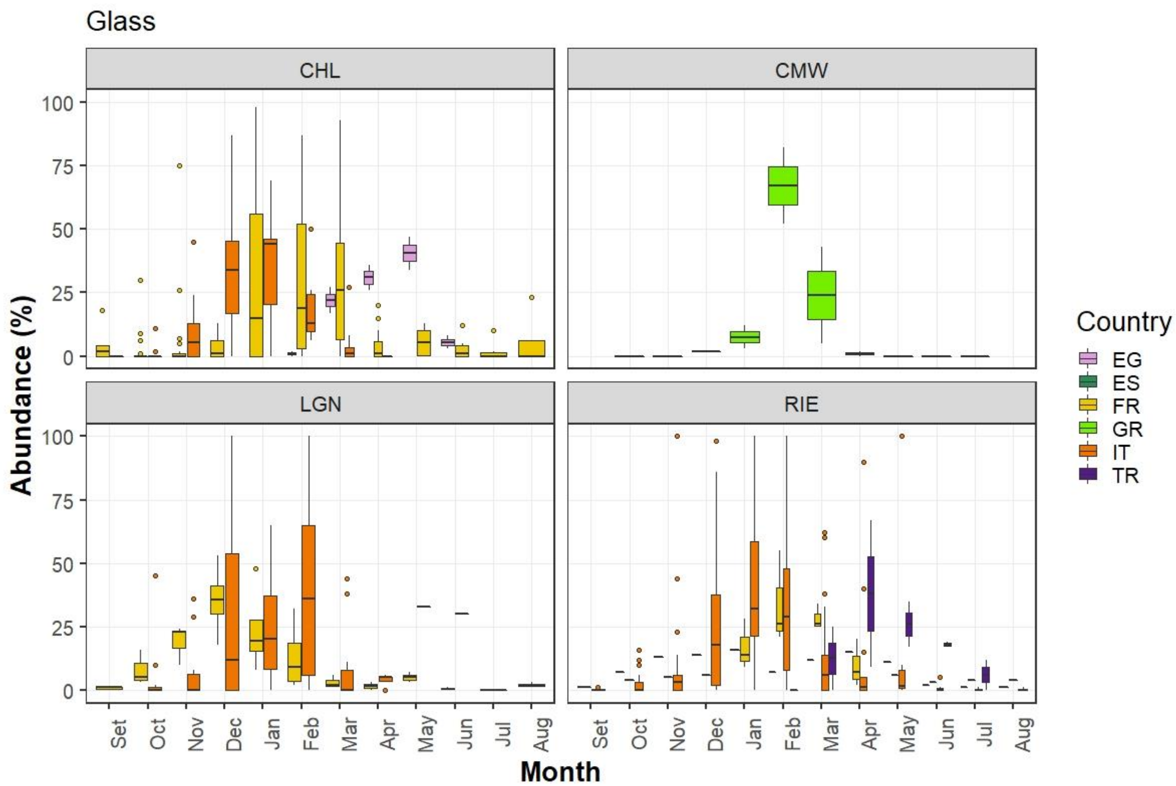


Figure 5.16a Monthly relative abundance (percent) of glass eels by habitat (CMW= coastal marine water, LGN = lagoon, RIE = river estuary, CHL = Channel with pumping station) and country (EG = Egypt, ES = Spain, FR = France. GR = Greece, IT = Italy, TR = Türkiye).

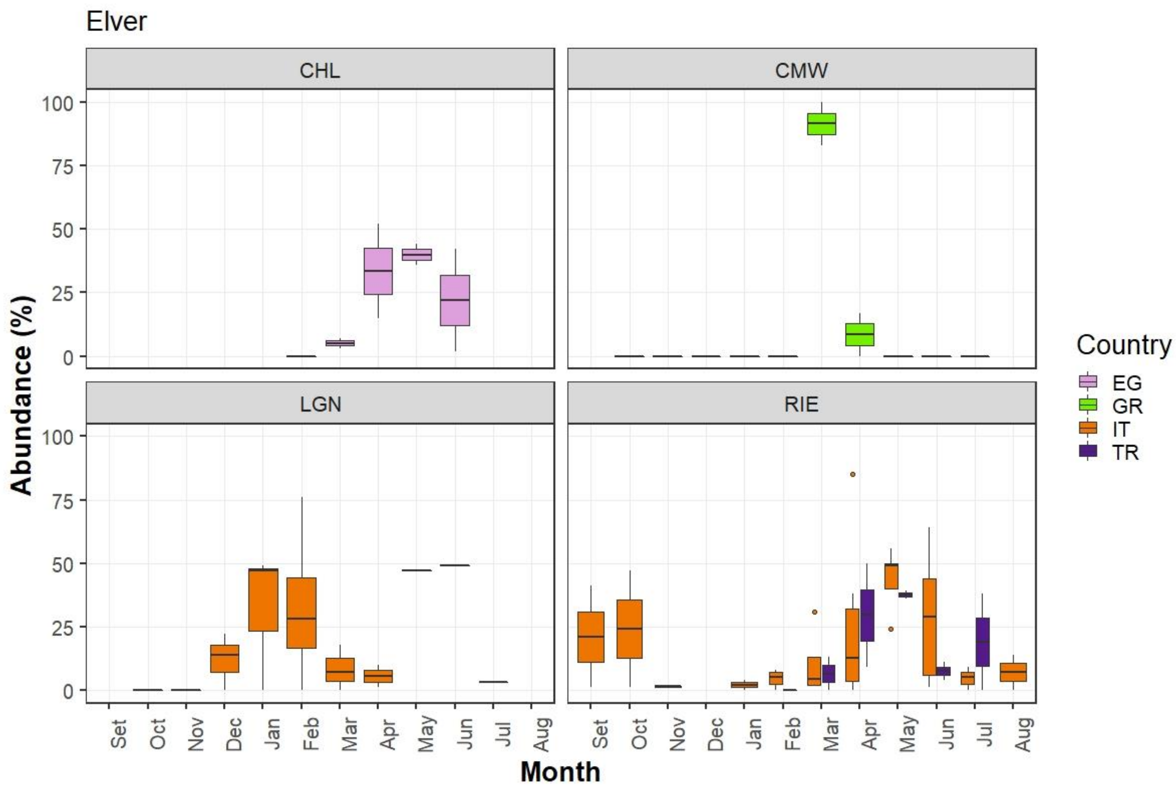


Figure 5.16b. Monthly relative abundance (percent) of elvers by habitat (CMW= coastal marine water, LGN = lagoon, RIE = river estuary, CHL = Channel with pumping station) and country (EG = Egypt, GR = Greece, IT = Italy, TR = Türkiye)

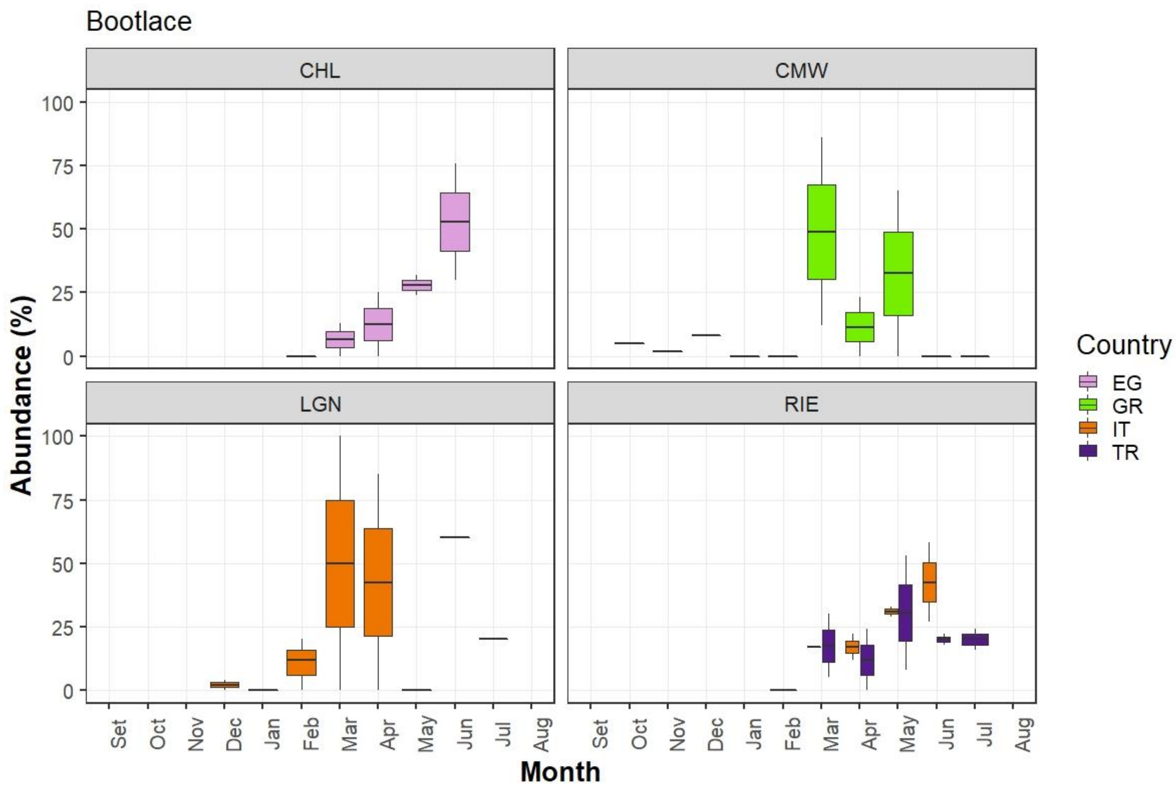


Figure 5.16c. Monthly relative abundance (percent) of bootlace eels by habitat (CMW= coastal marine water, LGN = lagoon, RIE = river estuary, CHL = Channel with pumping station) and country (EG = Egypt, GR = Greece, IT = Italy, TR = Türkiye)

These dynamics of recruitment are also clear when focusing on specific sites for which exhaustive data are available related to life stage composition (Figure 5.17).

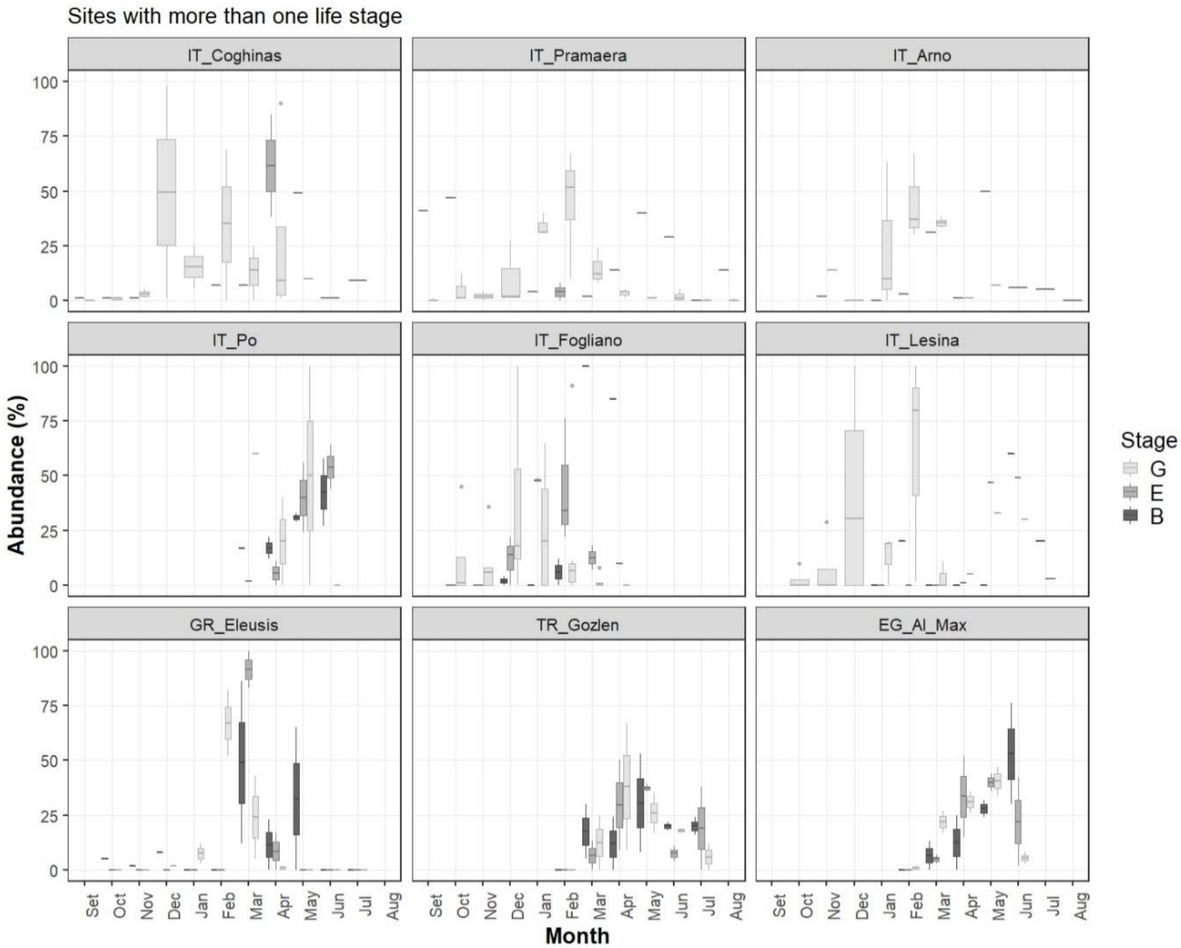


Figure 5.17. Monthly relative abundance (percent) at specific sites for which exhaustive data of recruitment dynamics for each life stage (G = glass eel, E = elver, B = bootlace eel) are available.

Checks were made to determine whether there was evidence of seasonal trends in recruitment patterns across the whole time period for which data were available, that is, pre-1950 historic data, pre-1980, before stock declines (Dekker, 2002; ICES, 2001) and after the implementation of the eel regulation in 2007 (European Union, 2007). Monthly abundance data were too scattered, particularly for the pre-1950 period and covered only a few years for many sites. Therefore, comparisons can only be made for a few sites, two in France (Rhone and Vaccares) and two in Italy (the mouth of the river Marta and the Tevere estuary) comparing seasonal trends in glass eel peaks of abundance in the 1980–2009 period and after 2009 (Figure 5.18). In the two French sites and in the river Marta, there is evidence of a shift towards the peak of migration occurring later in the season. On the other hand, on the Tevere, the reverse seems to occurred, with the main peak of abundance moving from January to December.

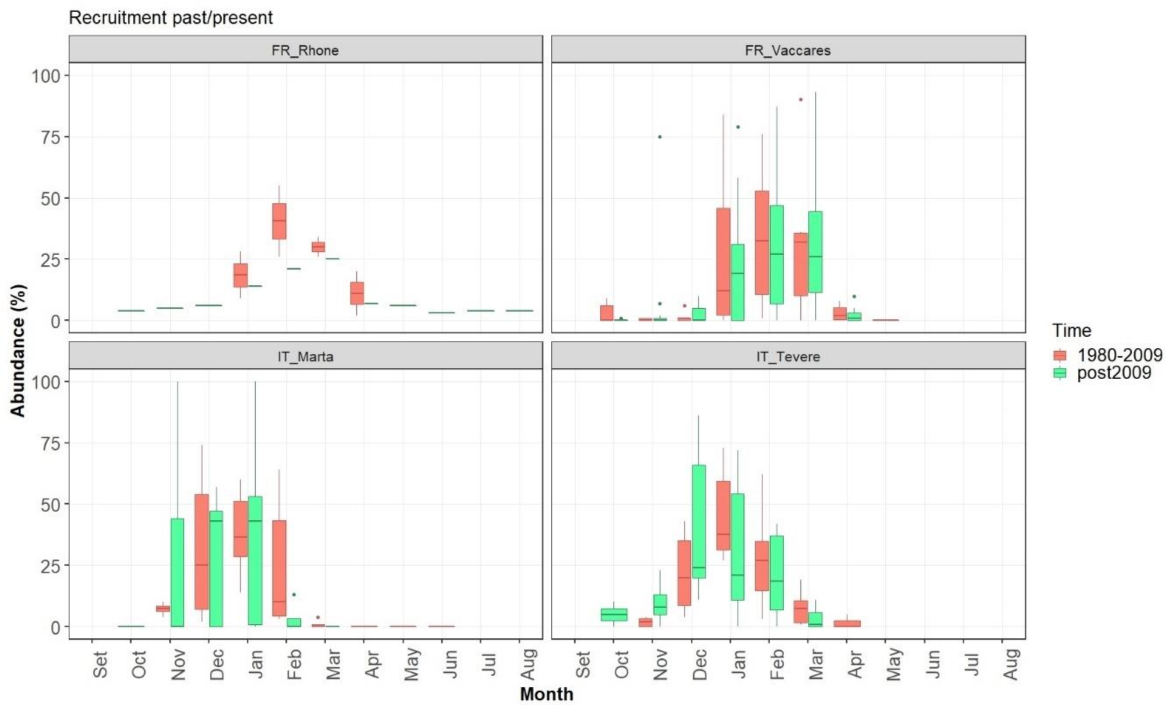


Figure 5.18. Monthly abundance (percent) of eel recruits in specific sites (Rhone, Vaccares, Marta and Tevere), before (1980–2009) and after implementation of the 2007 eel regulation.

5.4. DISCUSSION AND CONCLUSIONS

A comprehensive description of recruitment in the Mediterranean was built for the first time, based on past and present information and an exhaustive search of available data. Recruitment was documented at 79 sites across the Mediterranean, with all transitional eel habitats being included. The north-western part of the Mediterranean region is where most information is available, both for past and recent times, as well as in relation to the presence of fisheries that developed in this area during the 1970s and 1980s when eels were relatively abundant. For the eastern and southern parts of the Mediterranean, recruitment has been documented in many sites, but abundance was relatively low before the recruitment decline, so data such as time-series for catches or sampling are not present.

In the north-western Mediterranean, there were high levels of recruitment across most of the twentieth century, including the period before the 1950s and through the 1980s, when most glass eel fisheries developed. There were consistent declines in abundance in the 1990s, that took place at the same time in most parts of the region, with the lowest levels of recruitment occurring in the early 2010s. Some signs of recovery were observed, at some sites, around 2015 but these were not sustained. Current recruitment levels are considered to be at their lowest and the overall trend seems consistent with the trend observed across Europe in the Atlantic and in the North Sea.

A distinctly seasonal recruitment pattern has been described, that is generally consistent with the seasonal pattern described for the overall distribution area of European eel. Some specific seasonal patterns of recruitment are found in different parts of the Mediterranean region, but environmental features of sites also influence glass eel behaviour and further define both intra-seasonal migration dynamics and seasonal abundance.

The data collected within this task have been used to build a general descriptive analysis of recruitment, but this data set offers opportunities for further analysis. Time constraints prevented further exploration of other aspects of recruitment, such as the influence of local-level environmental factors on the intra-seasonal dynamics of recruitment and the consequent differences between sites. Nevertheless, these aspects will be investigated as soon as possible. Other potential issues include the analysis of time trends in the Mediterranean compared to recruitment trends observed in the rest of Europe, as new time-series are now available for the Mediterranean. These new datasets from the Mediterranean could also make it possible to further explore the estimation of annual absolute glass eel recruitment at the Mediterranean spatial scale by appropriate models such as GEREM (Drouineau *et al*., 2016). The previous application of Bornarel *et al*. (2018), to the ecoregion corresponding to the Western Mediterranean Sea yielded results that were not completely consistent with the recruitment index trend evaluated for 'Elsewhere in Europe' in the decades 1990–2010. Integration of the data-set could produce new, more reliable, results, particularly as it was highlighted by the authors that better modelling results required the use of a larger number of time-series and possibly over longer time scales.

Nevertheless, from the management perspective, these results affirm that the glass eel stage of the eel life cycle requires full protection in the Mediterranean. Specific measures are needed to guarantee migration and colonization of all habitats. Many countries are already protecting recruitment with total glass eel fisheries bans (see Chapter 13 WP1), while others have implemented fishing closure periods. However, at present these do not seem to be fully consistent with established seasonal patterns of recruitment.

With such low recruitment levels, it does not seem to be justified to carry out any type of fishing activity for glass eels in the Mediterranean, for any use, including for restocking. The catch trends over time, the definitive ending of some fisheries and minimum catch records observed in others, highlight the possibility that demand from internal or local markets might provide sufficient incentive to increase fishing effort in those areas where glass eels are still being fished, even for very low catches. However, the results support a fisheries management option aimed at reducing all glass eel fishing mortalities to zero, and the implementation of local management measures aimed at protecting current recruitment levels by mitigating all potential impacts at this stage.

There is the need to continue monitoring or establish monitoring across a network of key sites to track long term recruitment trends in the Mediterranean area. This network needs to include all eel habitats, covering the different geographical areas of the Mediterranean. Key sites can be identified based on the results of this comprehensive analysis, implementing fishery-independent monitoring methods in programmes with time-schedules that take into account specific environmental factors and seasonality patterns of the sites.

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Supplementary Material on the Methodology – ReadMe spreadsheet for the WP3 database relative to eel recruitment, including the list of variables and relative information for compilation

Table 5SM.1. Metadata spreadsheet

Country	
Scientific Partners (senior + junior)	
Contact person name	
Ownership, point of contact of original data	Reference to the data collection
Contact person name	
Programme/Regulation/Official Stats.	
Methods used	A brief description of the data collection and processing methods: eg. declarations, logbooks and interview (census or estimation of total captures from subsamples)
Data Quality Overview	Quality check on the data, both in terms of how the data were gathered and subsequently treated
WP3 Database description	Brief description of content of datasets
Nature of the data with respect to the original data scope	Raw, aggregated or analysed
Data processing procedures	Brief description of the data processing procedures: report on corrections, editing or quality control procedures applied to the data to suit the WP3 Database
Expert Judgment	
Data coverage with respect to the original data scope	Percent
Estimate of final uncertainty in the data	1 - low, 2- medium, 3 - high if medium or high add "underestimation" or "overestimation"
Any comments	

Table 5SM.2. Readme spreadsheet for glass eel captures, fishing effort and market

SITE INFORMATION	CODE	EXPLANATION	UNITS	TYPE OF UNITS	NOTES
Country	**Country_fullname**	Full name of your Country		Character	
Country code	**Country_code**	Two letter code of your Country		Character	
Region	**Region**			Character	
EMU	**EMU_nameshort**	See ***EMU*** codes in the *General INFO* spreadsheet		Character	
Habitat	**Habitat_code**	See ***HABITAT*** codes in the *General INFO* spreadsheet		Character	
Site	**Site_name**	The name you give to your site - add successive rows for different sites		Character	
Year	**Year**	Four digits (YYYY) - add successive rows for different years		Number	
Info source	**Info_source**	Origin of the data collected: EU project (e.g. DCF [Reg. 199/2008], EU-MAP [Decision EU 2016/1251], etc.), national/regional/local project, other project (e.g. LIFE, Interreg, etc.), scientific papers, grey literature, data dependent on fishery, other data (specify)		Character	
GLASS EEL FISHERY	**CODE**	**EXPLANATION**	**UNITS**	**TYPE OF UNITS**	**NOTES**
Captures	**Catches_glass**	Total kilograms of glass eels caught per year	kg	Number	
Quantity per restocking	**Quant_restock**	Percentage of glass eels **(on the annual total catches)** allocated to restocking	%	Number	
Quantity per aquaculture	**Quant_aquac**	Percentage of glass eels **(on the annual total catches)** allocated to aquaculture	%	Number	
Quantity per trade	**Quant_trade**	Percentage of glass eels **(on the annual total catches)** destined to trade (local market, catering, export, etc.)	%	Number	

FISHING EFFORT	CODE	EXPLANATION	UNITS	TYPE OF UNITS	NOTES

Fishing gear	**Gear_type**	See ***FISHING GEAR*** codes in the *General INFO* spreadsheet	Character	
Mean number of gears per day per fisherman	**Gear_day_fisherman**	Mean number of gears per day per fisherman	Number	
Maximum number of authorized fishermen (potential capacity)	**Potential_capacity**	Number of fishers with fishing rights or licenses, or number of licenses, or number of authorizations released per year	Number	
Potential capacity parameter	**Fishermen_parameter**	Specify the parameter collected in the potential capacity field: number of fishers with fishing rights or licenses, number of licenses, or number of authorizations released	Character	
Months in the fishing period	**Fishing_months**	Number of months in the authorized fishing period	Number	
Number of effective fishing days	**Fishing_days**	Number of effective fishing days, e.g. consider weather conditions or other causes that can limit the fishing activities	Number	*Include this information, when available, even when the fisher goes just to inspect and specify it in the "notes" field. Then, describe in detail the type of fishing gear/method used with all the information available in the word qualitative questionnaire*

Number of fishing hours per day	**Fishing_hours_day**	Number of fishing hours per fishing day (when available)		Number	

GLASS EEL ILLEGAL UNREGULATED UNREPORTED	CODE	EXPLANATION	UNITS	TYPE OF UNITS	NOTES
Glass eels seized	**Glass_quant_IUU**	Quantity of glass eels annually seized from illegal fishery	kg	Number	
Type of violation	**Violation_type**	Single unauthorized fisher, single authorized fisher out of the competent fishing zone or off the authorized fishing period, unauthorized company, authorized company fishing out of the competent fishing zone or off the authorized fishing period		Character	
Destination	**Dest_IUU**	IUU destination of the seized glass eels: internal direct consumption, local market, catering, fish farming, stocking, export, other (specify), not traceable		Character	
Export to	**Export**	if export, specify to which country/route		Character	
Comments, notes and other data	**Notes**	Report here if your data are different from those specified in the database, if there is a particular situation in your country not described here, or any other information you think could be useful to be added to the database		Character	
Indication of data reliability	**Data reliability**	Judgment on the reliability of the data for each record: 1- if you are confident with your data; 2- if the reliability is medium; 3- if the data are not validated		Character	

CHAPTER 6. EEL LOCAL STOCK BIOLOGICAL FEATURES IN THE MEDITERRANEAN

ABSTRACT

The main tasks of this chapter are to provide an overview of the biological features of local stocks and the impacts of habitat type and environmental conditions on eel growth and to estimate growth parameters and natural mortality rates. The data used in this chapter were collected through consultation with all relevant institutions, administrations and agencies in the partner countries. Historical biometric data are incomplete, and the available data varies from country to country. The data considered in this study are from the year 2000 onwards. About 41.5 percent of the data comes from lagoons, 31.3 percent from rivers, 23.1 percent from estuaries and 4.1 percent from lakes. A separate biometric descriptive analysis was carried out for each life stage. The effects of the lagoons' latitudinal variability on the mean length of female and male silver eels showed that the average length of female silver eels increases with latitude ($r^2 = 0.528$, $P = 0.05$), while in males this relationship is absent ($r^2 = 0.155$, $P = 0.16$). Growth rates in females were inversely related to latitude ($r^2 = 0.472$, $P = 0.02$), while in male silver eels, latitude had a weak effect on growth rate ($r^2 = 0.026$, $P = 0.2$). The results showed that higher temperatures are accompanied by higher growth rates for silver eels. The growth rates of male and female silver eels were positively correlated to the trophic status of lagoons, according to phosphorus and chlorophyll concentrations. Eels from eastern Mediterranean lagoons were characterized by faster growth rates. The overall $L_{infinity}$ (L_∞) of the von Bertalanffy growth function was significantly higher for female silver eels (831.9 mm) than for males (506.1 mm), whereas parameter k (the growth coefficient) was significantly lower in females (0.117) than in males (0.317). Females were dominant and comprised 66.9 percent of the eels in lakes. In lagoons, the proportion of males to females was close to 1:1, while in rivers, males comprised 53.8 percent of the population. With regard to the seasonality of silver eel escapement, although migration occurs year-round, certain locations show a distinctly seasonal pattern of migration, with a main peak in the autumn and early winter months (October–February) and a second peak centred in March also recorded. These results might be helpful for designing more efficient eel conservation management strategies in the Mediterranean.

HIGHLIGHTS

- All life history parameters analyzed showed comparable values to those recorded in previous studies conducted in the Mediterranean region.
- A comprehensive review of eel local stocks in the Mediterranean was performed for the first time, integrating literature data with recent monitoring and research results.
- The overall picture highlights differences in growth rates and sex ratios between habitat types; for lagoons, where data coverage for local eel stocks was wider, differences related to latitude, temperature and trophic status were also found.
- The data gathered for this task provided essential information that was used for the assessment in work package (WP) 4.

Future needs

- Collect biological variables for local eel stocks across the Mediterranean on a continuous basis.
- Encourage countries to dedicate further research on eel populations in southern and eastern Mediterranean countries, including north African countries.

6.1. INTRODUCTION

There is widespread consensus that the European eel, *Anguilla anguilla* (Linnaeus, 1758) is currently critically endangered (Moriarty and Dekker, 1997; EIFAC/ICES, 2003). The European eel stock is at a historical minimum, as is recruitment. For more than half a century, stock abundance and fishing yields have declined by about 5 percent annually, down to less than 10 percent of their historical levels (Dekker, 2003a, 2004a, 2019). From 1980 to 2010, recruitment of young eels (glass eels) from the ocean towards the continent dropped consistently by approximately 15 percent per year, down to between 1 and 10 percent of former levels (Dekker, 2000a; ICES, 2018; Moriarty, 1990). The causes of these downward trends are not clear, and consequently, remedies and mitigation measures are hard to design (Dekker, 2016, 2019). Therefore, the establishment of sustainable exploitation tactics and active conservation policies are critical for the global conservation of European eel and other *Anguilla* species (Dekker *et al.*, 2003).

Despite the concern of the scientific community over the fate of European eel, present knowledge of the stock status is based chiefly on indirect measurements, such as total harvests or catch per unit effort. The species was listed in Appendix II of the CITES Convention in 2007, and the International Union for the Conservation of Nature (IUCN) classified it in the Red List as "Critically Endangered" in 2008 (Pike, Crook and Gollock, 2020) (see Introduction). Measures are suggested for the sustainable use of the declining eel stock by European Council (EC) Regulation Nº 1100/2007, as well as by recommendations from international organizations such as the International Council for the Exploration of the Sea (ICES), the European Inland Fisheries and Aquaculture Advisory Commission (EIFAAC) and the General Fisheries Commission for the Mediterranean (GFCM) (Amilhat *et al.*, 2019; Hanel *et al.*, 2019).

Estimating demographic characteristics and identifying the mechanisms that control them may help to predict the future dynamics of the eel population in the face of environmental changes and anthropogenic pressures (Boulenger *et al.*, 2014). Eel life-history traits are complex and interact with anthropogenic pressures and environmental gradients (Yokouchi *et al.*, 2008).

For endangered fish species such as eels, management plans represent essential tools to assist with conservation actions (EC, 2007). To develop sound management plans, detailed knowledge of the species' biology and population, including age structure, growth rates, rates of survival and mortality, age at the onset of sexual maturity, and longevity are needed. However, comprehensive population data are rarely available (Simon, 2015). Svedang and Gippeth (2012) highlighted the necessity of scientific research to evaluate the implementation and effectiveness of management measures. The complicated life-history features, variety in habitat use and vast distribution range of elvers and glass eels emerging from parental stocks from varied locations of origin make it difficult to obtain an overall population assessment for this species. Scientific investigations on life-history features and the demographic structure of European eel in locations with data shortages are therefore particularly important.

Biological and biometric data are essential to allow for a more comprehensive and reliable global population trend analysis for this species. The main tasks of this chapter are to analyse information and data provided by the nine partner countries in order to give an overview of the biological features of local stocks, the impacts of habitat type and environmental conditions on eel growth and to estimate growth parameters and natural mortality rates. This information is crucial to support a regional adaptive management plan for European eel in the Mediterranean region, under the auspices of the GFCM**.**

6.2. Material and Methods

6.2.1. Literature-based data

WP 3 relied on thorough research and sharing of all existing documentation through consultation with all relevant institutions, administrations and agencies in the nine partner countries. In addition, life-history data were collected from the relevant literature. Publications were selected through specific queries on ISI WEB of SCIENCE, SCOPUS and Google Scholar. Data on the various life-history traits were extracted from figures, tables or the text of publications. The life-history parameters assembled consisted of minimum, maximum and average length (mm), weight (g) and age (years), as well as the growth parameters (L_∞, K, t_o), and sex ratios represented by the proportion of females in the population (percent). In some cases, only maximum and minimum length, weight and age were available, so the average growth parameters were estimated.

The available data varied from country to country, with some reporting minimum and maximum values for length, weight and age, while others reported only average values and still others reported scattered individual length, weight and age observations. As a result, all data sets were standardized by computing averages from individual observations.

6.2.2. Estimation of life-history traits

A preliminary estimate of the growth parameters (L_∞, K and t_o) was obtained online through FishBase[1] life history key facts using empirical equations derived by Froese, Palomares and Pauly (2000). By using the average of the maximum recorded length in each habitat, the von Bertalanffy asymptotic length (L_∞), growth coefficient (K) and hypothetical age-at-zero length (t_o) were estimated from maximum length using an empirical relationship between L_∞ and L_{max} (Froese and Binohlan, 2000). The natural mortality coefficient (M) was estimated from the empirical equation of Pauly (1980) based on the parameters of the von Bertalanffy growth function and on the mean annual water temperature (T) of the different eel habitats.

Growth rate measurements (mm/year) were computed by dividing the average length (mm) at each site in Mediterranean lagoons by the average age reported at the same site in the same publication.

Statistical analyses, two-way ANOVA tests and Mann–Whitney U-tests were performed with the statistical software SPSS (Statistical Package for the Social Sciences) version 9.0. A Kruskal–Wallis H-test was used to test for significant differences between mean characteristics of eels in each habitat, using a significance level of 0.05.

There was a lack of data from coastal waters and only a few data series from estuaries, as well as scarce information on biometrics at the glass eel stage compared to the yellow eel and silver eel stages, where most information was present. In addition, there was very little information on age.

It should also be recognized that biometric parameters may be affected by the collection protocol. However, given the limited scope of this project, these protocols were not checked, and thus the results should be taken with caution and require further analyses. Therefore, the data given for a particular site may not be representative of that population.

6.3. RESULTS

6.3.1. Description of the data

WP 3 collected all available qualitative and quantitative information on local stocks of eels. This information concerned all inland eel stages and included growth, reproductive biology and population structure. The task was carried out by collecting all available literature (published and grey, old and recent, local and international) that could contribute to the characterization of local stocks of eels in the Mediterranean.

Historical biometric data are incomplete, and the available data varied by country. Some countries provided one set of data collected in one year and one habitat (Albania and Egypt), while others provided a series of length and weight data sets (Greece and France) and still others provided dispersed biometric data. In addition, there was high heterogeneity among the time series, as they covered varying time intervals, with some dating back to 1928 (Tunisia) and others updated to 2021 (Egypt).

[1] www.fishbase.org

The data considered in this study are from only the year 2000 and onwards (Table 6.1). About 41.5 percent of the biometric data originated from lagoons, 31.3 percent from rivers, 23.1 percent from estuaries and only 4.1 percent from lakes.

Separate descriptive analyses were carried out for glass eels, yellow eels, silver eels (females and males), and mixed yellow and silver eels.

Glass eel biometry data originated from four countries, with five records from southern Mediterranean countries (Algeria and Tunisia) and the rest from northern Mediterranean countries (20 from France and five from Italy). All 30 glass eel biometry records provided length and weight measurements (Table 6.2, Figure 6.1), with 80 percent of data originating from lagoons (Table 6.3 and Figure 6.2).

Seven countries, mostly from the northern Mediterranean, provided yellow eel biometric data, including 128 length and 82 weight records. Two of the nine country partners provided series of at least five years of data for length and weight. In total, 38 records for age determination were provided by four countries (Table 6.2, Figure 6.1). Most of the length and weight measurements were from yellow eel located in rivers, while about 65 percent of the age data originated from lagoons (Table 6.3, Figure 6.2).

Of the 143 records of female silver eels provided by seven countries, 139 included length measurements and 134 included weight measurements. Six countries provided 66 records of age for female silver eels, mostly from lagoon habitats. France provided a nine-year data series for length and weight. Ten estimates of growth parameters were collected from the published literature of four countries (Table 6.2, Figure 6.1). Most of these data came from lagoons (Table 6.3, Figure 6.2).

There were 126 length records for male silver eels and 122 weight measurements provided by eight countries. Seven countries provided 47 age data records, and eight estimates of growth parameters were collected from the published literature of four countries. France had a nine-year series of data for length and weight. Data for silver eel sex ratios, represented by the percentage of males, were accounted for by 120 records provided by seven countries (Table 6.2, Figure 6.1). More than 90 percent of male silver eel data originated from lagoons (Table 6.3, Figure 6.2).

Of the 75 length records for yellow and silver eel (mixed), 72 weight data were provided, as well as 25 age records for yellow and silver eel (mixed). The yellow and silver eel (mixed) length and weight data came from eight countries, while the age data came from five countries, mostly from lagoons (Table 6.3, Figure 6.2). Greece had a nine-year series of data for length and weight.

Table 6.1 Summary of available time series per habitat type (RIV = river, RIE = river estuary, LGN = lagoon, LAK = lake) and country within the nine partner countries (n+1 refers to the number of years in the time series, n-1 refers to the number of missing years).

Country	Habitat	First year	Last year	n+1	n-1
Albania	RIV	2000	2000	1	0
Algeria	RIE	2005	2013	8	1
	LGN	2007	2014	4	4
	RIV	2007	2014	8	0
France	RIE	2004	2021	18	0
	LGN	2011	2019	9	0
	RIV	2012	2020	9	0
Egypt	LGN	2021	2021	1	0
Greece	LGN	2009	2019	9	2

Country	Habitat	First year	Last year	n+1	n-1
Italy	RIE	2017	2019	3	0
	LGN	1975	2020	16	30
	RIV	1986	2020	8	27
	LAK	2010	2016	4	3
Spain	LGN	2000	2000	1	0
	RIV	2015	2019	3	2
Tunisia	RIE	1929	2007	3	76
	LGN	1928	2018	15	76
	RIV	2004	2004	1	0
Türkiye	RIE	1989	1990	2	0
	LGN	1986	2016	6	25
	RIV	1961	2015	16	39
	LAK	2010	2016	2	5

Table 6.2. Number of biometric records provided by each country for different eel life stages (glass eel, yellow eel, female silver eel, male silver eel and mixed yellow and silver eel).

				Silver eel								
	Glass eel	**Yellow eel**		**Female**			**Male silver**				**Yellow and silver eel**	
Country	(L, W)	(L, W)	Age	(L, W)	Age	Growth parameters	(L, W)	Age	Growth parameters	Sex-ratio	(L, W)	Age
Albania				1	1	1	1	1	1	1		
Algeria	1	1		1	1	1	2	1	1	3	18	6
France	20	53		75	25		79	15		79	3	
Egypt											3	
Greece		1		13	7		2	2		2	14	7
Italy	5	60	30	44	26	4	33	20	3	28	20	5
Spain		2	2				2	2		1	1	
Tunisia	4	5	5	6	6	4	6	6	3	6	2	2
Türkiye		6	1	3			1				14	5

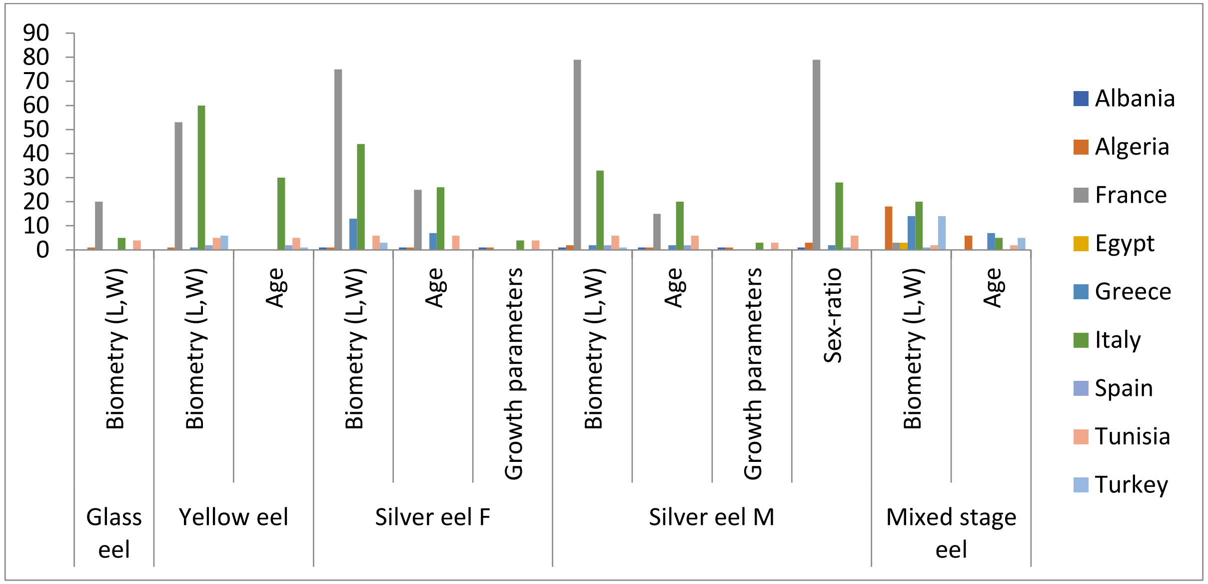


Figure 6.1. Number of biometric records provided by each country for different eel life stages (glass eel, yellow eel, female silver eel, male silver eel and mixed yellow and silver eel)

Table 6.3. Number of biometric records (L [length] and W [weight]) from different habitats (RIE = estuaries), (LGN = lagoons), (RIV = rivers) and (LAK = lakes) for all eel life stages.

	Glass eels	**Yellow eels**		**Silver eels F**			**Silver eels M**				**Mixed stages**	
	Biometry (L, W)	Biometry (L, W)	Age	Biometry (L, W)	Age	Growth parameters	Biometry (L, W)	Age	Growth parameters	Sex-ratio	Biometry (L, W)	Age
RIE	4	1	1								10	3
LGN	20	44	24	126	61	7	110	36	5	107	41	13
RIV	1	69	6	5	2	2	8	6	2	6	28	7
LAK		14	7	10	5	1	10	5	1	8	13	3

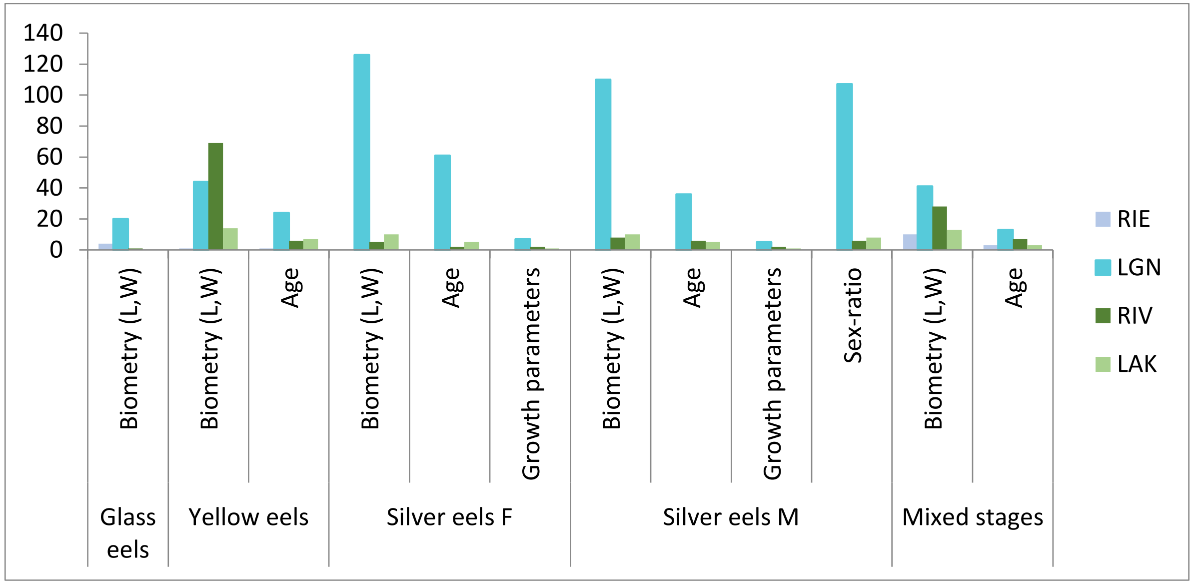


Figure 6.2. Number of biometric records for all life stages originating from different habitats (RIE estuaries), (LGN lagoons), (RIV rivers) and (LAK lakes).

6.3.2. Spatial and temporal variations in biometry

Environmental and habitat changes can have profound and complex impacts on fish. In the current study, spatial variations in mean length and growth of eels in relation to the latitude, temperature and trophic status of the lagoons in the nine partner countries were analysed.

Biometric data (minimum, average and maximum) for length, weight and age of eels in different life stages (glass, yellow, silver and mixed yellow and silver) were compared among the different partner countries and among different habitats (estuaries, lagoons, rivers and lakes)

The largest range of length and weight was recorded for glass eels from Algerian estuaries, while the smallest range was recorded for the lagoons of Italy.

The average lengths of glass eels among the different habitats showed that the glass eels collected from lagoons and estuaries mostly had the same mean total length (TL) (TL = 66 mm, N = 20 in lagoons; TL = 66 mm, N = 4 in estuaries) (p = 0.279 for TL and p = 0.556 for weight) (Figure 6.3). Meanwhile, glass eels in estuaries had significantly higher mean weights (Wt) (Wt = 0.47 g) than glass eels in lagoons (Wt = 0.25 g).

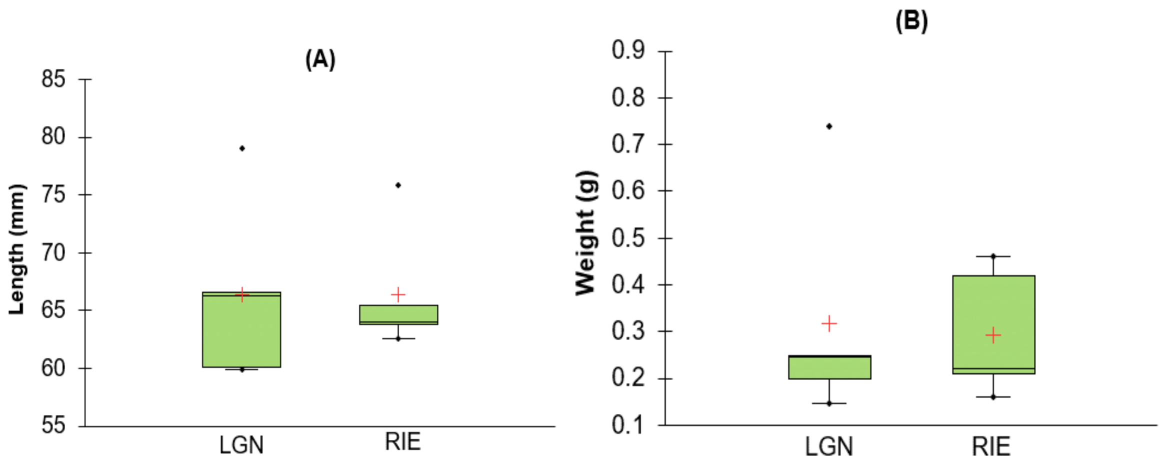


Figure 6.3. Mean parameters (panel A shows mean length and panel B shows mean weight) of glass eels collected from lagoons (LGN) and estuaries (RIE) represented by box plots (minimum, first quartile, median, third quartile, and maximum).

The greatest average length of yellow eel was recorded in lakes (TL = 476 mm, N = 14), followed by lagoons (TL = 455.8 mm, N = 44) and finally by rivers (TL = 359 mm, N = 69). The age of yellow eels ranged from 2 to 16 years. Mean age varied between different habitats: from 2 to 14 years in lagoons (N = 24), from 2 to 16 years in rivers (N = 6) and from 2 to 16 years in lakes (N = 7). The maximum age determined (16 years) was recorded for yellow eels in rivers in Albania, while the minimum age (2 years) was recorded in lagoons in Algeria and Greece (Figure 6.4).

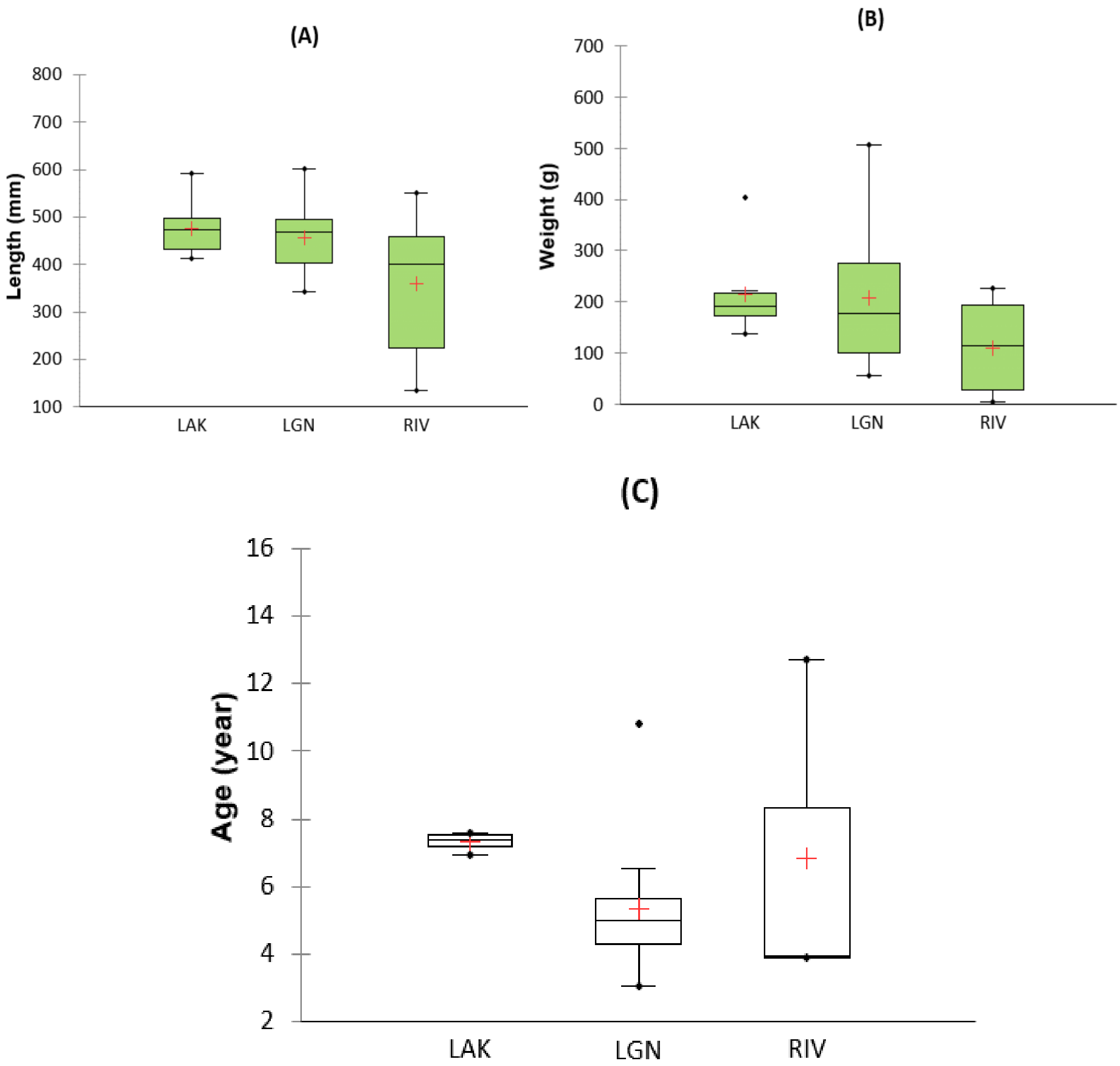


Figure 6.4. Mean parameters (panel A shows length, panel B shows weight and panel C shows age) of yellow eels collected from different habitats (LAK = lake, LGN = lagoon, RIV = river) represented by box plots (minimum, first quartile, median, third quartile, and maximum).

The greatest average length for female silver eels was recorded in lakes (TL = 661 mm, N = 10), followed by lagoons (TL = 585 mm, N = 126), and the smallest average length was observed in rivers (TL = 552 mm, N = 5) (Figure 6.5A). The highest weight of female silver eels (Wt = 1 200g) was recorded in lagoons, as was the lowest weight (Wt = 120 g) (Figure 6.5B).

The average length of male silver eels was similar among the different habitats, with TL equalling 375 mm, 403 mm and 397 mm in lakes, lagoons and rivers, respectively (Figure 6.6A). The highest average weight (Wt = 130 g) of male silver eels was recorded in lakes (Figure 6.6B).

Figure 6.5C shows that the age of female silver eels ranged from 3 to 17 years. The mean age varied among different habitats: from 1 to 18 years in lagoons (N = 61), from 4 to 16 years in rivers (N = 2), and from 6.5 to 23 years in lakes (N = 5). The age of male silver eels ranged from 1 to 11 years. Mean age varied among different habitats: from 1 to 10 years in lagoons (N = 36), from 4 to 10 years in rivers (N = 6) and from 2.5 to 6.8 years in lakes (N = 5) (Figure 6C).

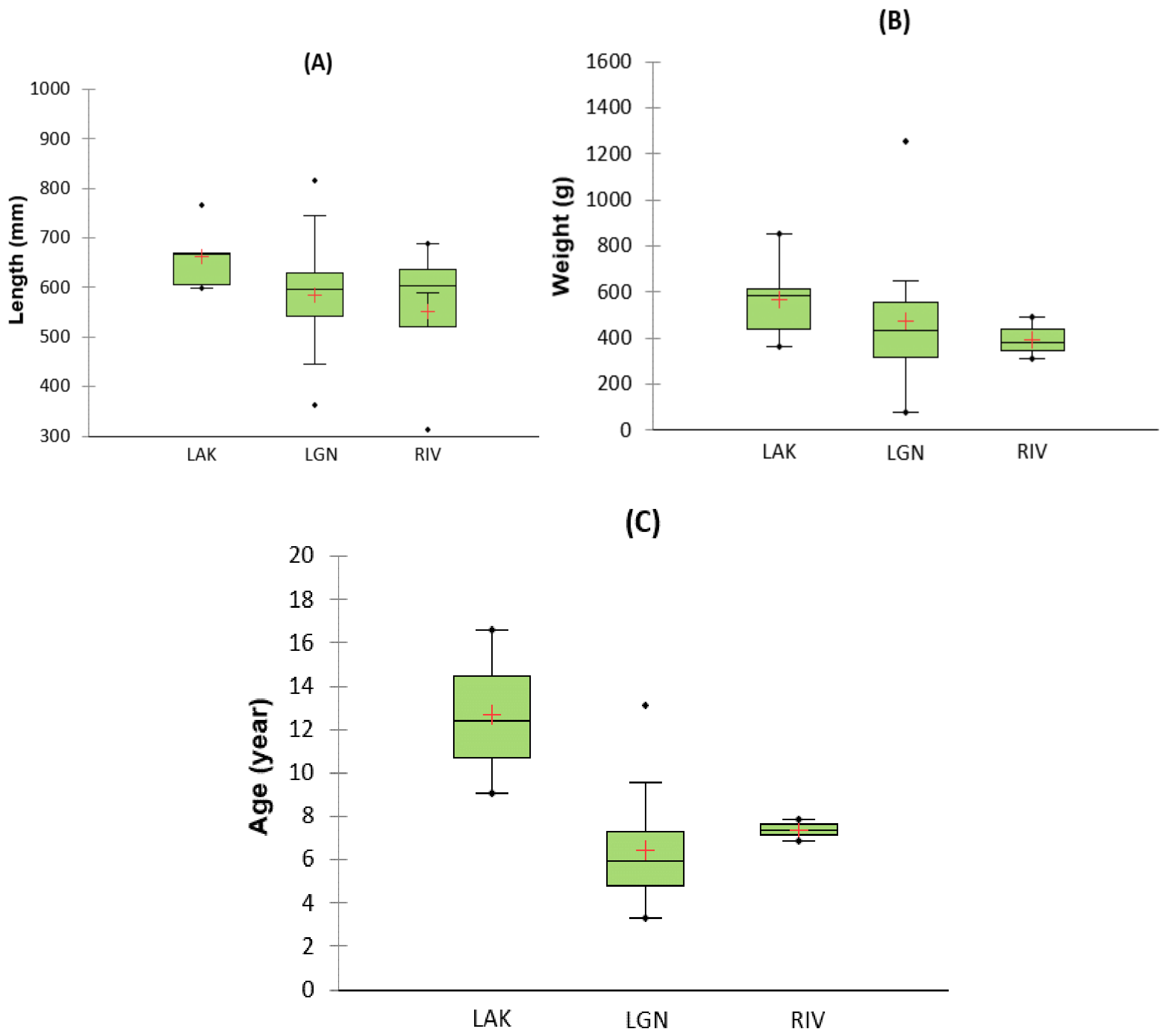
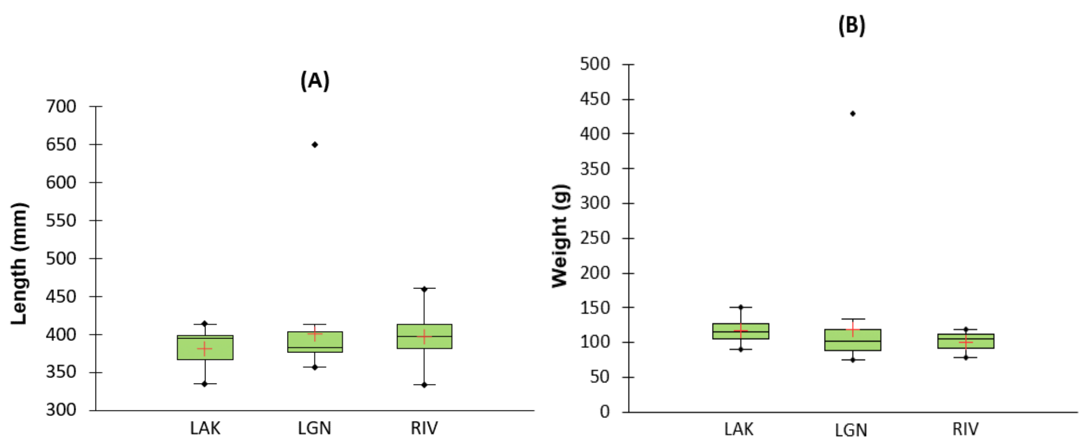


Figure 6.5. Mean parameters (panel A shows length; panel B shows weight and panel C shows age) of female silver eels collected from different habitats (LAK = lake, LGN = lagoon, RIV = river) represented by box plots (minimum, first quartile, median, third quartile, and maximum).



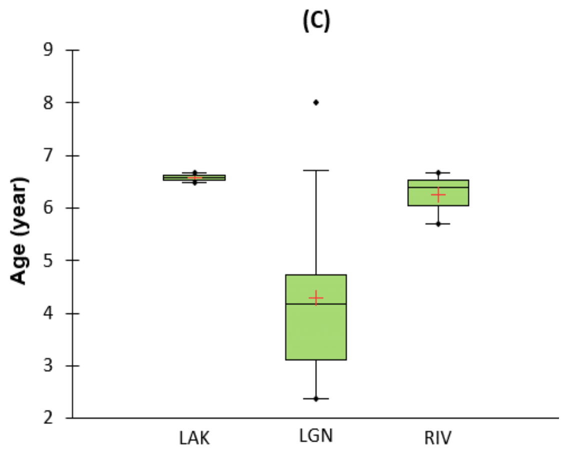
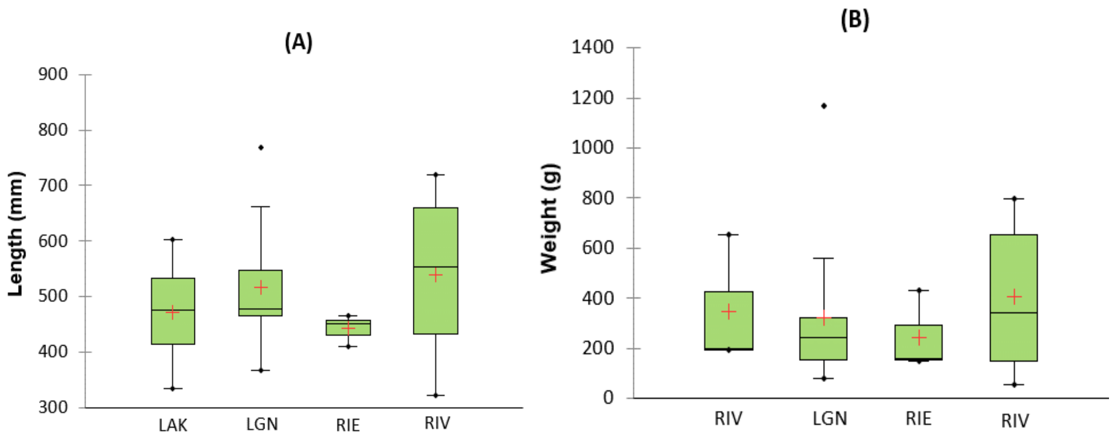


Figure 6.6. Mean parameters (panel A shows length, panel B shows weight and panel C shows age) of male silver eels collected from different habitats (LAK = lake, LGN = lagoon, RIV = river) represented by box plots (minimum, first quartile, median, third quartile, and maximum).

The biometric data of mixed yellow and silver eels (Figure 6.7) showed that the greatest average length was recorded in rivers (TL = 539 mm, N = 28). followed by lagoons (TL = 519 mm, N = 41), lakes (TL = 472 mm, N = 13) and finally estuaries, where the smallest average length was recorded (TL = 442 mm, N = 10). The highest average weight (Wt = 390 g) was recorded in rivers (Figure 7B). The age recorded for the mixed yellow and silver eel ranged from 1 to 17 years. Mean age varied among different habitats. It was 14 years in lagoons (N = 13), from 4 to 17 years in rivers (N = 7), from 1.5 to 14 years in estuaries (N = 3) and from 6.5 to 8.5 years in lakes (Figure 7C).



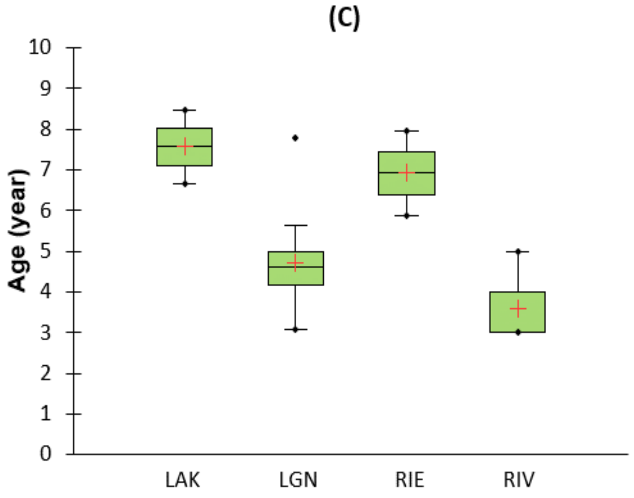


Figure 6.7. Mean parameters (panel A shows length, panel B shows weight and panel C shows age) of mixed yellow and silver eels collected from different habitats (LAK = lake, LGN = lagoon, RIV = river) represented by box plots (minimum, first quartile, median, third quartile, and maximum).

6.3.3 Effects of latitude and temperature

Fish species with distribution areas covering a wide range of latitudes exhibit geographical variations in their growth features (Campana *et al*., 1996; Frisk and Miller, 2006). These latitudinal variations in the growth of fish can be attributed to temperature, which exerts a major influence on fish growth (Brett, 1979), and to other factors related to the environment, such as hydrology and food availability, or to individual fish traits, including sex and genetics.

European eel is distributed across most of the coastal countries of Europe and North Africa, with its southern limit found off Mauritania (30° N) and northern limit in the Barents Sea (72° N) and spanning the entire Mediterranean basin (ICES, 2014b). The spawning area in the Sargasso Sea is thought to lie between latitudes 23° N and 29.5° N and in a wider longitudinal range from 48° W to 78° W (McCleave, Kleckner and Castonguay, 1987; Tesch and Wegner, 1990). At the continental scale, eels have a wide and scattered distribution and are found in virtually all types of water bodies, from rivers and lakes to estuaries and coastal waters.

As most of the data collected for this study originates from lagoons, the present analysis focused on the influence of the latitude, temperature and habitat characteristics (oligotrophic, mesotrophic, eutrophic, and hypereutrophic) of the different lagoons in the nine partner countries on the variability of mean eel length (mm) and growth rate (mm/year).

The latitudinal variability in mean length for female and male silver eels in lagoons (Figure 6.8) showed that the average length of female silver eels increases with increasing latitude ($r^2 = 0.528$, $P = 0.05$), while the same relationship is absent for males ($r^2 = 0.155$, $P = 0.16$). Growth rates of females were inversely related to latitude ($r^2 = 0.472$, $P = 0.02$). The very low correlation between the growth rate of male silver eels and latitude ($r^2 = 0.026$, $P = 0.2$) (Figure 6.9) suggests that latitude has only a weak effect on the growth rate of male silver eels.

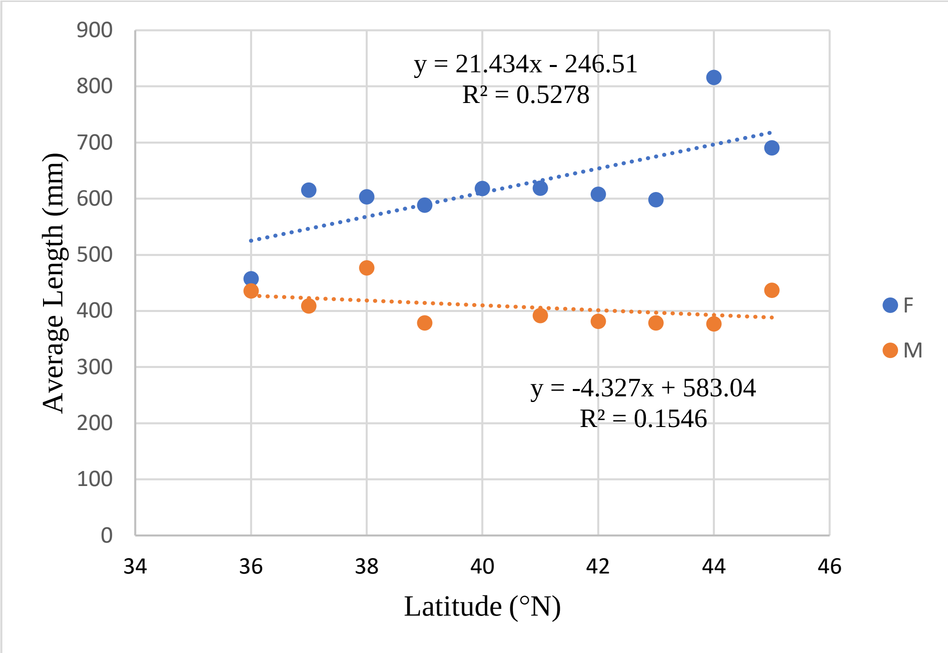
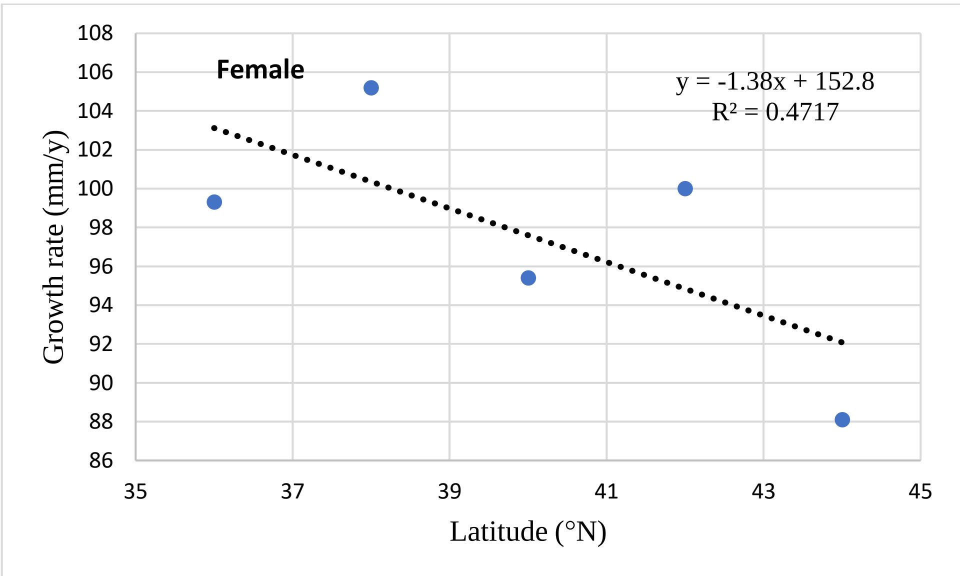


Figure 6.8. Effect of latitude on average length (mm) of female (blue circles) and male silver eels (orange circles) in Mediterranean lagoons.



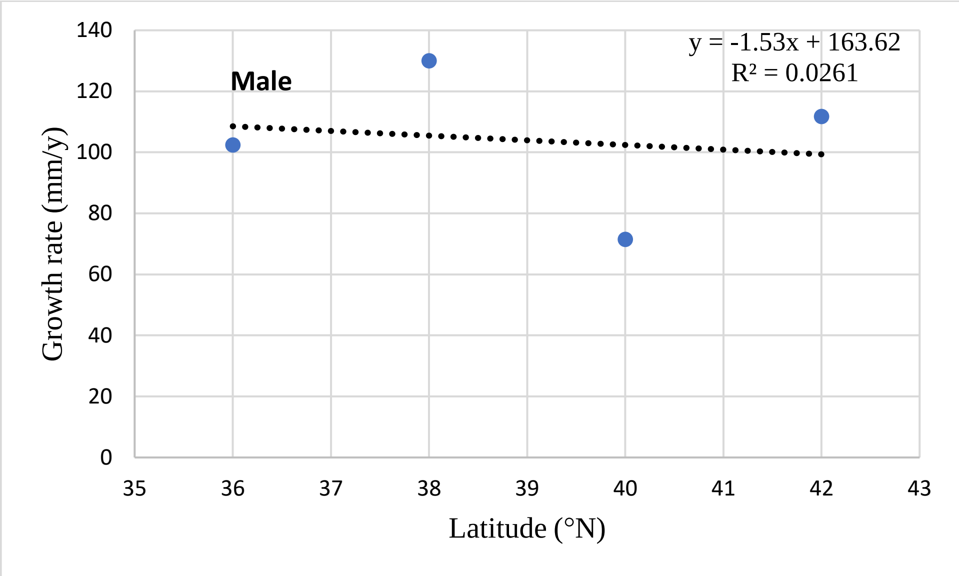
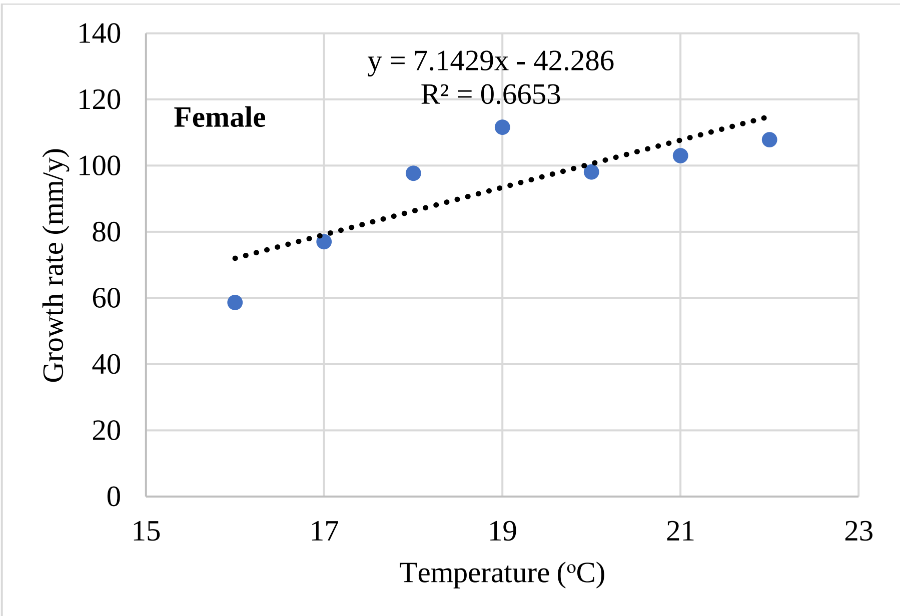


Figure 6.9. Effect of latitude on growth rate (mm/year) of female and male silver eels in Mediterranean lagoons.

Glass eels, yellow eels and silver eels are influenced by temperature gradients (Nyman, 1975; Vøllestad and Jonsson, 1988; Vøllestad *et al.*, 1986; Westin, 1990). It is well known that yellow eels benefit from higher temperatures (Karås, 1981), with an optimum temperature for growth of around 22ºC (Sadler, 1979).

The mean growth rate (mm/year) of male and female silver eels in Mediterranean lagoons was correlated with the mean water temperature (ºC). The positive relationship between the growth rate of female silver eels and temperature indicates that higher temperatures are favourable for growth. Despite the weak correlation between temperature and growth rate of male silver eels, male growth rate also increases with temperature (Figure 6.10).



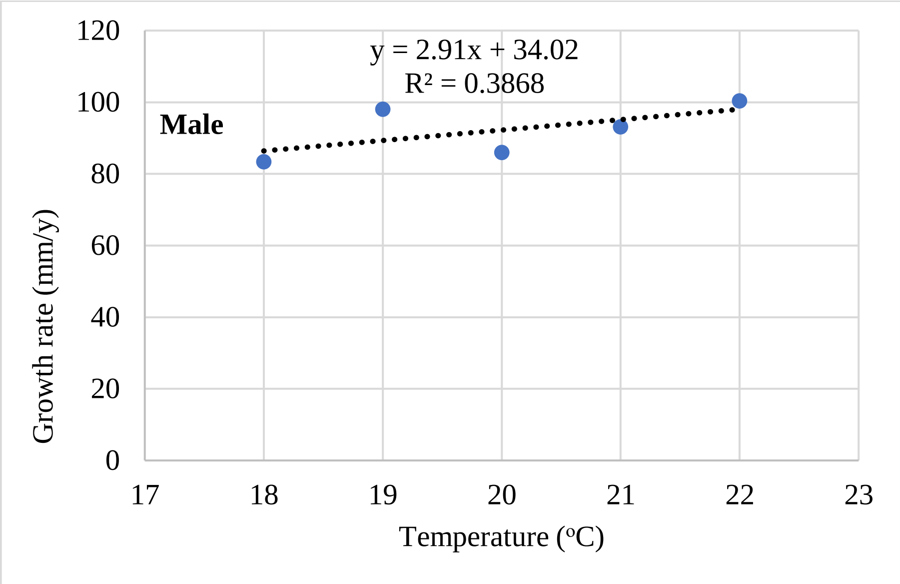


Figure 6.10. Effect of temperature on growth rate (mm/year) of female and male silver eels in Mediterranean lagoons.

6.3.4. Silver eel growth in lagoons of different trophic status

The trophic status of a water body can be roughly assessed by using information on the concentrations of the limiting nutrient (phosphorus), chlorophyll (an indicator of phytoplankton biomass) and transparency (dependent on both algal biomass and sediment resuspension, expressed as Secchi depth). The trophic status of Mediterranean lagoons can be classified as either oligotrophic (low primary productivity due to nutrient deficiency), mesotrophic (intermediate level of productivity), eutrophic (high biological productivity, due to excessive nutrients, especially nitrogen and phosphorus) or hypereutrophic (very nutrient-rich, greater than 100 micrograms/litre phosphorus).

The relationship between phosphorous (P) concentrations, representing the trophic status of the lagoons, and silver eel growth rate is shown in Figure 6.11. The results revealed that mesotrophic habitats host slower growing female silver eels (73.0 mm/year), while the fastest growing female silver eels (110.4 mm/year) were recorded in hypereutrophic lagoons. The highest growth rate of male silver eels (102.2 mm/year) was recorded in hypereutrophic lagoons while the lowest growth rate of male silver eels (78.6 mm/year) was recorded in eutrophic lagoons.

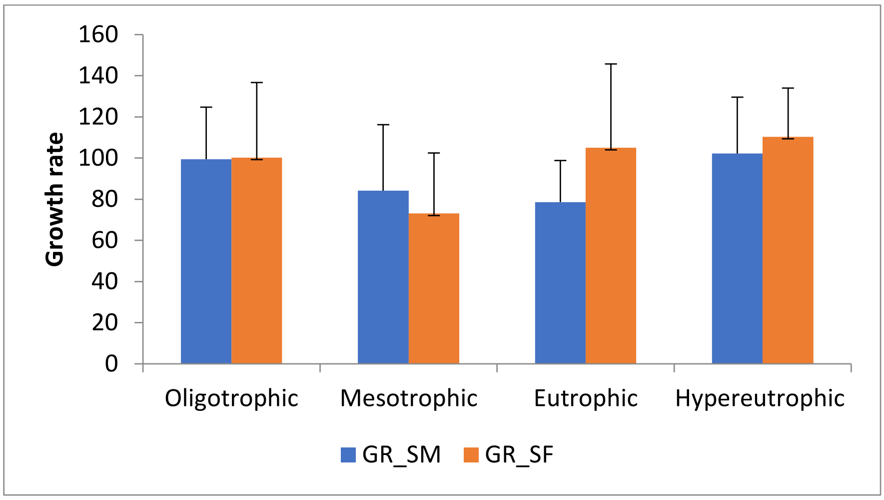


Figure 6.11. Silver eel growth rates in lagoons of different trophic status according to phosphorous concentrations (GR_SM = growth rate for male silver eels, GR_SF = growth rate for female silver eels).

Figure 6.12 illustrates the relationship between chlorophyll (Chl) concentrations, representing the trophic status of the lagoons, and silver eel growth rates. The results revealed that oligotrophic habitats hosted slower growing female silver eels (65.9 mm/year), while the fastest growing female silver eels (127.1 mm/year) were recorded in hypereutrophic lagoons (represented by the growth rate of only one individual). The highest growth rate of male silver eels (121.6 mm/year) was recorded in hypereutrophic lagoons (represented by the growth rate of only one individual), while the lowest growth rate for male silver eels (67.0 mm/year) was recorded in oligotrophic lagoons.

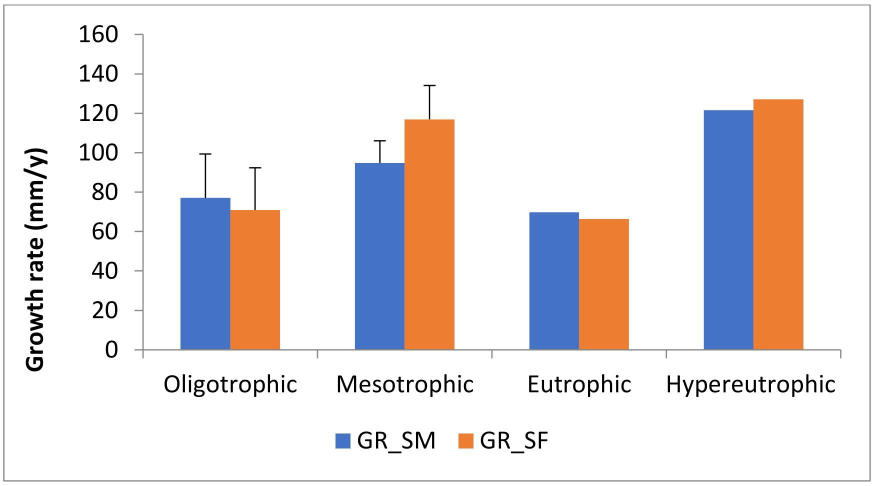


Figure 6.12. Silver eel growth rates in lagoons of different trophic status according to chlorophyll levels (GR_SM = growth rate for male silver eels, GR_SF = growth rate for female silver eels)

6.3.5 Regional variations in silver eel growth rates

To compare silver eel growth rates in different regions of the Mediterranean, growth rate data from five partner countries were used. Prior to any analysis, the growth rate data were classified into three groups according to their geographic location of origin:

- Northern Mediterranean: France, Italy
- Southern Mediterranean: Algeria, Tunisia
- Eastern Mediterranean: Greece

The growth rate of both sexes was very similar between the northern and southern Mediterranean countries (Figure 6.13). However, growth rates were faster in the eastern Mediterranean region, with average rates of 129.5 mm/year for females and 153.6 mm/year for males.

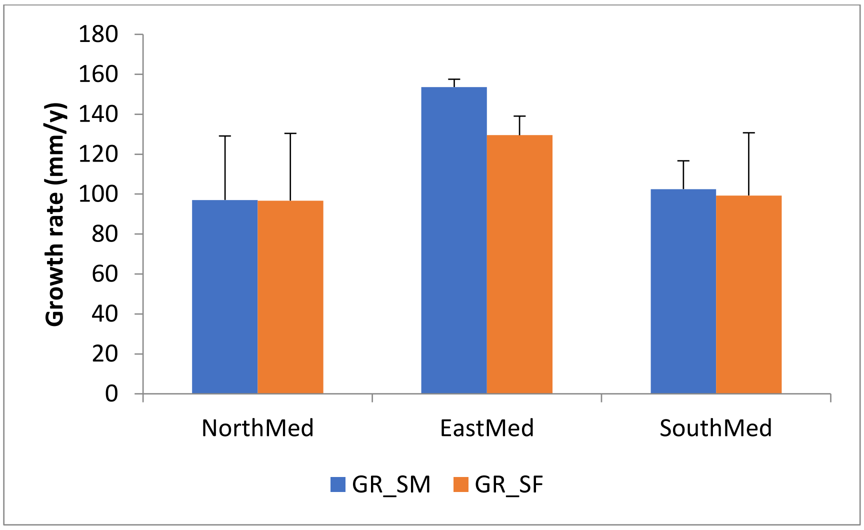


Figure 6.13. Growth rates of silver eels (males, GR_SM; females, GR_SF) in different Mediterranean regions (northern Mediterranean, NortMed; eastern Mediterranean, EastMed; southern Mediterranean, SouthMed).

6.3.6. Population Parameters

Growth is a crucial parameter in eel stock assessment, and the most common way to quantify it is to use the von Bertalanffy (1957) growth model (Melià *et al.*, 2014). However, it was difficult to adapt this model due to a lack of length-at-age data. A preliminary estimate of the growth parameters (L_∞, K and t_0) was obtained through FishBase life history key facts of fishes (Froese, Palomares and Pauly, 2000) empirical equations, using the average of the maximum recorded length in each habitat.

The overall L_∞ of the von Bertalanffy growth parameters was significantly higher (U-tests, d.f. 1, $p < 0.001$) for female silver eels (831.9 mm) than for males (506.1 mm), whereas the parameter k was significantly lower (U-tests, d.f. 1, $p < 0.001$) in females (0.117) than in males (0.317) (Table 6.4).

Comparing the estimated growth parameters and natural mortality rate values (L_∞, K, t_0, M) for female and male silver eels and mixed yellow and silver eels among different habitats (Table 6.4) revealed the highest mean value of L_∞ for female and male silver eels in lakes, while the smallest value was obtained for rivers. For mixed yellow and silver eels, the highest L_∞ value was recorded in estuaries (Figure 6.14).

There are hardly any empirical data available on the natural mortality of eels. A value of $M = 0.1386$/year is often applied, giving Dekker (2000b) as a reference, even though Dekker only assumed that this value is a sound empirical level describing mortality rate.

The empirical equation derived by Pauly (1980) was used, and the resulting estimated natural mortality rate (M) (Table 6.4) ranged from 0.15 in estuaries to 0.26 in lakes and lagoons, which is very close to the value provided by Dekker (2000b).

Table 6.4. Growth parameters (L_∞, K, t_0) and natural mortality (M) values of male and female silver eels and of mixed yellow and silver eels in different habitats (RIE = estuary, LAK = lake, LGN = lagoon, RIV = river)

	Silver Female				**Silver male**				**Mixed yellow and silver eel**			
	L_∞	**K**	t_0	**M**	**L_∞**	**K**	t_0	**M**	**L_∞**	**K**	t_0	**M**
RIE									970.9	0.08	-1.58	0.15
LAK	860.0	0.11	-1.18	0.20	547.4	0.27	-0.52	0.43	739.2	0.15	-0.89	0.26
LGN	796.8	0.13	-1.01	0.23	497.9	0.32	-0.45	0.50	721.0	0.15	-0.89	0.26
RIV	838.9	0.11	-1.18	0.20	473.0	0.36	-0.4	0.55	766.0	0.14	-0.95	0.24

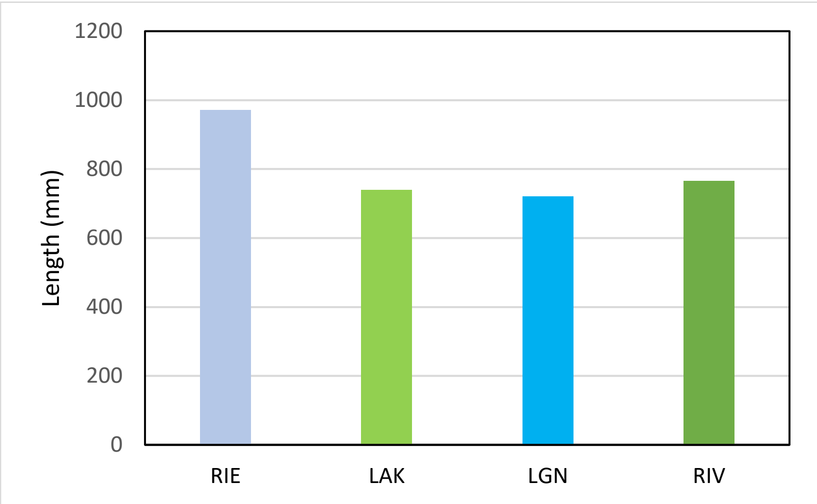


Figure 6.14. Asymptotic lengths (L_∞) of mixed yellow and silver eels in different habitats (RIE = estuary, LAK = lake, LGN = lagoon, RIV = river)

Differences in the proportion of male and female eels were recorded in the different habitats. Females tended to predominate, comprising 66.9 percent of the eel population in lakes (N = 8). In lagoons, there were almost equal numbers of males and females (N = 106), while in rivers, males were the dominant sex, accounting for 53.8 percent (N = 6) of the population (Figure 6.15, Figure 6.16).

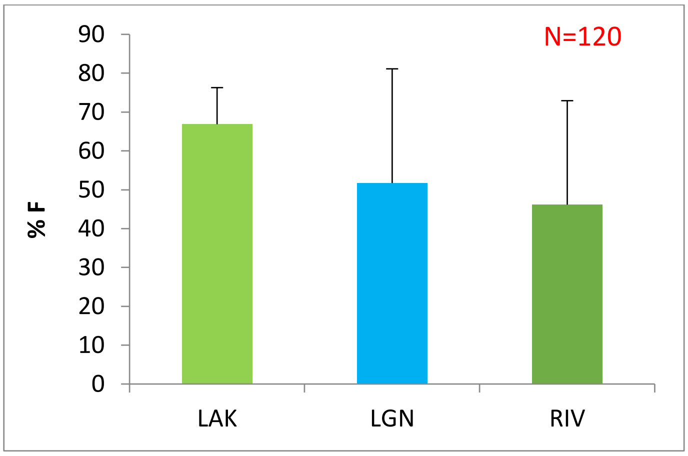


Figure 6.15. Average proportion of female silver eels (percent) in different Mediterranean habitats (LAK = lake, LGN = lagoon, RIV = river).

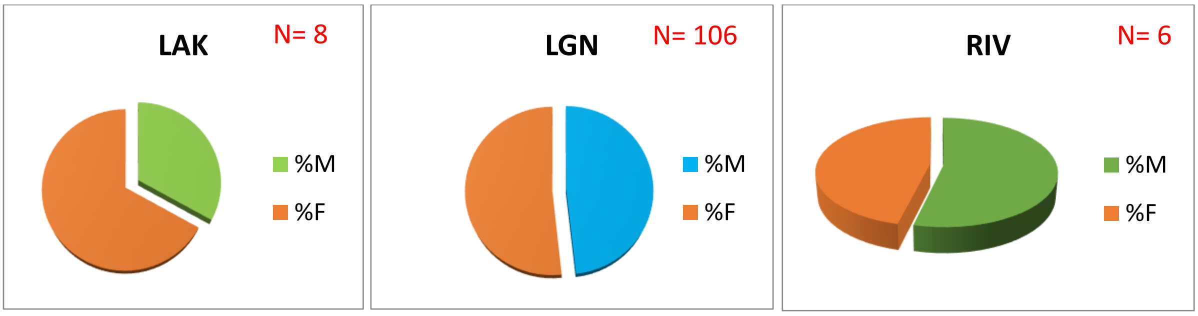


Figure 6.16. Sex ratios of silver eels in different habitats (LAK = lake, LGN = lagoon, RIV = river) of the Mediterranean (N is the number of individuals).

6.4. DISCUSSION AND CONCLUSIONS

6.4.1. Length, weight and age

Data on different biological features of eels from the nine partner countries in the Mediterranean revealed a variety of demographic differences among the four habitats. Glass eels attained higher maximum lengths in lagoons. The greatest lengths and weights of yellow eels were recorded in lagoons, while the highest ages were observed in rivers. When comparing all habitats, it was concluded that the largest female silver eels were found in lakes. Although the upper size limit of female silver eels was similar between the different habitats, the average size differed, and the highest average length and age were recorded in lakes. The conclusion that eels in Mediterranean rivers and lagoons are small, short-lived, and mostly males agrees with most results obtained elsewhere (Lobón-Cerviá, Utrilla and Rincón, 1995).

The overall mean age was significantly higher ($p < 0.01$) for females (13 years) than for males (7 years) across all habitats, which is consistent with other studies (Penáz and Tesch, 1970; Poole and Reynolds, 1996a; Ciccotti *et al.*, 2012). The highest mean age for female silver eels (23 years) was recorded in lakes, while the highest mean age for male silver eels (10 years) was recorded in lagoons.

6.4.2. Growth rate

Growth is a key parameter in population dynamics. Along with other processes, growth has implications for the lifetime mortality of fish by modulating the time required to reach maturity. Growth also conditions reproductive success by affecting size at reproduction and fecundity (Rose *et al*., 2001).

The average growth rate of female and male silver eels in Mediterranean lagoons (101.8 mm/year for females and 103.5 mm/year for males) was faster than growth rates reported for other temperate eel species in a variety of studies on age and growth of female silver eels (Vøllestad, 1992; Poole and Reynolds, 1996; Svedäng *et al*., 1996; Oliveira, 1999; Oliveira and McCleave, 2002; Jessop, Shiao and Tzeng, 2004; Ciccotti *et al*., 2012; Rosell, Evans and Allen, 2005; Simon, 2007; Capoccioni, 2012; Simon, 2015). Berg (1990) reviewed aging studies for *A. anguilla* from nearly 50 publications and concluded that annual growth rates, in most cases, varied between 30 mm/year and 60 mm/year and did not exceed 100 mm/year. Higher rates, up to 300 mm/year, were shown to apply to the fastest growing individuals in ponds or lakes stocked for the first time but could not be extrapolated. His review showed a considerable degree of uniformity across the European continent, from Mediterranean countries to Scandinavian countries. However, nearly all the data sets came from populations in the northern part of the range and largely from the richer waters in which eel fishing takes place (Moriarty, 2003). Slower growth, up to 14 mm/year, has been demonstrated in oligotrophic waters (Poole and Reynolds, 1996). Much faster growth has been reported in coastal lagoons and estuaries in Mediterranean climates. In the

Guadalquivir estuary (southwestern Spain), Fernandez-Delgado *et al.* (1989) reported growth of 390 mm/year at three years of age for both males and females. A recent mark and recapture experiment in the Rhône river delta (southern France) showed that eel growth rates were quite variable and high, ranging between 15 cm/year and 20 cm/year or more. Eels of 70 cm could be between 2 and 12 years old (Panfili *et al.*, 2022).

European eel body growth is highly variable as a consequence of inter-individual variation within the same subpopulation and geographical variation among different habitats (Vøllestad, 1992; Panfili 1994; Melià *et al*., 2006; Daverat *et al.*, 2012). This variability may be partially explained by differences in density, system productivity and temperature regime (Panfili *et al.*, 1994; Aprahamian *et al*., 2007; Daverat *et al*., 2012). Moreover, the species shows marked sexual dimorphism, with females being larger than males of similar age and attaining greater body size (Vøllestad, 1992; De Leo and Gatto, 1995; Daverat *et al.*, 2012).

6.4.3. Effects of latitude and temperature

The present results showed that the total length of female silver eels in Mediterranean lagoons was correlated with latitude and temperature. Growth rates decreased with increasing latitude and increased with higher temperature. A large number of fish species show decreases in growth rates as latitude increases (Beverton, 1987; Belk and Houston, 2002), which is usually attributed to the latitudinal cline in temperature.

The absence of correlation between male silver eel length or growth rate and latitude in Mediterranean lagoons can be attributed to the fact that lagoons are peculiar habitats and each site has its own ecological story. It is difficult to analyse local situations and determine the characteristics of local eel stocks, while differences between the sexes in terms of their response to latitudinal variations and life-history traits may be due to differences in life-history strategies.

The general pattern of habitat use described for eels suggests that they prefer brackish and marine habitats at higher latitudes, while eels at lower latitudes are believed to prefer fresh waters (Daverat *et al*., 2006). This phenomenon is attributed to latitudinal differences in aquatic productivity between freshwater and seawater habitats. In other words, productivity at lower latitudes is higher in freshwater than in seawater, whereas at higher latitudes, productivity is higher in seawater than in freshwater (Gross, 1987). Nevertheless, this observation does not take into account the fact that the most productive habitats in the Mediterranean are transitional waters, particularly coastal lagoons (Acou *et al.*, 2003).

Movement of eels between habitats, wherever they occur, are short-range (approximately ten km) and are of considerable importance because they occur during the prolonged yellow eel growth stage and involve switching between completely different environments in terms of salinity, temperature, substrate and depth, as well as a large number of other environmental conditions (Thibault, Dodson and Caron, 2007). As a consequence, the mechanism of facultative catadromy for eels at different latitudes is still controversial and cannot be predicted directly by given environmental conditions, such as aquatic productivity, alone (Capoccioni *et al*., 2013).

The effects of temperature on eel growth are well known in aquaculture (Dosoretz and Degani, 1987; Holmgren, 1996; Ciccotti and Fontenelle, 2001), where eels are reared at an optimal temperature of 23–25°C. Sadler (1979) determined both upper and lower lethal temperatures for eels. These authors highlighted that the critical thermal maximum varied between 33°C and 39°C and that eels enter a state of torpor at temperatures between 1°C and 3°C. It is likely that global warming has also affected eel habitats over the last century. Temperatures have already increased by 2°C in a century, and climate projections for Europe predict temperature increases of 1.4°C–5.8°C within 50 years (IPCC, 2001). Contrary to many cold-water fish species, eel growth rates would benefit from this temperature increase (Reist *et al.*, 2006).

The positive relationship observed between temperature and growth rates was in agreement with the common observation of higher growth rates in the southern Europe, as seen in Italy (Rossi and Colombo, 1976), compared to northern Europe (Sinha and Jones, 1967) and the correlation between growth rates and latitude (Vøllestad, 1992).

The temperature–size rule (increase in body size at lower temperatures) evidently applies to European eel females, but not to males. No current life history model provides a satisfactory explanatory mechanism for the temperature–size rule or for anguillid life-history strategies.

6.4.4. Effects of trophic status

Growth of eels in the Mediterranean region has been shown to be faster in brackish water sites than in adjacent freshwater sites (Panfili *et al.*, 1994). Field observations have shown that low-pH, oligotrophic habitats contain slower growing eels (Moriarty, 1979; Poole, Reynolds and Moriarty, 1992; Poole and Reynolds, 1998) compared to higher trophic level habitats in the same region (Moriarty, 1983). Likewise, eel growth rates and body condition near estuaries are often higher than in the upper reaches of a river catchment (Daverat *et al.*, 2006; Lasne *et al*., 2008).

The relationship between phosphorus levels in Mediterranean lagoons and growth rates of female silver eels revealed that the slowest growth was observed in mesotrophic lagoons, while fastest growth was seen in hypereutrophic lagoons. Using chlorophyll concentrations as an indicator of the trophic status of lagoons, the slowest growth of female silver eels was recorded in oligotrophic lagoons and the highest rates in hypereutrophic lagoons.

6.4.5. Growth parameters and natural mortality

Growth parameters are used to analyse population dynamics in relation to exploitation and management measures in stock assessment models (Cailliet and Andrews, 2008). Estimates of demographic parameters, such as growth and mortality rates, are fundamental to proposing suitable sustainable environmental management methods, especially for endangered species (Caswell, 2000). Eel growth is characterized by clear sexual dimorphism and high inter-individual variability (Vollestad, 1992; Panfili *et al.*, 1994; De Leo and Gatto, 1995).

The estimated growth parameters showed a trend towards smaller L_∞ and greater growth coefficient (K) and t_0 values in male than in female silver eels in all habitats. The results showed that female silver eels grow faster in lagoon habitats. Melià *et al.*, (2006) and Daverat *et al.* (2012) reported that in brackish systems, eels usually grow at faster rates than those in riverine habitats. A plausible explanation is the higher productivity of estuaries and coastal lagoons and lower osmoregulation costs (Tzeng *et al.*, 2003). Brackish systems, particularly coastal lagoons and estuaries, also support higher densities of eels compared to upstream river stretches (Costa *et al*., 2008). Despite the importance of these ecosystems for the management of this panmictic species, they have received less attention in eel stock assessments.

Eels are a long-lived species, with the yellow eel stage lasting to 2 to 20 years for males and 5 to 50 years for females (Dekker, 2002). According to Vollestad (1992), mean length and age at silvering differ significantly between males (405.6 mm; 5.99 years) and females (623.2 mm; 8.73 years). However, when compared to other fish, growth is slower, usually 3 to 4 cm/year (Dekker, 2002). Annual growth can be as low as 1 cm/year or less in northern areas (Poole, Reynolds and Moriarty, 1992) and up to 15 cm/year in more southern areas (Dekker, 2002). The mean length of female silver eels increases with latitude, while the same relationship is absent for males; higher latitude also corresponds to an increase in age (ICES, 2010).

Natural mortality is poorly understood in anguillid eels, and experimental information on the natural mortality of European eel is very scarce. At present, it is unclear whether eel survival is more strongly linked to age or body size, whether females and males are subject to different mortality rates or even whether individual survival is influenced by population abundance over the whole lifespan of an eel.

For this reason, previous demographic models have been based on *a priori* assumptions such as age-dependent mortality (De Leo and Gatto, 1995) or a constant mortality rate (Dekker, 2000b).

For the post-settlement yellow eel stage, Bevacqua *et al*. (2011) calibrated a generic model for natural mortality that took into account the impacts of body mass, temperature, stock density and gender. The estimated natural mortality rate from the available growth parameters in different habitats ranged from 0.15 in estuaries to 0.26 in lakes and lagoons, which range coincides very closely to the values reported by Dekker (2000b).

6.4.6. Sex ratios

The sex ratio of eels was more evenly split in lagoon habitats than in rivers and lakes. In Mediterranean rivers, there were more male silver eels than females, while in lakes there were more females than males. These population characteristics have been described for other brackish water systems, including the Thames estuary in the United Kingdom (Naismith and Knights, 1993) and the Camargue lagoons (Melià *et al*., 2006; Reckordt *et al*., 2014). Generally, the proportion of males in an eel stock decreases with increasing distance between the freshwater body and the sea (Penáz and Tesch, 1970).

Higher proportions of females to males have also been observed in other estuaries, coastal lagoons and rivers (Fernandez-Delgado *et al*., 1989; Ciccotti *et al*., 2012). Sexual differentiation in eels has been described as environmentally dependent, namely on density (Vøllestad and Jonsson, 1988; Krueger and Oliveira, 1999) and temperature (Beullens *et al*., 1997). Several authors have also suggested that growth in the early stages of development may influence the future sex of eels (Holmgren and Mosegaard, 1996; Holmgren, Wickstrom and Clevestam, 1997).

6.5. ANALYSIS OF ESCAPEMENT IN THE MEDITERRANEAN

6.5.1. Introduction

European eel is a species that performs long-distance migrations, covering several thousand kilometres, the details of which are still largely unknown (Aarestrup *et al*., 2009; Righton *et al*., 2016). It is a panmictic species (Als *et al*., 2011; Palm *et al.*, 2009), and adult fish congregate in the Sargasso Sea to spawn. The leptocephali drift with ocean currents and transform into glass eels along the continental shelf before entering continental waters in the form of estuaries or coastal lagoons for months or years until they approach the mouths of freshwater rivers. They then undergo a full transformation in morphology, physiology and behaviour. They move from their planktonic oceanic environment, migrate upstream during the summer (Durif, Dufour and Elie, 2005; Balm *et al*., 2007) and live for several years as apex freshwater predators. As they become sexually mature, they reverse their migration downstream during the autumn towards the ocean and back to spawning grounds to complete their life cycle (Deelder, 1984; Vøllestad *et al.*, 1986). However, in some cases, a substantial portion of the migration may also occur in the spring (Aarestrup *et al*., 2008; Reckordt *et al*., 2014; Stein *et al*., 2016).

Seasonal yellow eel migrations in coastal and estuarine waters are well recorded. However, observations from both silver eel fisheries in autumn and year-round downstream trapping, such as that described by Vøllestad and Jonsson (1986), confirm that downstream movement of yellow eels is rare, although local movements from shallow to deep water in winter have been observed (Moriarty, 2003). The downstream migration of anguillid species has been the subject of several studies. According to Tesch (2003), in the northern hemisphere, the autumn downstream migration of silver eels takes place earlier at higher latitudes (in August and September) than at lower latitudes, where migration occurs between October and January (Haro, 2003). However, permanent monitoring in the Warnow River in Germany revealed continuous migration activity with high temporal variation (Reckordt, *et al*., 2014). A better understanding of the dynamics of eel migrations is required to ensure maximum escapement of silver eels from each catchment (Feunteun, 2002; Baisez and Laffaille, 2005; Laffaille *et al*. 2006; Acou *et al*., 2008).

In 2007, the European Union adopted regulation 1100/2007 to support the protection of European eel, establishing measures for the recovery of the stock. To step up the protection effort beyond the measures taken at the national level, in 2018 the European Union introduced a closure period of three consecutive months via the annual "TAC and quota regulation" (regulation 2018/120 for the 2018 fishing season and regulation 2019/124 for the 2019 fishing season). In 2018, the closure covered commercial marine catches of eels longer than 12 cm in European Union waters of the ICES area, and the three-month closure was to be set by each Member State between 1 September 2018 and 31 January 2019. In 2019, the scope of the closure was extended to also cover catches in transitional waters, recreational catches and eels at all life stages (including glass eels and elvers). Moreover, the TAC and quotas regulation for 2019 transposed the closures determined in Recommendation GFCM/42/2018/11 for a multiannual management plan for European eel in the Mediterranean Sea. The consecutive three-month closure was to be set by Member States between 1 August 2019 and 29 February 2020 for the European Union waters of the ICES area and in accordance with the conservation objectives of the recommendation and the migration patterns of eel in the waters of GFCM contracting and cooperating non-contracting parties (CPCs) in the Mediterranean. For the Mediterranean, the closures were adopted as transitional measures, pending the results of this European Union-funded GFCM research programme.

The main task of the present analysis (within WP 3) was to review, widen and update information and data on yellow and silver eel migration in the different relevant regions in the Mediterranean and the European Union, with the aim of defining the migration period and peak time of escapement of European silver eels towards the Sargasso Sea, the period and peak time of migration of yellow eels, when relevant (when, where from and where to), and to facilitate targeted protection measures.

6.5.2. Methodology

Less information on the seasonality of migration was available for yellow eels and silver eels. The seasonality of migration of silver eels can differ between the northern and southern parts of the species' distribution area (Amilhat *et al.*, 2019). Therefore, WP 3 relied on thorough research and collection of all available information, old and recent, on yellow and silver eel migration timing and peaks at Mediterranean sites. Data was collected through literature searches, the compilation by partners of a dedicated spreadsheet within WP 3, and the gathering of data from any monitoring and survey activities carried out in countries, within any national framework.

An intensive literature review was conducted in order to compile data that would describe the temporal migratory patterns of European eel in the Mediterranean and European Union countries. Papers were obtained through specific queries on the ISI WEB of SCIENCE, SCOPUS and Google Scholar. Data on various life-history traits were extracted from figures, tables or the text of the publications using the following search term combinations: upstream migration timing, downstream migration and escapement seasonality and peak.

All studies were re-examined in detail to extract important information about site location and features, migratory behaviour, seasonality and any other factors. Data were standardized when necessary and used to create tables and a matrix for the descriptive aspects of escapement and to perform subsequent analyses. All data from monitoring, landings and literature from different sources were merged and analysed irrespective of the source or type of data (quantitative or qualitative).

Prior to analysis, the papers were examined to identify and describe the seasonality patterns within European regions. All relevant quantitative data, as monthly occurrences over an annual cycle at the same location, were normalized to proportions according to Righton *et al*. (2016). Studies reporting only qualitative data, such as the start and end of the migration season, peak of occurrence or presence at a specific site and month, were converted into ranks of occurrence per month according to a scale ranging from 0 to 4 (xxxx), with 0 equivalent to no catch, x equivalent to 0 to 25 percent of total occurrence, xx equivalent to 25 to 50 percent, xxx equivalent to 50 to 75 percent, and xxxx equivalent to 75 to 100 percent (peak of presence).

The search returned 72 scientific papers and yielded data from 20 countries, providing good coverage. All data were checked for quality. A technical quality check included duplication of rows, site names with spelling errors, inconsistencies between coordinates and sites (for example, same site with different coordinates, or same coordinates for different sites), errors in habitat classification and empty cells. Captured time series were verified with scientific partners, and grey literature and data from reports were cross-checked for consistency.

A clear distinction was made between the actual reported zero-values and "no data available". In this sense, only the actual zero-values have been kept, i.e. when a measurement has been made and the observation is 0 units.

Monitoring was selected according to the number of months with non-zero-values and more than five months per year. To avoid a reduction in spatial coverage, for countries with only a few years of time series available, the limit value was reduced to three months. In all other cases, data series of less than five months were not considered.

Results of migration timing and peaks were described separately for each eel life-stage (yellow eels and silver eels) and habitat type (freshwater, transitional, lagoons and lakes). The information collated from literature for each life stage should be considered as a complement to the information obtained from the database of WP 3.

6.5.3. Results

Seven of the nine partner countries provided data on the seasonality of silver eels (Table 6.5). These data covered two habitat types, with 42 sites in lagoons and eight sites in rivers. The integrated data from scientific partners and literature are depicted in Figure 6.17. The map shows that seasonality of yellow and silver eels was recorded at 47 Mediterranean sites. The sites covered all habitats inhabited by eels (as identified by the Habitat-task in WP3). The migration period of yellow eels was recorded at six river sites, two freshwater lakes, two lagoons in Greece and Italy and one river estuary in France (Gironde estuary).

The migration period of silver eels was covered by 45 sites, including 28 sites in lagoons with varying environmental characteristics, 12 sites in rivers, three sites in freshwater lakes and two estuary sites in France and Tunisia (Figure 6.17). Many rivers were of intermediate size, and due to their small size, some were referred to as creeks. Some rivers in Sardinia (Italy) and Tunisia are seasonal rivers that dry up at different times of year.

The majority of the papers give details on the effects of environmental factors on the timing and duration of migration, including hydrological variables (e.g. discharge, flow velocity and water temperature), climatic variables (e.g. barometric pressure, precipitation and air temperature) and the lunar cycle. Many papers addressed the silvering process, which involves a series of morphological and physiological transformations marking the transition between a sedentary growth phase (yellow eel) and a catadromous (downstream) migration phase (silver eel) and prepares the eels for deep sea migration. Several recent papers used electronic tagging techniques and telemetry to map the oceanic migration. This information was very valuable for understanding the dynamics of eel migrations.

European eel is one of the major components of many estuarine and fluvial aquatic systems. The species is found in practically all habitat types; it is quite often the only species that occurs in shallow waters unsuitable for any other species, and it dominates the fish communities of many inland aquatic systems. For example, it represents more than 50 percent of the fish biomass in estuarine systems, such as lagoons (Feunteun, 1994; Feunteun and Marion, 1994), and in rivers of the Mediterranean or the Atlantic coast, at least in their downstream reaches (Chancerel, 1994; Feunteun *et al*., 1998). Evidence from literature indicated that physical structures in water bodies represent an important habitat component providing appropriate refuge for eels. Where such structures are lacking, eels will be more susceptible to predation. Literature also shows that structural heterogeneity within water bodies influences the abundance of macroinvertebrates (Walker *et al*., 2013), which are an important component of the eel diet.

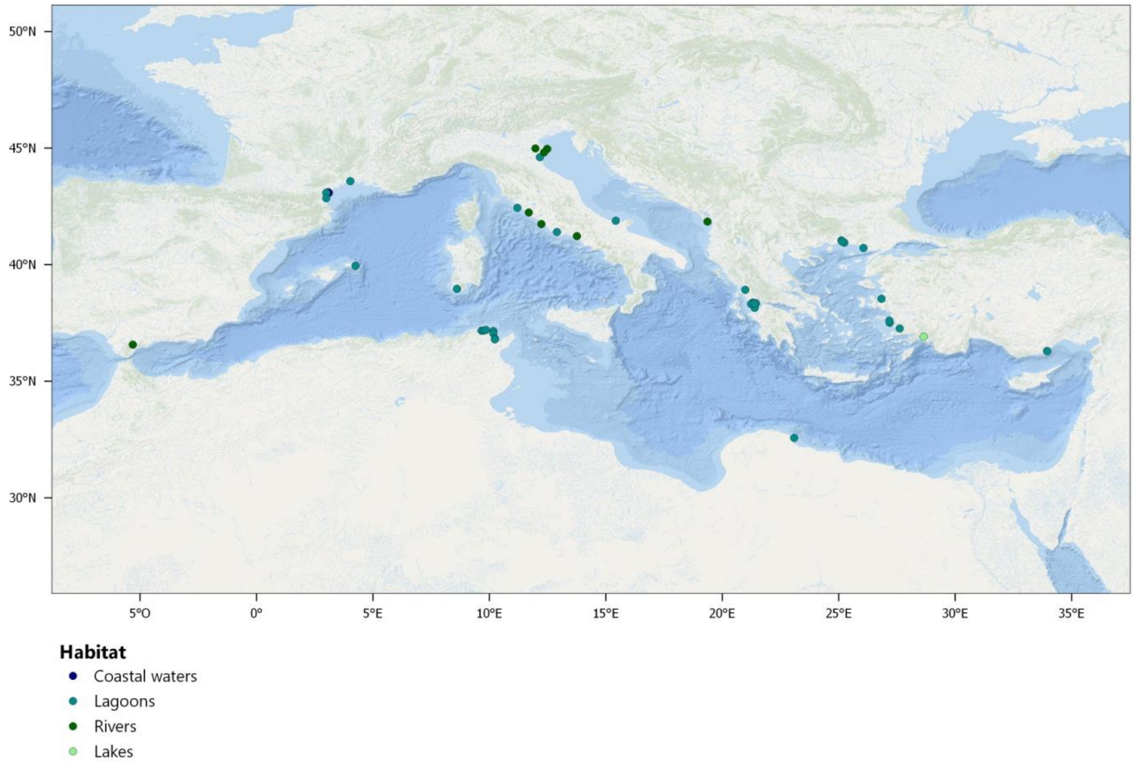


Figure 6.17. Map showing the location of the 47 Mediterranean sites where silver eel escapement was documented from literature, fisheries, scientific surveys and monitoring (reference years 1979–2021). The colour of the circle indicates the habitat type of the sites.

Methodologies adopted to study the seasonality and migration periods of yellow and silver eel differed among the papers and between sites. Figure 6.18 shows the methodology or the type of survey that yielded the information on silver eel migration and escapement at each site. Most of the papers (33.5 percent) used scientific monitoring, and about 30 percent of the papers used fishery-dependent data. In many of the papers (15.3 percent) and for many sites, detailed observations and sampling were carried out, lasting one year or one season, though in some cases across several years.

At many sites, monitoring schemes have been put in place in recent years (*Monitoring*), sometimes focusing on sites already surveyed previously. Sandlund *et al*., (2017) analysed the time series of silver eel downstream migration in Burrishoole, Ireland (1971–2015), and Imsa, Norway (1975–2015) to determine factors regulating silver eel migration from freshwater to the sea. Righton *et al*., (2016) used fishery data from 20 rivers across Europe and concluded that peak escapement occurred between August and December (*Fishery-based*).

Recently, acoustic telemetry methods have been used intensively, particularly in northern Europe, to track the movements of eel migration (Simon, *et al*., 2011; Tambets *et al*., 2021) as a scientific survey. Monteiro *et al*. (2020) also used this methodology in the Mondego River, Portugal, located further south.

Data on longer-term abundance of silver eels was available only for rivers and lagoons in Italy and for estuaries in France (*Fishery-based*), where more-or-less complete time series were available.

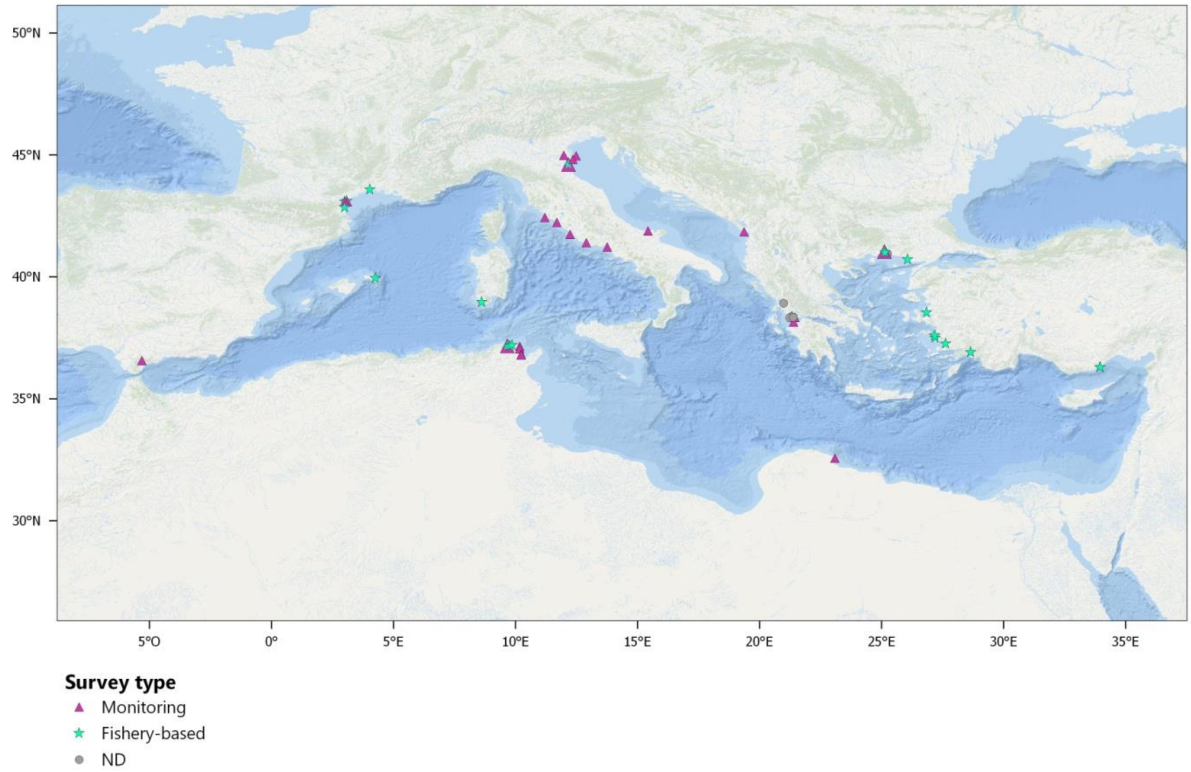


Figure 6.18. Map showing the survey type that yielded the information on silver eel escapement at each sites, either from fisheries or monitoring for the years 1979–2021. (Monitoring = data from monitoring with varying methodologies; fishery-based = time series from monitoring with methodologies overlapping with fishing activities; ND = no data available on the methodology).

Three data sources – fisheries, monitoring data from the WP 3 spreadsheet and information from literature – were used to provide information on seasonal silver eel migration patterns in the Mediterranean. Table 6.5 shows an overview of the presence and relative abundance of silver eels during each single month based off information obtained from eight countries related to single sites and habitat types, specifying also the source of data and reference years. Although migration occurs all year round in certain locations, such as in the Guadiaro River in Spain and the Köyceğiz lagoon in Türkiye, there is a distinct seasonal pattern of migration, with a main peak in the autumn and early winter months from October to February (Figure 6.19). A second peak occurring in March was also recorded in the Comacchio lagoon in Italy (Table 6.5).

Table 6.5. Seasonal occurrence of silver eel along the Mediterranean coasts. Data per year of several years of monitoring per site have been averaged per month. Data available per site before and after the implementation of the Eel regulation is reported separately. Empty cell = no monitoring; 0 = no catch; x = ≤ 25 percent of total occurrence; xx = <50 percent; xxx = < 75 percent; xxxx = ≤ 100 percent, peak of presence. ND = no data available. RIV = river; LAG = lagoon. Source: M = monitoring; L = literature. Survey type: SM = scientific monitoring; FD = fisheries-dependent monitoring.

Country	Habitat	Site	Source	Survey type	Year	Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Reference
Spain	RIV	Guadiaro	M	SM	2015	S	X	X	X	X	X	X	XX	XX	XX	XX	X	X	EMP Andalusia, 2010
Spain	LGN	Albufera	L	FD	2006–2012	S									X	X	X	X	Righton *et al*., 2016
France	LGN	Bages-Sigean	L	FD	2007	S										X	XX	X	Amilhat *et al*., 2009
France	LGN	Or	L	FD	2009–2010	S	X									XX	X	X	Charrier *et al*., 2012
France	LGN	Bages-Sigean	M	SM	2019–2021	S	X	X	X	X						X	XX	X	Lagarde *et al*., 2019
France	LGN	Salses-Leucate	L	FD	2006–2012	S									X	X	X	X	Righton *et al*., 2016
France	LGN	Gruissan	L	FD	2006–2012	S									X	X	X	X	Righton *et al*., 2016
Italy	LGN	Comacchio	L	FD	2011	S	XXX								XX	X	XXX	XXX	Aschonitis *et al*., 2017
Italy	LGN	Porto Pino	L	FD	1979–1981	S	X	X									X	XXX	Rossi and Cannas, 1984
Italy	LGN	Comacchio	M	SM	2011	S			XX	X	XXX	X				XXX	XX		DCF (Reg. 199/2008)?
Italy	LGN	Fogliano	M	SM	2014–2019	S	XX	X	0							X	XX	XX	ARSIAL 2014-2019
Italy	RIV	Marta	M	SM	2014–2015	S	XXX	X								0	X	XX	ARSIAL2013?
Italy	RIV	Tevere	M	SM	2014–2019	S	X	X	0							X	XX	XXX	ARSIAL2014-15
Italy	RIV	Garigliano	M	SM	2017–2018	S										XX	XXX	X	Unimar?
Italy	LGN	Lesina	M	SM	2017–2018	S										XX	XX	X	Unimar?
Italy	LGN	Orbetello	M	SM	2019	S										0	XX	XXX	Unimar?
Italy	RIV	Po	M	SM	2019	S										XX	XX	XX	Unimar?
Italy	RIV	Po di Berra	M	SM	2019	S										XX	XX	XX	Unimar?
Italy	RIV	Po di Goro	M	SM	2019	S										XX	XX	XX	Unimar?
Tunisia	LGN	Ichkeul	L	FD	2013–2014	S	X	X										XXX	Derouiche *et al*., 2016
Tunisia	LGN	Ghar El Melh	L	SM	2006	S	X	XX									XX	X	Kalai, 2008
Tunisia	LGN	Tunis South	L	SM	1980	S	X	X	XX								XX	X	Sanekli, 1981
Tunisia	LGN	Tunis North	L	SM	2005	S	X	X	XX								XX	XXX	Attya; 2006
Tunisia	LGN	Ichkeul	L	SM	2004–2007	S	X	XX									XX	X	Hizem Habbechi, 2014
Tunisia	LGN	Kalaat El Andalous	L	SM	2007	S	X	XX									XX	X	Hizem Habbechi, 2014
Tunisia	LGN	Tunis North	L	SM	2010–2015	S	X	XX									XX	X	Derouiche *et al*., 2016
Tunisia	LGN	Ghar El Melh	L	SM	2010–2015	S	X	XX									XX	X	Derouiche *et al*., 2016
Tunisia	LGN	Ichkeul	L	SM	2010–2015	S	X	XX								X	XX	XXX	Derouiche *et al*., 2016
Albania	RIV	Buna	M	SM	2020	S	XXX	X	X								XX	XXXX	CSBL (III)?
Libya	LGN	Umm Hufayan	L	SM	2015	S	X	X								X	X	XXX	Abdalhamid *et al.*, 2018
Greece	LGN	Messolonghi-Etoliko	L	FD	1988–1998	YS				X	X	X	X	XX	XXX	XXXX	XXXX	XXX	Katselis *et al*., 2003
Greece	LGN	Vistonida-Porto Lagos	L	FD	2012–2013	S	X	X	X							X	X	X	MacNamara *et al*., 2014
Greece	LGN	Vistonida	M	SM	2009	S	XX	X									X	XX	EU project - DCF?
Greece	LGN	Vistonida	M	SM	2012–2019	S	XX	X									X	XX	EU project - DCF
Greece	LGN	Prokopou	M	SM	2015	S	XX	X									X	XX	EU project - DCF
Greece	LGN	Klisova	M	SM	2014	S	XX	X									X	XX	EU project - DCF
Greece	LGN	Palaiopotamos	ND	ND	2014	S	XX	X									X	XX	ND
Greece	LGN	Ptelea	ND	ND	2014	S	XX	X									X	XX	ND

Country	Habitat	Site	Source	Survey type	Year	Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Reference
Greece	LGN	Prokopanistos	ND	ND	2014	S	XX	X									X	XX	ND
Greece	LGN	Shoinias	ND	ND	2014	S	XX	X									X	XX	ND
Greece	LGN	Tholi	ND	ND	2014	S	XX	X									X	XX	ND
Greece	LGN	Vasiladi	ND	ND	2014	S	XX	X									X	XX	ND
Türkiye	LGN	Akgöl-Paradeniz	L	FD	2007	S		X	X	X	X	X	X	X	X	X	X		Rad *et al*. 2013
Türkiye	LGN	Köyceğiz	L	FD	1986	S	X	X	X	X	X	X	X	X	X	X	X	X	Yerli, 1991
Türkiye	LGN	Enez	L	FD	2014–2015	S	X	X					X	X	X	X	X	X	Tosunoğlu *et al.*, 2017
Türkiye	LGN	Homa	L	FD	2014–2015	S	X	X					X	X	X	X	X	X	Tosunoğlu *et al.*, 2017
Türkiye	LGN	Akköy	L	FD	2014–2015	S	X	X					X	X	X	X	X	X	Tosunoğlu *et al.*, 2017
Türkiye	LGN	Karina	L	FD	2014–2015	S	X	X					X	X	X	X	X	X	Tosunoğlu *et al.*, 2017
Türkiye	LGN	Güllük	L	FD	2014–2015	S	X	X					X	X	X	X	X	X	Tosunoğlu *et al.*, 2017
Türkiye	LGN	Köyceğiz	L	FD	2014–2015	S	X	X					X	X	X	X	X	X	Tosunoğlu *et al.*, 2017

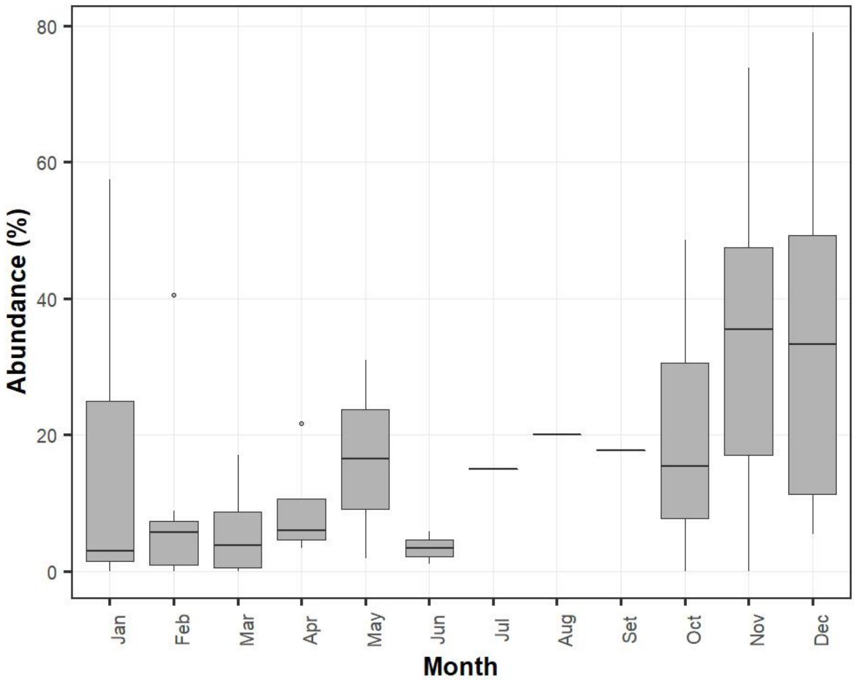


Figure 6.19. Relative abundance (percent) of silver eels in lagoon and riverine habitats

Information from a number of countries revealed different seasonal escapement patterns in the different habitats (Figure 6.20). Lagoons showed an autumn migration period from October to March, based on data from Italy. Data mostly from France on the monthly abundance of silver eels in estuaries showed that the migration period extends almost year-round with a distinct peak in November and a second peak in March–April. In rivers, based mostly on data from Italy, a main seasonality period for silver eels was recorded from October to February.

Data were very scarce for yellow eel migration seasonality, with no complete time series representing the abundance of migrating yellow eels. However, it could be concluded that yellow eel migration occurs from April to October in rivers, from April to June in estuaries and from April to August in lakes. However, a distinct peak in May and June was observed in all three habitats (Table 6.6).

Table 6.6. Seasonal pattern of yellow and silver eel migration in different habitats. Empty cell = no monitoring; 0 = no catch; x = ≤ 25 percent of total occurrence; xx = <50 percent; xxx = < 75 percent; xxxx = ≤ 100 percent, peak of presence. Stage: S = silver eel; Y = yellow eel; SY = mixed silver and yellow eel. RIV = river; LGN = lagoon; RIE = estuary

	Stage	***Jan***	***Feb***	***Mar***	***Apr***	***May***	***Jun***	***Jul***	***Aug***	***Sep***	***Oct***	***Nov***	***Dec***
RIV	S	x	x	x	x	x	x	x	x	x	xx	xx	xx
RIV	Y				x	xxx	xxx	x	x	x	x		
LGN	S	xx	x	x	x	x	x	x	x	x	x	xx	xx
LGN	SY								x	x	xx	xx	x
RIE	S	x	x	x	x	x	x	x	x	x	x	xx	x
RIE	Y				x	xx	x						
LAK	Y			x	x	xx	xx	x	x				

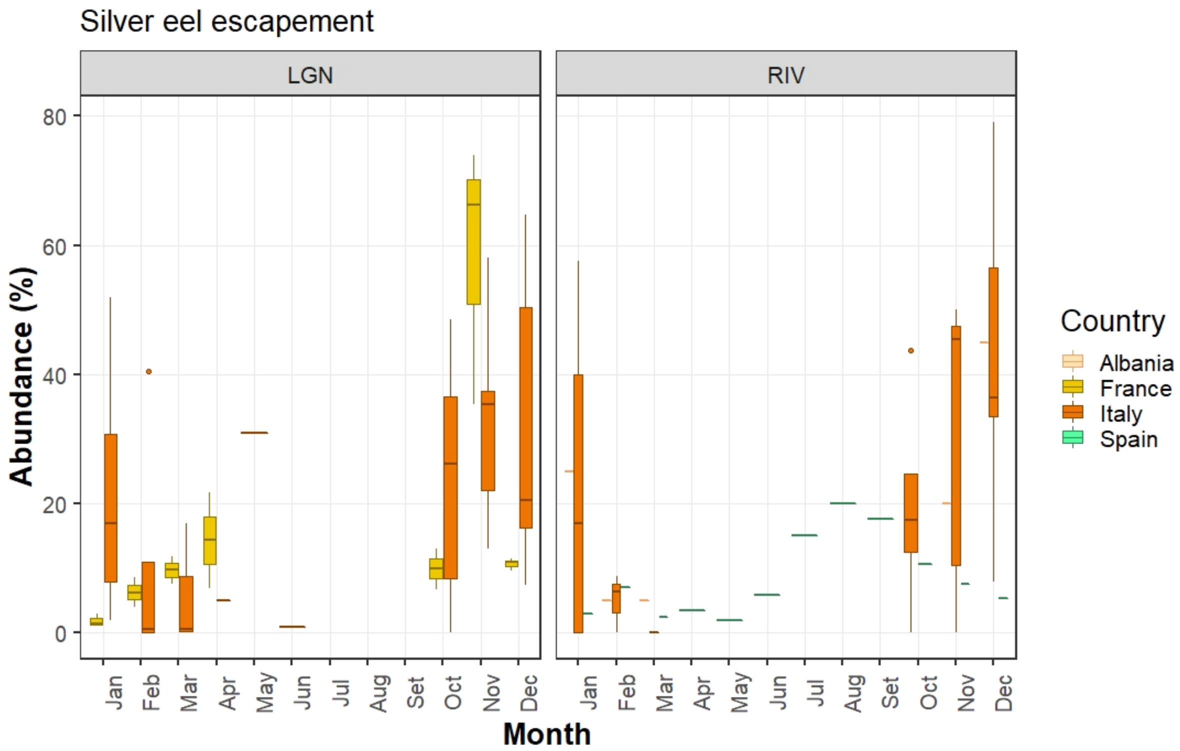


Figure 6.20. Relative abundance (percent) of silver eels by habitat (RIV = river; LAG = lagoon) and country.

The literature review covered 41 sites from 20 countries including four habitat types: rivers, lagoons, freshwater lakes and estuaries (Table 6.7). The information on the timing, duration and peaks of migration of yellow and silver eels were extracted from figures, tables and the text of publications.

It is well documented that European eel exhibit two transoceanic migrations, one towards their marine spawning ground and the other towards coastal or inland waters (Feunteun *et al*., 2000). Conversely, upstream migration mechanisms and movements in freshwater habitats are not very well documented. Most of the scientific literature describing the life history and movement dynamics of yellow eels (Holmgren, Wickstrom and Clevestam, 1997; Baras *et al.*, 1998; Chadwick *et al.*, 2007; Riley *et al.*, 2011) suggest a spring (March to June) upstream migration, while other authors (Naismith and Knights, 1988; Durif, Dufour and Elie, 2005) report a longer period, extending from April to October. The seasonal movement of yellow eels depends upon population characteristics (density and size), environmental conditions (seasonal variations in habitat quality) and individual ontogenetic history (Feunteun *et al.*, 2003). Metamorphosis from the yellow phase to the silver phase begins weeks to months before downstream or seaward migration (Fontaine, 1994).

Only a few scientific studies explicitly measure the peak time or duration of European silver eel escapement. A literature review suggested that downstream migration of adult anguillid eels in freshwater habitats marks the end of a long and generally slow growth phase and the initiation of a seaward spawning migration. Haro (2003) stated that for temperate and subtropical *Anguilla* spp., migratory periods are usually associated with decreasing water temperatures and increasing flow. *Anguilla* spp. in the northern hemisphere usually emigrate between August and December, while those in the southern hemisphere leave freshwater habitats between January and March. However, Tesch (1977) concluded that the migration date of *A. anguilla* could not be predicted based on geography alone. Using fishery data from 20 rivers across Europe, Righton *et al*., (2016) showed that most eels begin their oceanic migration between August and December.

Studies such as Feunteun *et al*. (2000) and Acou *et al*. (2008) in the Frèmur River in France reported a downstream migration occurring in the spring, with these movements often occurring in areas regulated by dams. Silver eel spring migration was also reported in the Gudenå River and Randers Fjord in Denmark (Aarestrup *et al.*, 2008, 2009). Spring migration of silver eels, in addition to autumn runs, have also been reported in Lake Fardume in Sweden (Westin, 2003) and in the Warnow River in Germany (Reckordt *et al*., 2013).

The downstream migration of silver eels has been extensively investigated by means of telemetry in northern Europe, for example in the Elbe and Havel Rivers in Germany (Stein *et al*., 2016; Righton *et al*., 2016) and in the Narva River in Estonia (Tambets *et al*., 2021). A study using the same methodology was also conducted in the Mondego River, Portugal, in southern Europe (Monteiro *et al.*, 2020).

In southern Norway on the Imsa River, migration can start as early as July, but the main peak is in September and October, while most individuals have migrated by November. (Vøllestad *et al*., 1986; Sandlund *et al.*, 2020). The timing of migration is similar in Ireland, with an early start in July to August and a maximum in November (Sandlund *et al*., 2017) in the Burrishoole River, while MacNamara and McCarthy (2012) recorded an extended period of migration until February in the Shannon River. The silver eel migration season on the River Erne in Ireland typically occurs from late August or early September through early January of the following year (Matthews *et al*., 1999). In Portugal on the Mondego River, silver eels start their downstream migration in October, and escapement to the sea occurrs from late December until late January.

In Libya, along the southern coast of the Mediterranean, Abdalhamid *et al*., (2018) reported that the migration of silver eels in Umm Hufayan lagoon peaked in December, while in Tunisian lagoons, the migration period extended from November until March. In the eastern Mediterranean (Türkiye), silver eels are caught all year round.

From these studies, it appears that the onset of migration is related to geographical location (Amilhat *et al*., 2016; Capoccioni *et al*., 2014) and the distance that migrating eels must travel to reach the Sargasso Sea (Derouiche *et al*., 2016). It appears that eels start migrating earlier at northern latitudes, such as in the Imsa River in Norway (Vøllestad *et al*., 1986). Bergersen and Klemetsen (1988) studied eels from the northern limit of their distribution area along the northern Norwegian coast and concluded that silver eels mostly migrated in August, though they started in July. By leaving earlier, these eels, which have more distance to cover, will likely reach the spawning ground at the same time as other subpopulations.

Table 6.7. List and characteristics of the scientific studies reviewed dealing with the timing and peaks of silver and yellow eel migration. LGN = lagoon, RIV = river, RIE = river estuary, LAK = lake. Habitat: T = transitional waters, F= freshwater. Stage: S = silver eel, Y = yellow eel

Author	Country	Site	Habitat_code	Habitat	Stage	Year of sampling	Study type	Gear/Monitoring equipment
Rossi and Cannas, 1984	Italy	Porto Pino	LGN	T	S	1979–1981	Fishery-dependent	Fykenet, barrier
Aschonitis *et al*., 2017	Italy	Comacchio	LGN	T	S	2011	Fishery-dependent	Fykenet, net
Feunteun *et al*., 2000	France	Frémur	RIV	F	S (majority), YS	Sep 1996–Jun 1998	Scientific monitoring	Trap
Acou *et al*., 2008	France	Frèmur	RIV	F	S	1996–2004	Scientific monitoring	Trap
Amilhat *et al*., 2009	France	Bages- Sigean	LGN	T	S	2007	Fishery-dependent	Fykenet, net
Charrier *et al*., 2012	France	Or	LGN	T	S	Oct 2009–Jan 2010	Fishery-dependent	Fykene, net
Westerberg *et al*., 2021	France	Captured in French lagoons/ released in the Gulf of Lion		T	S	2013–2015	Scientific monitoring	Satellite tags
Durif, Dufour and Elie, 2005	France	Loire	RIV	F	S	2000–2002, 1994–2002	Scientific monitoring	Stow nets, pots, fyke, electrofishing
Durif, Dufour and Elie, 2005	France	Nive	RIV	F	S	2000, 2002	Scientific monitoring	Trap, electrofishing
Durif, Dufour and Elie, 2005	France	Certes	RIV	F	S	1999, 2001	Scientific monitoring	Trap
Durif, Dufour and Elie, 2005	France	Rhine	RIV	F	Y	1996–2002	Scientific monitoring	Electrofishing, fyke nets
Durif, Dufour and Elie, 2005	France	Sainte-Eulalie	RIV	F	S	2001–2002	Scientific monitoring	Eel weir
Durif, Dufour and Elie, 2005	France	Gironde estuary	RIE	T	Y	2001	Scientific monitoring	Trawl nets
Righton *et al*., 2016	France	Loire River and the Salses Leucate and Gruissan lagoons	RIV, LGN	T	S	2006–2012	Fishery-dependent	Fishing gear
Simon *et al*., 2011	Germany	Havel	RIV	F	pre-S, S	2007–2009	Fishery-dependent	Fishery gear, telemetry
Reckordt *et al*., 2013	Germany	Wornow	RIV	F	S			
Behrmann and Eckmann, 2003	Germany	Mosel	RIV	F	S			
Stein *et al*., 2016	Germany	Elbe	RIV	F	S	2007–2011		Telemetry
Righton *et al*., 2019	Germany	Eide and Havel	RIV	F	S	2006–2012	Fishery-dependent	Fykenet, stownet
Sandlund *et al*., 2017	Ireland	Burrishoole	RIV	F		1971–2015	Scientific monitoring	Trap
MacNamara and Mc Carthy, 2012	Ireland	Shannon	RIV	F	S	2008–2011	Fishery-dependent	Trap, fykenet
Rad *et al*., 2013	Türkiye	Göksu River Basin (Akgöl and Paradeniz)	LGN	T	S	2007	Fishery-dependent	Barrier

Author	Country	Site	Habitat_code	Habitat	Stage	Year of sampling	Study type	Gear/Monitoring equipment
Cobo, Sánchez-Hernández and Vieira, 2014	Spain	Ulla	RIV	F	S, Y	1999–2011	Scientific monitoring	Trap
Righton *et al.*, 2020	Spain	La Alburfera	LGN	F	S	2006–2012	Fishery-dependent	Fishing gear
Derouiche *et al.*, 2016	Tunisia	Ichkeul	LAK	F	S	2013–2014	Fishery-dependent	Fykenet, barrier
Righton *et al.*, 2017	Ireland	Shannon River; Lough Mask and Lough Owel lakes	RIV, LAK	T	S	2006–2012	Fishery-dependent	Fishing gear
Righton *et al.*, 2018	Sweden	Enningdal and Atran	RIV	F	S	2006–2012	Fishery-dependent	Trap, fishing gear
Holmgren, Wickstrom and Clevestam, 1997	Sweden	Fardime tra¨sk	LAK	F	S			
Holmgren, Wickstrom and Clevestam, 1997	Sweden	Fardime tra¨sk	LAK	F	Y			
Chadwick *et al.*, 2007	Scotland	Dee	RIV	F	Y			
Tosunoğlu *et al.*, 2017	Türkiye	Enez, Homa, Karina, Akköy, Güllük, and Köyceğiz	LGN	T	S	2014–2015	Fishery-dependent	Fykenet, barrier
Abdalhamid *et al.*, 2018	Libya	Umm Hufayan	LGN	T	S	2015	Scientific monitoring	Fykenet, net
Correia *et al.*, 2019	Portugal	Santo Andre	LGN	T	S	2011–2012, 2016–2017	Fishery-dependent	Fykenet
Sandlund *et al.*, 2020	Norway	Imsa	RIV	F	S	1975–2015	Scientific monitoring	Trap
Durif *et al.*, 2020	Norway	Imsa	RIV	F	S (majority), Y	1975–2017	Scientific monitoring	Trap
Baras *et al.*,1998	Belgium	Meuse	RIV	F	Y			
Tambets *et al.*, 2021	Estonia/ Russia	Narva Reservoir and Narva River	RIV	F	S	2018–2019	Scientific monitoring	Acoustic telemetry
Katselis *et al.*, 2003	Greece	Messolonghi-Etoliko	LGN	T	YS	1988–1998	Fishery-dependent	Fykenet, barrier
MacNamara *et al.*, 2014	Greece	Vistonis	LAK	F	S	2012–2013	Fishery-dependent	Barrier
Balm *et al.*, 2007	Netherlands	Grevelingen	LAK	F	Y			
Balm *et al.*, 2007	Netherlands	Grevelingen	LAK	F	S			
Aarestrup *et al.*, 2008	Denmark	Gudenaa	RIV	F	S			
Aarestrup *et al.*, 2009	Denmark	Randers Fjord	RIV	F	S			
Naismith and Knights, 1988	England	Thames	RIV	F	Y			
Riley *et al.*, 2011	England	Itchen	RIV	F	Y			
Monteiro *et al.*, 2020	Portugal	Mondego	RIV/RIE	F/T	S	2014–2016	Scientific monitoring	Acoustic telemetry

6.5.4. Discussion

European eels make one of the longest animal migrations (Righton *et al.*, 2016) of any species, travelling between 5 000 and 10 000 km from their inland freshwater, brackish water and seawater feeding habitats to their spawning area in the Sargasso Sea. In the context of efforts to increase European eel spawning biomass, reliable measurements of the escapement of silver eels are necessary to assess the effectiveness of conservation management measures. The results of this research programme, particularly monitoring the seasonality of silver eel escapement, might be helpful to design more efficient eel conservation management strategies in the Mediterranean.

The seasonal pattern of silver eel migration in the Mediterranean was described using data from fisheries, monitoring data in the WP 3 spreadsheet and data from literature. Although silver eels are caught year-round in certain locations, such as on the Guadiaro River in Spain, the Bages-Sigean lagoon in France and the Köyceğiz lagoon in Türkiye, there is a distinct seasonal pattern of migration, with a main peak in the autumn and early winter months (October–February), though a second peak centred in March was also recorded in the Comacchio lagoon in Italy. These results are comparable to those recorded by almost all authors interested in the seasonality of silver eel escapement (See Table 6.3).

Silver eel migration monitoring was carried out between 1999 and 2001 on the River Nive in France (Durif, 2004; Durif *et al*., 2003; Gosset *et al*., 2005). In 1999, migration occurred over a period of 19 days out of 60 sampling nights. Of the total number of eels caught in the trap, 75 percent were captured during eight consecutive nights. In 2000, migration was monitored for 75 days, and the eels migrated during 20 of those days, with 36 percent of the silver eels migrating during two consecutive nights. Finally in 2001, monitoring took place for 90 days, and eels were caught on 22 days, with 40 percent of the eels being captured over four consecutive days. All these studies concluded that silver eels start their spawning migration in September and it extends into February.

Downstream migration of anguillids has been linked to a variety of putative environmental variables, including hydrological variables (for example, discharge, flow velocity and water temperature), climatic variables (for example, barometric pressure, precipitation and air temperature) and the lunar cycle. Investigations described by Oberwahrenbrock (1999) in the River Mosel at the Fankel hydropower station in Germany showed that during three months of nocturnal sampling (by means of an anchored 10 × 5 m stow net in the tailrace of the hydropower station), a migration peak was observed one night during a waning moon and a period of increase in river discharge.

Silver eel migration is often linked to increasing discharge events (Lowe, 1952; Hadderingh *et al.*, 1999) from both natural and artificial sources (Cullen and McCarthy, 2003; Acou, *et al.*, 2005). Discharge regulation is thought to obscure the periodicity of the lunar cycle in regulated river systems (Cullen and McCarthy, 2003; Acou, *et al.*, 2005). Some studies have reported no significant influence of moon phase on silver eel migration (Marohn, Prigge and Hanel, 2014; Reckordt, *et al.*, 2014), while experimental studies have concluded that eels avoid artificial light (Hadderingh *et al.*, 1999; Cullen and McCarthy, 2000) and show a preference for nocturnal behaviour (Petersen, 1906; Riley *et al.*, 2011).

In northern Brittany, France, Acou *et al*. (2008) observed migration peaks at water temperatures between 6°C and 10°C. Vøllestad *et al.* (1986) determined an optimal water temperature of around 9°C in Norwegian waters. In the German Warnow River, Reckordt *et al.* (2014) identified higher weekly migration rates at air temperatures above 10.4°C, in combination with increasing discharge and wind speed. Haro (1991) identified a range between 10°C and 18°C through experimental laboratory studies for Atlantic eels (*Anguilla* spp.).

Escapement within a given lagoon may change from year to year depending on environmental conditions and the age structure of the other stages in the eel population (Amilhat *et al*., 2009). On the other hand, in large rivers, eels may take several years before reaching the estuary (Amilhat *et al*., 2009). Therefore, interannual variations in migration peaks and periods within a specific catchment are influenced by a wide range of factors, including environmental conditions, the hydrographic conditions of the system, habitat type, small or large catchments and whether or not the system is tidal.

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Supplementary Material on the Methodology– Read Me Spreadsheet of the WP3 Local stock Database

Table 6SM.1. Metadata spreadsheet

Country	
Scientific Partners (senior + junior)	
Contact person name	
Ownership, point of contact of original data	Reference to the data collection
Contact person name	
Programme/Regulation/Official Stats.	
Methods used	A brief description of the data collection and processing methods: e.g. declarations, logbooks and interview (census or estimation of total captures from subsamples)
Data Quality Overview	Quality check on the data, both in terms of how the data were gathered and subsequently treated
WP3 Database description	Brief description of content of datasets
Nature of the data with respect to the original data scope	Raw, aggregated or analysed
Data processing procedures	Brief description of the data processing procedures: report on corrections, editing or quality control procedures applied to the data to suit the WP3 Database
Expert Judgment	
Data coverage with respect to the original data scope	Percent
Estimate of final uncertainty in the data	1 - low, 2- medium, 3 - high if medium or high add "underestimation" or "overestimation"
Any comments	

Table 6SM.2. Read me spreadsheet for Biological and ecological features of eel local stock

SITE INFORMATION	CODE	EXPLANATION	UNITS	TYPE OF UNITS	NOTES
Country	**Country_fullname**	Full name of your Country		Character	
Country code	**Country_code**	Two letter code of your Country		Character	
Region	**Region**			Character	
EMU	**EMU_nameshort**	See ***EMU*** codes in the *General INFO* spreadsheet		Character	
Habitat	**Habitat_code**	See ***HABITAT*** codes in the *General INFO* spreadsheet		Character	
Site	**Site_name**	The name you give to your site - add successive rows for different sites		Character	
Year	**Year**	Four digits (YYYY) - add successive rows for different years		Number	*it could be recorded also a single data on a specific site or a very old data*

GLASS EEL	CODE	EXPLANATION	UNITS	TYPE OF UNITS	NOTES
Data info					
Methodology	**Method**	Type of data collecting: fishery dependent, scientific monitoring		Character	
Info source	**Info_source**	Origin of the data collected: EU project (e.g. DCF [Reg. 199/2008], EU-MAP [Decision EU 2016/1251], etc.), national/regional/local project, other project (e.g. LIFE, Interreg, etc.), scientific papers, grey literature, data dependent on fishery, other data (specify)		Character	
Biometry					
Min lenght	**Length_min_G**	Minimum length **(in millimetres)** per site / year (glass eel)	mm	Number	*The measures are referred to the whole sample considered*

GLASS EEL	CODE	EXPLANATION	UNITS	TYPE OF UNITS	NOTES
Mean length	**Length_ave_G**	Average length **(in millimetres)** per site / year (glass eel)	mm	Number	*The measures are referred to the whole sample considered*
Max length	**Length_max_G**	Maximum length **(in millimetres)** per site / year (glass eel)	mm	Number	*The measures are referred to the whole sample considered*
Length standard deviation	**Length_SD_G**	Standard deviation of the length measurements per site / year (glass eel)		Number	*The measures are referred to the whole sample considered*
Min weight	**Weight_min_G**	Minimum weight **(in grams)** per site / year (glass eel)	g	Number	*The measures are referred to the whole sample considered*
Mean weight	**Weight_ave_G**	Average weight **(in grams)** per site / year (glass eel)	g	Number	*The measures are referred to the whole sample considered*
Max weight	**Weight_max_G**	Maximum weight **(in grams)** per site / year (glass eel)	g	Number	*The measures are referred to the whole sample considered*
Weight standard deviation	**Weight_SD_G**	Standard deviation of the weight measurements per site / year (glass eel)		Number	*The measures are referred to the whole sample considered*
Seasonality					

GLASS EEL	CODE	EXPLANATION	UNITS	TYPE OF UNITS	NOTES
Glass eel recruitment (seasonality info)	**Recru_G**	Description of the recruitment phase: kilograms of glass eels or percentage of glass eels per each month of the whole migration period. In case the quantitative data is not available, put an "X" for every month cell when the recruitment phase occurred and fill the month cells with a grey-scale colour linked to the glass eels abundance to identify start, peaks and end of the recruitment (e.g. dark grey for the peak phase)	kg, percent	Number, Character	*The main purpose is to describe the seasonality from a qualitative point of view at a regional level of key sites. You can have complete information (monitoring that covers the entire migration phase), or information not collected continuously or directly, but which can be integrated from e.g. literature, personal observation, fishers communications*

YELLOW EEL	CODE	EXPLANATION	UNITS	TYPE OF UNITS	NOTES
Data info					
Methodology	**Method**	Type of data collecting: fishery dependent, scientific monitoring		Character	

YELLOW EEL	CODE	EXPLANATION	UNITS	TYPE OF UNITS	NOTES
Info source	**Info_source**	Origin of the data collected: EU project (e.g. DCF [Reg. 199/2008], EU-MAP [Decision EU 2016/1251], etc.), national/regional/local project, other project (e.g. LIFE, Interreg, etc.), scientific papers, grey literature, data dependent on fishery, other data (specify)		Character	
Biometry					
Min length	**Length_min_Y**	Minimum length **(in millimetres)** per site / year (yellow eel)	mm	Number	*The measures are referred to the whole sample considered*
Mean length	**Length_ave_Y**	Average length **(in millimetres)** per site / year (yellow eel)	mm	Number	*The measures are referred to the whole sample considered*
Max length	**Length_max_Y**	Maximum length **(in millimetres)** per site / year (yellow eel)	mm	Number	*The measures are referred to the whole sample considered*
Length standard deviation	**Length_SD_Y**	Standard deviation of the length measurements per site / year (yellow eel)		Number	*The measures are referred to the whole sample considered*
Min weight	**Weight_min_Y**	Minimum weight **(in grams)** per site / year (yellow eel)	g	Number	*The measures are referred to the whole sample considered*
Mean weight	**Weight_ave_Y**	Average weight **(in grams)** per site / year (yellow eel)	g	Number	*The measures are referred to the whole sample considered*
Max weight	**Weight_max_Y**	Maximum weight **(in grams)** per site / year (yellow eel)	g	Number	*The measures are referred to the whole sample considered*
Weight standard deviation	**Weight_SD_Y**	Standard deviation of the weight measurements per site / year (yellow eel)		Number	*The measures are referred to the whole sample considered*
Min age	**Age_min_Y**	Minimum age per site / year (yellow eel)		Number	*The measures are referred to the whole sample considered*

YELLOW EEL	CODE	EXPLANATION	UNITS	TYPE OF UNITS	NOTES
Mean age	**Age_ave_Y**	Average age per site / year (yellow eel)		Number	*The measures are referred to the whole sample considered*
Max age	**Age_max_Y**	Maximum age per site / year (yellow eel)		Number	*The measures are referred to the whole sample considered*
Age standard deviation	**Age_SD_Y**	Standard deviation of the age measurement per site / year (yellow eel)		Number	*The measures are referred to the whole sample considered*

SILVER EEL	CODE	EXPLANATION	UNITS	TYPE OF UNITS	NOTES
Data info					
Methodology	**Method**	Type of data collecting: fishery dependent, scientific monitoring		Character	
Info source	**Info_source**	Origin of the data collected: EU project (e.g. DCF [Reg. 199/2008], EU-MAP [Decision EU 2016/1251], etc.), national/regional/local project, other project (e.g. LIFE, Interreg, etc.), scientific papers, grey literature, data dependent on fishery, other data (specify)		Character	
Biometry - FEMALE					
Min length (F)	**Length_min_SF**	Minimum length **(in millimetres)** per site / year (silver eel, female)	mm	Number	*The measures are referred to the whole sample considered*
Mean length (F)	**Length_ave_SF**	Average length **(in millimetres)** per site / year (silver eel, female)	mm	Number	*The measures are referred to the whole sample considered*
Max length (F)	**Length_max_SF**	Maximum length **(in millimetres)** per site / year (silver eel, female)	mm	Number	*The measures are referred to the whole sample considered*

SILVER EEL	CODE	EXPLANATION	UNITS	TYPE OF UNITS	NOTES
Length standard deviation (F)	**Length_SD_SF**	Standard deviation of the length measurements per site / year (silver eel, female)		Number	*The measures are referred to the whole sample considered*
Min weight (F)	**Weight_min_SF**	Minimum weight **(in grams)** per site / year (silver eel, female)	g	Number	*The measures are referred to the whole sample considered*
Mean weight (F)	**Weight_ave_SF**	Average weight **(in grams)** per site / year (silver eel, female)	g	Number	*The measures are referred to the whole sample considered*
Max weight (F)	**Weight_max_SF**	Maximum weight **(in grams)** per site / year (silver eel, female)	g	Number	*The measures are referred to the whole sample considered*
Weight standard deviation (F)	**Weight_SD_SF**	Standard deviation of the weight measurements per site / year (silver eel, female)		Number	*The measures are referred to the whole sample considered*
Min age (F)	**Age_min_SF**	Minimum age per site / year (silver eel, female)		Number	*The measures are referred to the whole sample considered*
Mean age (F)	**Age_ave_SF**	Average age per site / year (silver eel, female)		Number	*The measures are referred to the whole sample considered*
Max age (F)	**Age_max_SF**	Maximum age per site / year (silver eel, female)		Number	*The measures are referred to the whole sample considered*
Age standard deviation (F)	**Age_SD_SF**	Standard deviation of the age measurement per site / year (silver eel, female)		Number	*The measures are referred to the whole sample considered*
L_{inf} (F)	**L_inf_SF**	according to von Bertalanffy growth curve		Number	*optional if row data of biometry are not available - indicate if are cumulative data or for males and females separated*
K (F)	**K_SF**	according to von Bertalanffy growth curve		Number	*optional if row data of biometry are not available - indicate if are cumulative data or for males and females separated*

SILVER EEL	CODE	EXPLANATION	UNITS	TYPE OF UNITS	NOTES
t_0 (F)	**t_zero_SF**	according to von Bertalanffy growth curve		Number	*optional if row data of biometry are not available - indicate if are cumulative data or for males and females separated*
Biometry - MALE					
Min length (M)	**Length_min_SM**	Minimum length **(in millimetres)** per site / year (silver eel, male)	mm	Number	*The measures are referred to the whole sample considered*
Mean length (M)	**Length_ave_SM**	Average length **(in millimetres)** per site / year (silver eel, male)	mm	Number	*The measures are referred to the whole sample considered*
Max length (M)	**Length_max_SM**	Maximum length **(in millimetres)** per site / year (silver eel, male)	mm	Number	*The measures are referred to the whole sample considered*
Length standard deviation (M)	**Length_SD_SM**	Standard deviation of the length measurements per site / year (silver eel, male)		Number	*The measures are referred to the whole sample considered*
Min weight (M)	**Weight_min_SM**	Minimum weight **(in grams)** per site / year (silver eel, male)	g	Number	*The measures are referred to the whole sample considered*
Mean weight (M)	**Weight_ave_SM**	Average weight **(in grams)** per site / year (silver eel, male)	g	Number	*The measures are referred to the whole sample considered*
Max weight (M)	**Weight_max_SM**	Maximum weight **(in grams)** per site / year (silver eel, male)	g	Number	*The measures are referred to the whole sample considered*
Weight standard deviation (M)	**Weight_SD_SM**	Standard deviation of the weight measurements per site / year (silver eel, male)		Number	*The measures are referred to the whole sample considered*
Min age (M)	**Age_min_SM**	Minimum age per site / year (silver eel, male)		Number	*The measures are referred to the whole sample considered*
Mean age (M)	**Age_ave_SM**	Average age per site / year (silver eel, male)		Number	*The measures are referred to the whole sample considered*
Max age (M)	**Age_max_SM**	Maximum age per site / year (silver eel, male)		Number	*The measures are referred to the whole sample considered*

SILVER EEL	CODE	EXPLANATION	UNIT S	TYPE OF UNITS	NOTES
Age standard deviation (M)	**Age_SD_SM**	Standard deviation of the age measurement per site / year (silver eel, male)		Numbe r	*The measures are referred to the whole sample considered*
L_{inf} (M)	**L_inf_SM**	according to von Bertalanffy growth curve		Numbe r	*optional if row data of biometry are not available - indicate if are cumulative data or for males and females separated*
K (M)	**K_SM**	according to von Bertalanffy growth curve		Numbe r	*optional if row data of biometry are not available - indicate if are cumulative data or for males and females separated*
t_0 (M)	**t_zero_SM**	according to von Bertalanffy growth curve		Numbe r	*optional if row data of biometry are not available - indicate if are cumulative data or for males and females separated*
Sex ratio	**Sex_ratio_S**	Sex ratio of silver eels		Numbe r	
Seasonality					
Silver eel escapement (seasonality info)	**Escap_S**	Description of the escapement phase: kilograms of silver eels or % of silver eels per each month of the whole migration period In case the quantitative data is not available, put a “X” for every month cell when the escapement phase occurred and fill the month cells with a grey-scale colour linked to the silver eels abundance to identify start, peaks and end of the escapement (e.g. dark grey for the peak phase)	kg, %	Numbe r, Charact er	*The main purpose is to describe the seasonality from a qualitative point of view at a regional level of key sites. You can have complete information (monitoring that covers the entire migration phase), or information not collected continuously or directly, but which can be integrated from e.g. literature, personal observation, fishers communications*
MIXED LIFE STAGE (YELLOW + SILVER)	**CODE**	**EXPLANATION**	**UNITS**	**TYPE OF**	**NOTES**

SILVER EEL	CODE	EXPLANATION	UNITS	TYPE OF UNITS	NOTES
				UNITS	
Data info					
Methodology	**Method**	Type of data collecting: fishery dependent, scientific monitoring		Character	
Info source	**Info_source**	Origin of the data collected: EU project (e.g. DCF [Reg. 199/2008], EU-MAP [Decision EU 2016/1251], etc.), national/regional/local project, other project (e.g. LIFE, Interreg, etc.), scientific papers, grey literature, data dependent on fishery, other data (specify)		Character	
Biometry - NOT SEPARATED SEXES (female + male)					
Min length	**Length_min_YS**	Minimum length **(in millimetres)** per site / year (yellow+silver, female+male)	mm	Number	*The measures are referred to the whole sample considered*
Mean length	**Length_ave_YS**	Average length **(in millimetres)** per site / year (yellow+silver, female+male)	mm	Number	*The measures are referred to the whole sample considered*
Max length	**Length_max_YS**	Maximum length **(in millimetres)** per site / year (yellow+silver, female+male)	mm	Number	*The measures are referred to the whole sample considered*
Length standard deviation	**Length_SD_YS**	Standard deviation of the length measurements per site / year (yellow+silver, female+male)		Number	*The measures are referred to the whole sample considered*
Min weight	**Weight_min_YS**	Minimum weight **(in grams)** per site / year (yellow+silver, female+male)	g	Number	*The measures are referred to the whole sample considered*
Mean weight	**Weight_ave_YS**	Average weight **(in grams)** per site / year (yellow+silver, female+male)	g	Number	*The measures are referred to the whole sample considered*

SILVER EEL	CODE	EXPLANATION	UNITS	TYPE OF UNITS	NOTES
Max weight	**Weight_max_YS**	Maximum weight **(in grams)** per site / year (yellow+silver, female+male)	g	Number	*The measures are referred to the whole sample considered*
Weight standard deviation	**Weight_SD_YS**	Standard deviation of the weight measurements per site / year (yellow+silver, female+male)		Number	*The measures are referred to the whole sample considered*
Min age	**Age_min_YS**	Minimum age per site / year (yellow+silver, female+male)		Number	*The measures are referred to the whole sample considered*
Mean age	**Age_ave_YS**	Average age per site / year (yellow+silver, female+male)		Number	*The measures are referred to the whole sample considered*
Max age	**Age_max_YS**	Maximum age per site / year (yellow+silver, female+male)		Number	*The measures are referred to the whole sample considered*
Age standard deviation	**Age_SD_YS**	Standard deviation of the age measurement per site / year (yellow+silver, female+male)		Number	*The measures are referred to the whole sample considered*
Comments, notes and other data	**Notes**	Report here if your data are different from those specified in the database, if there is a particular situation in your Country not described here, or any other information you think could be useful to be added to the database		Character	

CHAPTER 7. EEL QUALITY IN MEDITERRANEAN COUNTRIES

ABSTRACT

The aim of this task was to collect data on chemical contamination levels (heavy metals, organic pollutants) and biological infections (parasites, viruses, bacteria) in eels, based on available data from the nine partner countries. The data were used to evaluate the quality of local eel stocks, using the eel quality index (EQI) developed by ICES (2015), to identify key Mediterranean sites where eels are healthy and thus candidates for successful migration. This should make it possible to propose specific measures for the management of these priority sites.

Two datasets were created on the basis of information available in the WP3 habitat database (see Introduction), that also contained data on eel quality, one on pathogens and the other on chemical contaminants. Each database was integrated with additional data from available literature relevant to the Mediterranean. The eel quality index for disease, EQIDIS, the eel quality index for contaminants, EQICONT and the total eel quality index, EQITOT were calculated for sites for which information was available.

There were disparities in the availability of data between different partner countries, habitat typologies and specific parameters. Sixty-five datasets related to specific sites were obtained with information on parasites, the majority of which referred to the invasive parasite *Anguillicola crassus* (61 datasets), compared to only 36 containing information on other parasites. Furthermore, only three countries provided data on viruses and only one on bacterial pathogens. Concerning chemical pollutants, 41 datasets related to specific sites were obtained from six countries, the majority concerning heavy metals, while only three countries were able to provide data on organic pollutants in eel muscle tissue. For both biological and chemical contaminants, lagoon sites were the most studied.

Analysis of the data showed that 55 parasitic species or taxa were recorded from seven countries, with nematodes, trematodes and cestodes the most abundant taxonomic groups. The allochthonous parasite *A. crassus* occurred in eight Mediterranean countries and was distributed in all habitats, with unofficial information on its presence also in Albania, for which no studies were available.

EQIDIS index scores indicated that 56 percent of the sites, including 65 percent of analysed lagoons, were not infected or slightly infected by pathogens. Meanwhile the EQICONT index indicated that 80 percent of sites were not polluted, had low pollution levels or were slightly polluted, including 46 percent of analysed lagoons. The EQITOT index indicated that 84 percent of Mediterranean sites studied were not impacted or only slightly impacted, including 63 percent of analysed lagoons.

Overall, the results, although partial, demonstrated that local eel stocks in Mediterranean lagoons are relatively healthy and could therefore effectively contribute successfully towards stock recovery. Recommendations for managing these key sites were proposed.

HIGHLIGHTS

- There is great disparity in the availability of data, which varied according to countries, habitats and parameters studied.
- Lagoons were the most studied habitats, with France, Italy and Spain being the largest data providers.
- Fifty-five parasitic species or taxa were recorded from seven countries; only two species are known to have potentially negative impacts on eel populations.
- *Anguillicola crassus* was present in eight Mediterranean countries and spread over all habitats.
- Very few data existed on organic pollutants; the majority of studies concerned heavy metals.

- The majority of Mediterranean sites for which exhaustive information was available (mostly lagoons) were found to host relatively healthy eel stocks. No single Mediterranean site was classified as strongly impacted.
- Seven sites were identified as key sites for healthy eel local stocks. Specific management measures should be undertaken to protect them.

7.1 INTRODUCTION

Although the European eel (*Anguilla Anguilla*) has always been considered as a robust and resilient species, stocks have been steadily declining since the 1980s. Overexploitation, habitat degradation and loss, barriers to migration, climate change, chemical pollution and natural causes including pathogens such as viruses and parasites, appear to have acted synergistically, resulting in a general drop in the spawning stock biomass (Miller, Feunteun and Tsukamoto, 2016; Drouineau *et al.*, 2018; Bourillon, 2020; ICES, 2021).

Because of the peculiar life history of eels (long-lived and sedentary for many years, benthic and burrowing, at the top of the trophic chain, high lipid content, single spawner), they can accumulate significant amounts of pollutants during long inland migrations. This means that they could be considered as effective biomonitors (Tilghman, Garric and Coquery, 2009), serving as good indicators of the quality of the environment in which they live (Belpaire and Goemans, 2007; Bourillon, 2020).

Exposure to chemical pollutants such as heavy metals and organic pollutants, as well as their subsequent storage and release during migration, have a variety of consequences for eels, during freshwater growth and during ocean migration and spawning. A wide variety of metabolic processes may be affected including osmoregulation, stress responses, metamorphosis into silver eels, lipid accumulation, lipid mobilization, lipid utilization, sexual development, gonadogenesis, as well as embryonic and larval development (Robinet and Feunteun, 2002; Palstra *et al.*, 2006; Geeraerts and Belpaire, 2010; Van Ginneken *et al.*, 2009; Belpaire *et al.*, 2019; Freese *et al*., 2019).

Eels can also harbour a wide range of parasites. Jakob, Walter and Hanel (2016) identified 161 parasite species including *Anguillicola crassus* and *Pseudodactylogyrus* spp. that received special attention because they negatively impact their host. The nematode *A. crassus* causes severe damage to the swim bladder, disrupts the silvering process and reduces the swimming performance of silver eels, influencing their chances of reaching their reproduction location (Lefebvre, Cantounet and Crivelli, 2002; Palstra *et al.*, 2007; Fazio *et al.*, 2012). Similarly, *Pseudodactylogyrus* spp., damages gills and can induce asphyxiation in severely infected individuals (Imada and Muroga, 1978; Buchmann, 1993; Buchmann, Mellegaard and Køie, 1987; Saraiva, 1995; Kennedy, 2007).

Several viruses can damage eels, including the Herpes-like virus (AngHV-1), which is one of its major pathogens and may be lethal (Van Beurden et al., 2012), as well as the rhabdovirus EVEX, which also reduces the swimming capacity of eels (van Ginneken *et al.*, 2005).

All of these factors may have a substantial impact on the capacity of eels to migrate and reproduce, contributing towards potential stock collapse.

In order to recover eel stocks, efforts have been made to ensure the escapement of at least 40 percent of the pristine biomass. Nevertheless, this objective will only have tangible impacts if it takes into account the health status of eels and increase the likelihood that future spawners undergo their migration in good condition and are able to spawn sufficient quantities of healthy eggs to give viable larvae once they arrive at the Sargasso Sea. Since this is a unique stock, its entire geographic range, including the southern part, must also be included. However, little is known about eel quality in the Mediterranean region, as only a few studies have been carried out.

In this context, the aim of this chapter was to collect available data on levels of eel chemical (heavy metals, organic pollutants) and biological (parasites, viruses, bacteria) contamination in the nine partner countries. This allows calculation of an eel quality index (EQI) to identify key Mediterranean sites where eels can be considered as healthy and the proposal of management strategies for these priority locations.

7.2. METHODOLOGY

Within the framework of the research programme, an Excel database was prepared for eel habitats where partner countries were asked to provide data on natural mortality, on parasites and pathogens, such as the prevalence of *Anguillicola crassus* and the prevalence of other parasites, viruses and bacteria, as well as data on environmental quality parameters such as the concentration of pollutants including POPs and heavy metals in water, sediments, eels or other living organisms (see Chapter 4). From this initial database, two other databases were created, a parasites and pathogens database and a pollutants database.

The parasites and pathogens database was supplemented by further data from the available literature. Data on the swim bladder degenerative index (SDI) resulting from infection by the parasite *A. crassus* were used to assign a score from 1 = not infected to 4 = strongly infected, depending on the infestation rate at each site (Lefebvre, Cantounet and Crivelli, 2002). Where SDI data were not available, the percentage of prevalence (P) was used instead. Data on the highly pathogenic viruses EVEX and AngHV-1 were used to rank sites according to their infestation rate where the presence of one or both of the viruses directly conferred a score of 4 = strongly infected (Table 7.1).

The scores relating to pathogens and viruses were used to calculate an eel quality index for diseases (EQIDIS) and thus to assign a status for each site according to the following formula (ICES, 2015):

$$\textbf{EQIDIS} = [\textstyle\sum_{i=1}^{n} \boldsymbol{pathogen\ classes}]/\boldsymbol{n}$$

where n = the number of measured pathogens

Table 7.1. Values of the Eel Quality Index for diseases (EQIDIS)

EQIDIS classes	**Not infected**	**Slightly infected**	**Moderately infected**	**Strongly infected**
EQIDIS scores	1	2	3	4
SDI or **Prevalence of *A. crassus* (%)**	**0** **0**	**1-2** **< 33**	**3** **33-67**	**≥4** **≥ 67**
EVEX virus	Not present			Present
AngHV-1 virus	Not present			Present

In addition, the data available on other parasites and pathogens were used to obtain an overview of the diversity of helminths, bacteria and parasites in Mediterranean countries.

The pollutants database focused on the collection of data concerning the concentrations of pollutants in the muscle of eels, with additional data added from the literature.

An eel quality index for contaminants (EQICONT) was calculated by taking into account important contaminants including the sum of six PCBs (PCB28, PCB52, PCB101, PCB138, PCB153 and PCB180), the sum of three DDTs (p,p'-DDD, p,p'-DDT and p,p'-DDE), cadmium, lead and mercury (ng/g wet weight). EQICONT was calculated based on the boundary values in ng per g of wet weight of each quality class for a series of selected contaminants and defined as the average value of the quality classes for the measured contaminants (ICES, 2015).

$$\mathrm{EQI}_{CONT} = [\sum_{i=1}^{n} contaminant\ classes]/n$$

with n = the number of measured contaminants

It is important to note that this index was calculated for each habitat type and each site with an average value for all years reported. Furthermore, contaminant classes were extracted from Table 7.2 defining reference values and boundary values of the quality classes (ICES, 2015).

Table 7.2. Eel Quality Index for contaminants (EQICONT) values

EQICONT classes	**Not/low polluted**	**Slightly polluted**	**Polluted**	**Strongly polluted**
EQICONT scores	1	2	3	4
EQICONT	≤1.5	>1.5-2.5	>2.5-3.5	>3.5-4

In addition, for results displayed in range, the Mediterranean values were taken. Unless specified, PCBs were assumed as sum of the seven congeners most cited in literature. The sum of DDTs was used when DDTs in the datasets were undifferentiated. When p.p'-DDD, p.p'-DDT and p.p'-DDE concentrations were reported in the habitat database flowsheet, their sum was further calculated and added as new data.

The overall silver eel pollution profile was assessed by boxplots showing mean, median, first quartile and third quartile, minimum and maximum values. A logarithmic scale was sometimes used on y-axes to enhance the clarity of figures. Pollutant results represented mean values for each site and included individual values, whether reported in one year or as part of a time-series.

The Shapiro-Wilks test was used to test the normality of data. Differences between countries in the pollutant analysis were tested for significance using non-parametric methods (Kruskal–Wallis test) adjusted by the Bonferroni correction followed by a Duncan's multiple range test with a significance level of alpha = 0.05.

Principal component analysis (PCA) was carried out on some pollutant datasets (Hg, Cd, Pb and Cu) to explore differences among countries and to investigate the possibility of grouping countries based on their pollution status.

A total eel quality index (EQITOT) was calculated to determine the health quality of eels, based on both stressors (pathogens and pollutants) according to the following formula (ICES, 2015) in sites where the two indices EQIDIS and EQICONT were available:

$$\mathbf{EQITOT = (EQICONT + EQIDIS) / 2}$$

The reference values and boundary values of the EQITOT (ICES, 2015) are reported in Table 7.3.

Table 7.3. Total Eel Quality Index (EQITOT) values

EQITOT classes	**Not impacted**	**Slightly impacted**	**Impacted**	**Strongly Impacted**
EQITOT scores	**1**	**2**	**3**	**4**
EQITOT	**<1.5**	**>1.5-2.5**	**>2.5-3.5**	**≥3.5-4**

7.3 RESULTS

7.3.1 Descriptive analysis of the data

Overall, 63 datasets were collected from the parasites and pathogens database. Among the nine partner countries, data were collected from 16 sites in France, 11 in Italy and nine in Spain while very few came from Algeria (four), Egypt (three) and Albania (one) (Figure 7.1).

Data were found for each habitat (lagoon, LGN; lake, LAK; estuary, RIE, river, RIV; and coastal marine waters, CMW). Figure 7.2 shows that around 68 percent of the data were recorded in lagoon habitats while the least studied habitat was coastal marine waters (one site).

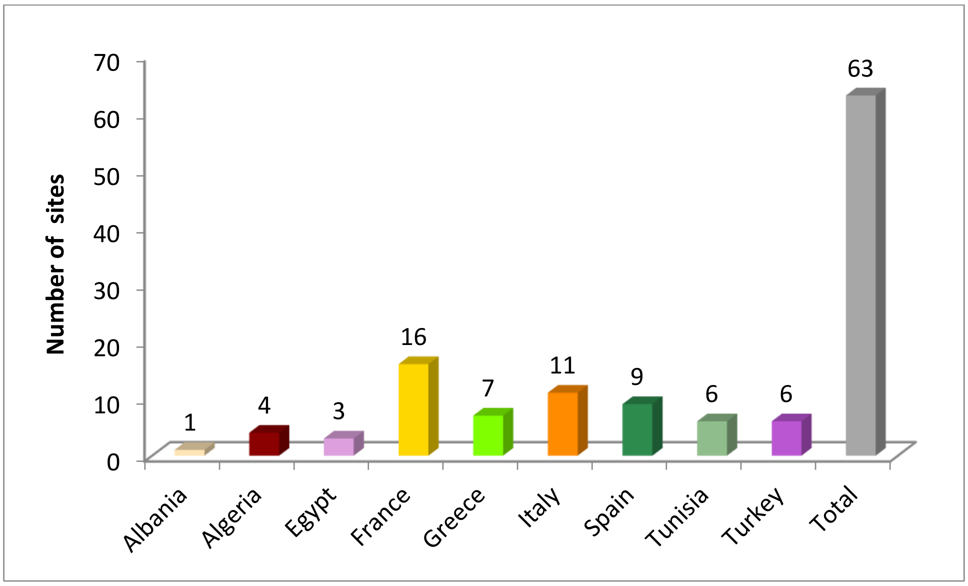

Figure 7.1. Number of sites providing datasets on parasites and pathogens by country in the Mediterranean region

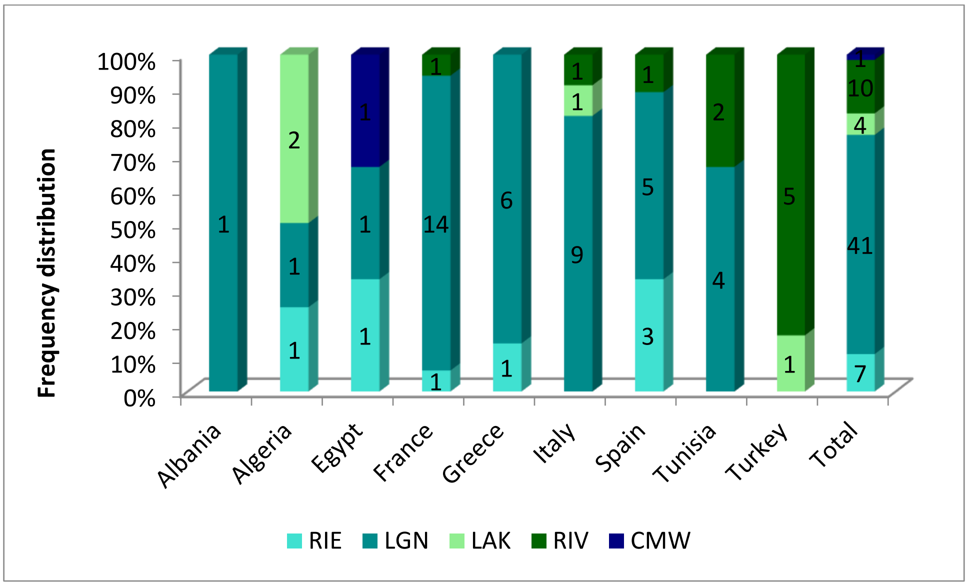

Figure 7.2. Frequency distribution of sites providing datasets on parasites and pathogens by habitat (RIE = estuary, LGN = lagoon, LAK = lake, RIV = river, CMW = coastal marine waters) in the Mediterranean region.

Note: Numbers indicate the number of sites.

Parasites data

<u>Anguillicola crassus</u>

IData on *Anguillicola crassus* were obtained from all partner countries except Albania (Figure 7.3). These data mainly concerned the prevalence of the parasite and came from 60 sites, mainly lagoons (Figure 7.4). On the other hand, data concerning the swim bladder degenerative index (SDI) were recorded in only three countries, France (four sites), Italy (three sites) and Tunisia (one site), all of which were lagoons.

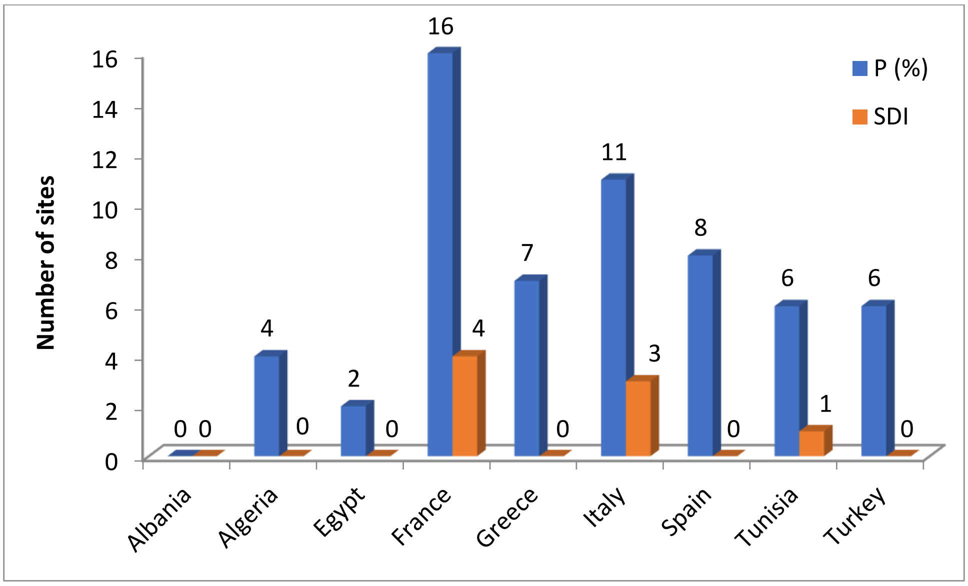

Figure 7.3. Number of sites providing data on *A. crassus* prevalence (P percent) and SDI by country in the Mediterranean region.

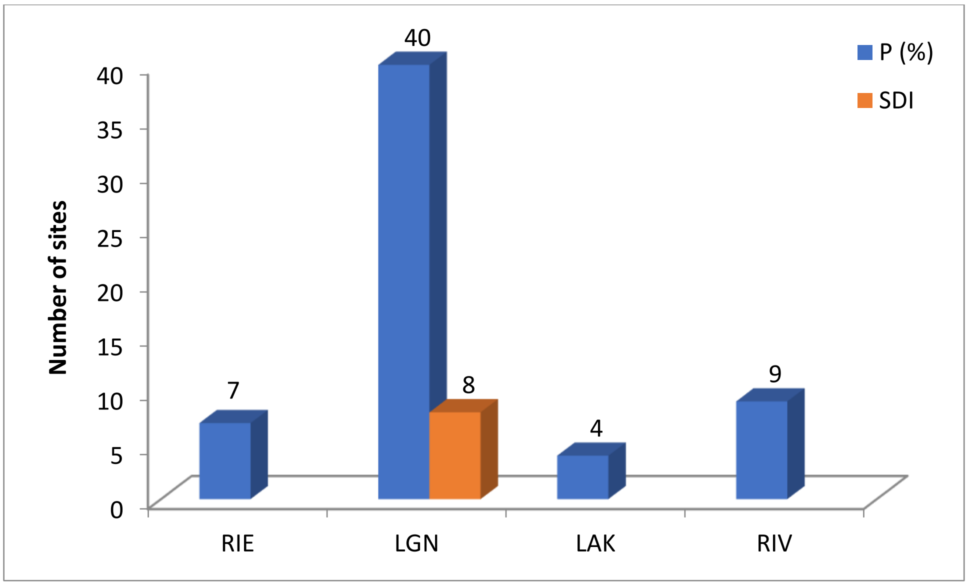

Figure 7.4. Number of sites providing data on *A. crassus* prevalence (P percent) and SDI by habitat (RIE = estuary, LGN = lagoon, LAK = lake, RIV = river) in the Mediterranean region.

Other parasites

Eight partner countries provided data on the presence of parasites other than *A. crassus*. The majority of the data came from France with 12 sites, while Albania and Türkiye reported only one site each and none came from Greece (Figure 7.5).

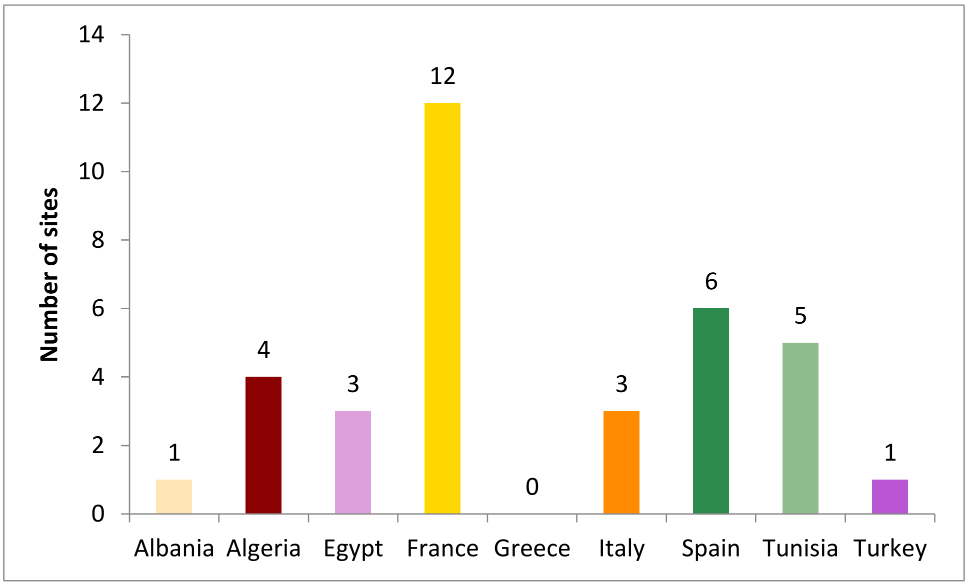

Figure 7.5. Number of sites providing data on parasites other than *A. crassus* by country in the Mediterranean region.

Other pathogens data

Virus-related data were collected from only Spain, France and Italy (Figure 7.6), and two habitats lagoons and river estuaries (Figure 7.7). EVEX data were found in four sites in France and two in Italy, all lagoon habitats. Herpes virus (Ang HV-1) was found in only two sites in Italy and four in Spain. These sites were distributed between three sites in lagoon habitats and three sites in estuary habitats. Furthermore, Spain was the only country to provide data on other viruses (one site in a lagoon).

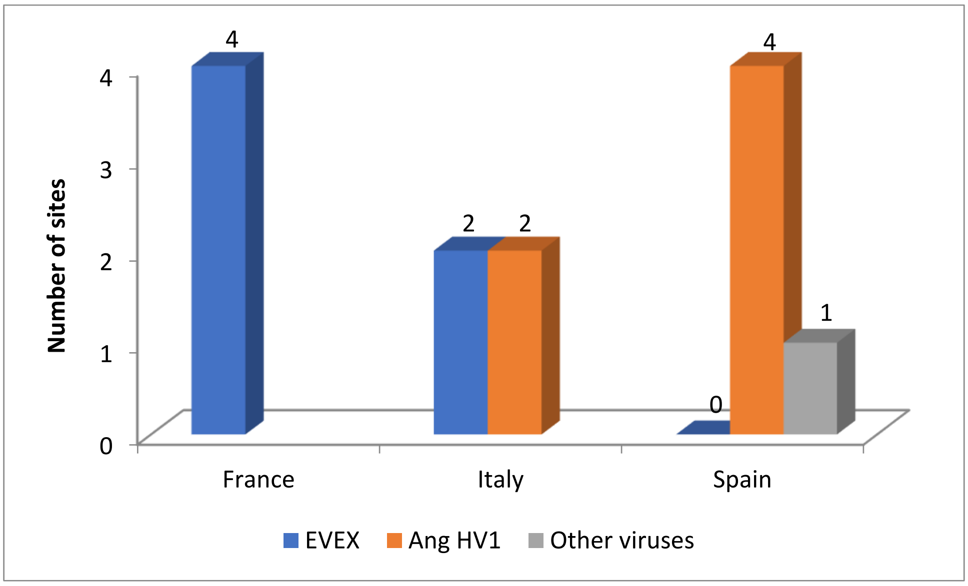

Figure 7.6. Number of sites providing data on viruses by country in the Mediterranean region.

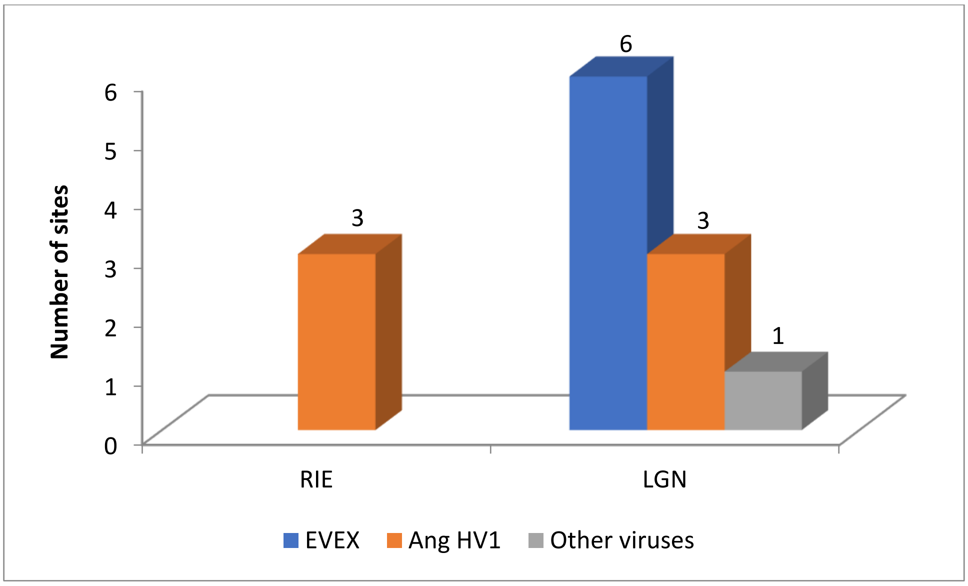

Figure 7.7. Number of sites providing data on viruses by habitat (RIE = estuary, LGN = lagoon) in the Mediterranean region.

Bacteria

Very little information was collected regarding bacterial contamination in eels. Indeed, data were obtained from only one site: the Albufera lagoon in Valencia (Spain).

7.3.2. General overview of the pollutants database

A total of 41 sites in six partner countries were identified for data on the quality of eels related to contaminant levels, as shown in Figure 7.8.

The most frequent habitat type was lagoons with 19 sites, followed by rivers (nine sites) and the least studied were lakes and estuaries, with seven and six sites, respectively. On the other hand, there was more comprehensive research on eel quality for contaminants in the north-western Mediterranean countries (Italy, Spain and France) compared to their south-western counterparts (Tunisia and Algeria).

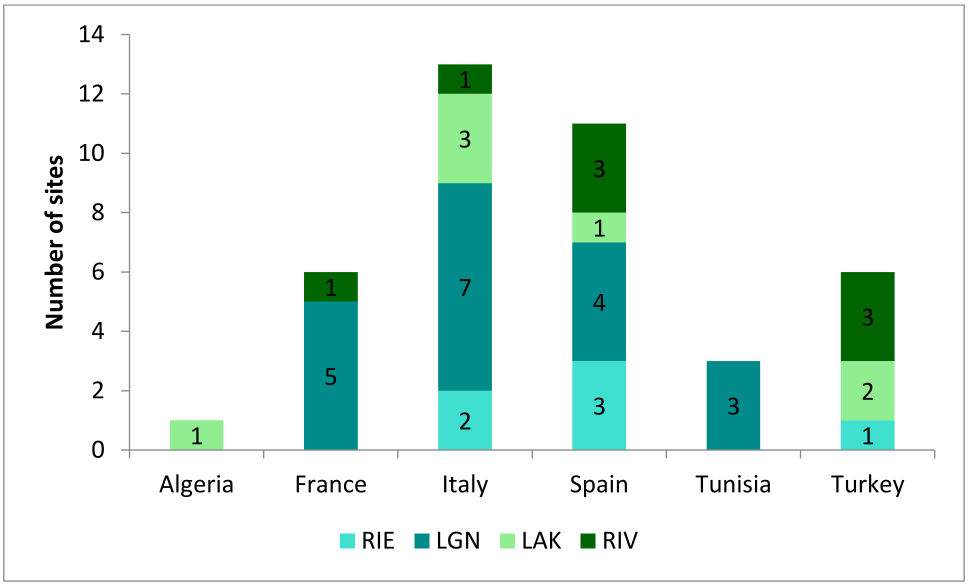

Figure 7.8. Number of sites providing datasets on contaminants by country and habitat type (RIE = estuary, LGN = lagoon, LAK = lake, RIV = river) in the Mediterranean region.

Persistent Organic Pollutants (POPs) are toxic chemicals that adversely affect human health and the environment around the world, and some are included in environmental monitoring programmes for eel quality in European countries such as France, Italy and Spain. The lack of data on these pollutants for other Mediterranean countries may be due to analytical limitations. Italy reported the most data on polychlorinated biphenyls PCBs (seven PCBs in eight sites), followed by Spain (five sites) and France (four sites). Hexachlorocyclohexane (HCH), the organochloride pesticide, was expressed differently between the three countries; Italy reported five contaminated sites by both alpha and gamma congeners, while France and Spain each presented three contaminated sites expressed as the sum HCH. The sum of DDTs and affiliated organochlorine pesticides (OCPs) were better reported in Spain (eight sites) followed by Italy (seven sites) than France (three sites). The POP Hexachlorobenzene (HCB) was only reported in the contamination data of Italy (seven sites). Although the manufacture and agricultural usage of most PCBs and OCPs was banned in Europe, the results show that there are still detectable concentrations in aquatic biota.

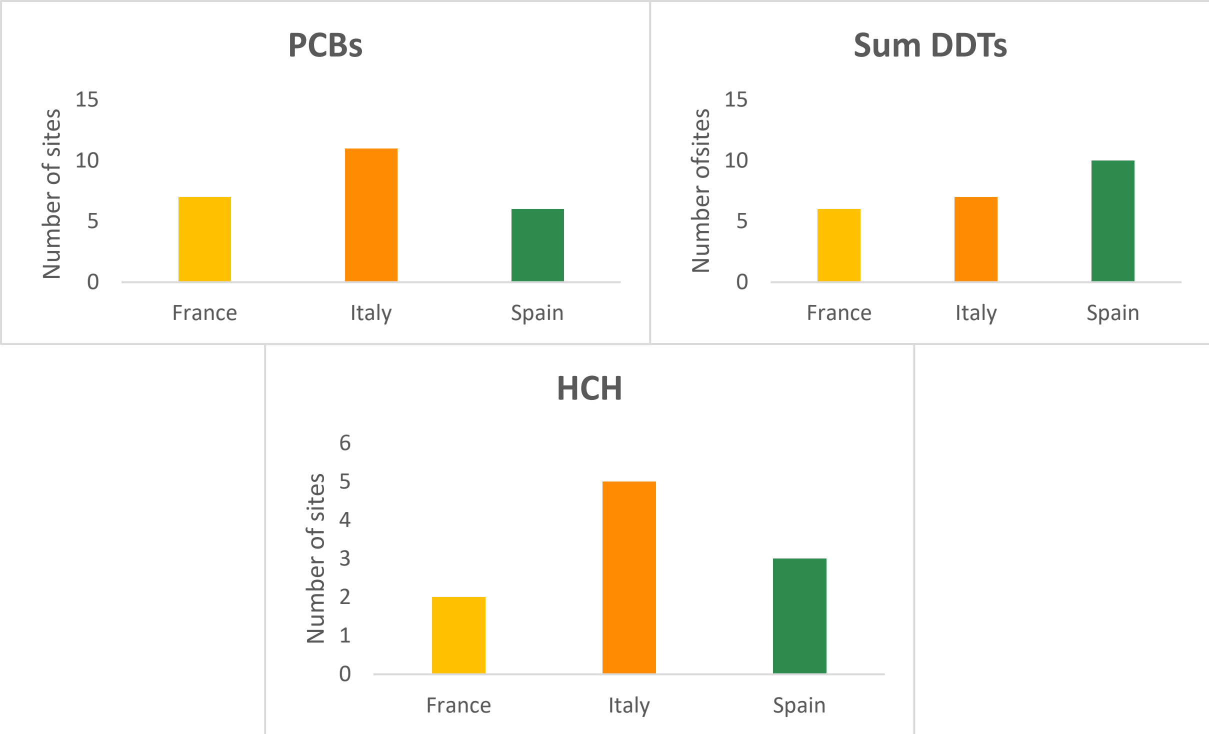

Figure 7.9. Number of sites providing datasets on pollutants by country in the Mediterranean region.

The measurement of toxic metals varied between the partner countries with the highest frequency of measurement by Italy, Türkiye, Spain, France Tunisia and Algeria, respectively (Figure 7.10). In total, seven metals were monitored in Türkiye, Italy, Spain and Algeria while France monitored three metals and Tunisia analysed only four. The three regulated toxic metals mercury (Hg), cadmium (Cd) and lead (Pb) were monitored in all countries except France where only cadmium was analysed. The essential metals zinc (Zn) and copper (Cu) were reported in all Mediterranean countries, while selenium (Se) was analysed once in eel muscle from Spain. A minimum of three sites per metal were studied for all countries, except Algeria, for at least three metals. Algeria was weakest in terms of sites monitored and France analysed the fewest metals.

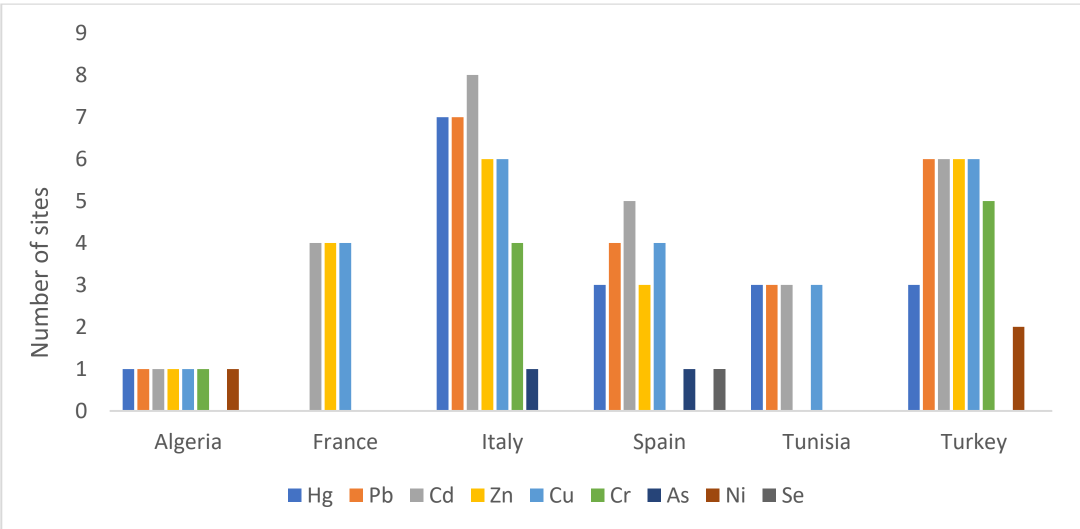

Figure 7.10. Number of sites providing datasets on heavy metals by country in the Mediterranean region.

7.3.3. Quantitative analysis of the data

Parasites and pathogens

<u>Parasites</u>

Anguillicola crassus

The swim bladder degenerative index (SDI), when provided, and the prevalence (P) of *A. crassus* allowed the assignment of scores from 1 to 4 in order to classify the 61 sites from not infected to strongly infected.

Figures 7.11 and 7.12 show that *A. crassus* was present in eight partner countries and in four habitats; estuaries, lagoons, lakes and rivers. However, Italy had five sites and Tunisia had three sites that were free of *Anguillicola*, representing 13 percent of all sites. Forty-three percent of sites in the eight partner countries were classified as slightly infected, with prevalences not exceeding 33 percent. Twenty percent of sites were classified as strongly infected in France, Spain, Türkiye and Italy with the majority (six sites) in France. Additional Results Part I provides details and classifications for each site according to the rate of infestation.

Anguillicola-free sites were mainly found in lagoons and in one river while strongly infected sites were distributed between estuaries, rivers and lagoons. More than 70 percent of lagoons were classified as not infected or slightly infected.

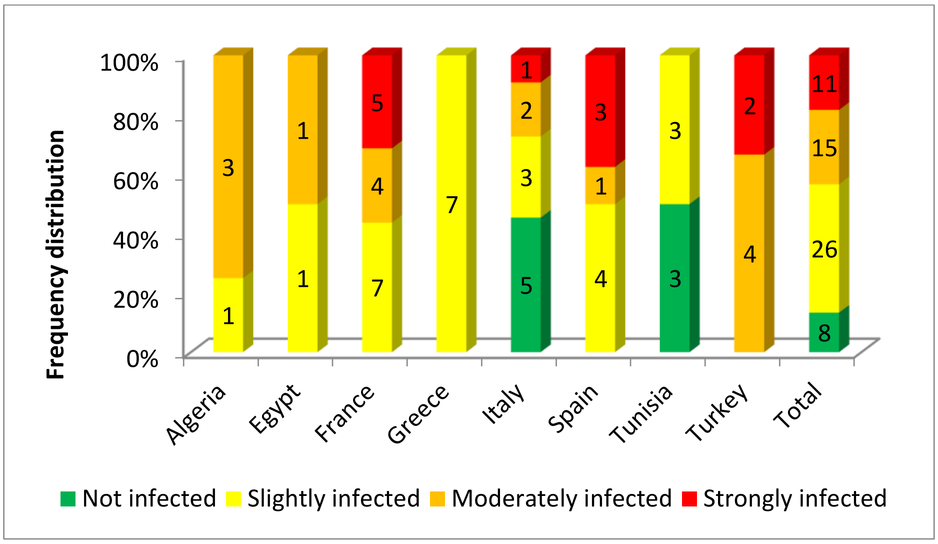

Figure 7.11. Frequency distribution (percent) of *A. crassus* quality classes in the Mediterranean region. Note: Numbers indicate the number of sites.

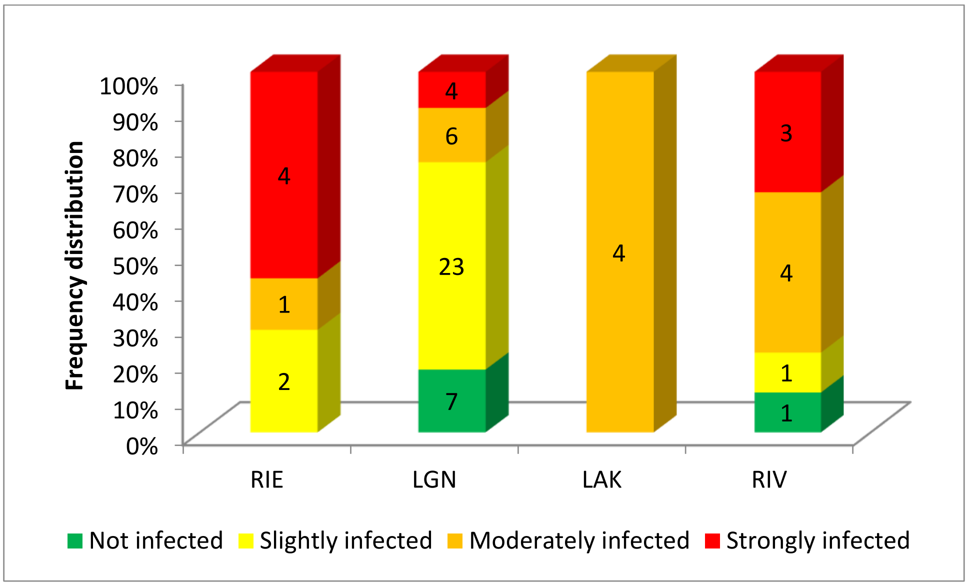

Figure 7.12. Frequency distribution (percent) of *A. crassus* quality classes by habitat (RIE = estuary. LGN = lagoon, LAK = lake, RIV = river) in the Mediterranean region.
Note: Numbers indicate the number of sites.

Pseudodactylogyrus spp.

The occurrence of *Pseudodactylogyrus anguillae* and *Pseudodactylogyrus bini,* grouped under *Pseudodactylogyrus* spp. was assessed in 29 sites over eight partner countries (Figure 7.13). This gill parasite was found at 22 sites, showing that it has spread in Mediterranean countries. However, it was not found in 29 percent of the study sites.

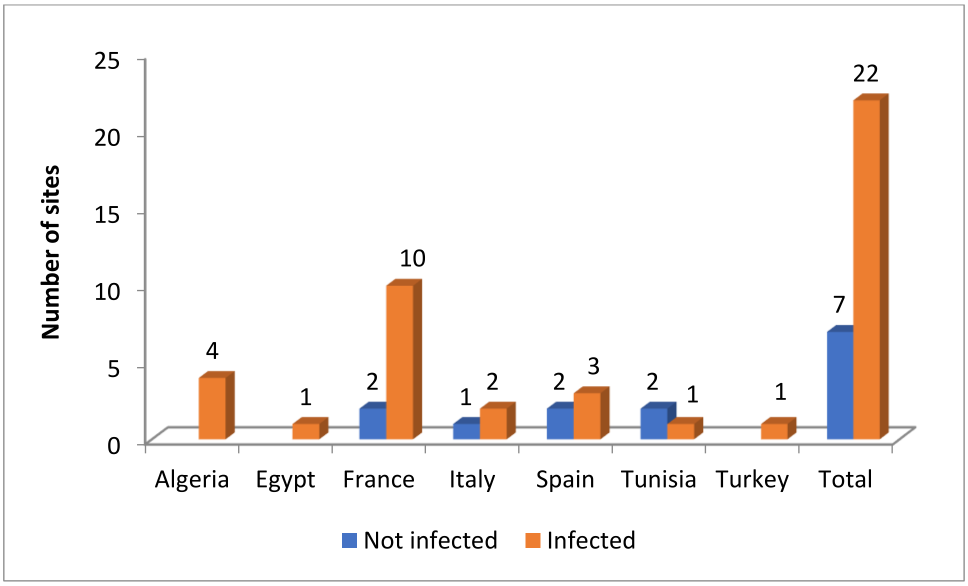

Figure 7.13. Number of *Pseudodactylogyrus spp.* infected and not infected sites in the Mediterranean region.

Parasite diversity

A total of 55 parasitic species or taxa were recorded for European eels from the nine partner countries. Protozoan parasites came from the classes Apicomplexa (one species), Myxozoa (three species) and

Ciliophora (three species). Metazoan parasites included the platyhelminth classes Trematoda (Digenea) (seven species), Monogenea (five species) and Cestoda (nine species), and the phyla Nematoda (17 species), Acanthocephala (four species), Arthropoda (6 species) and Annelida (one species). A checklist of species and taxa is presented in Additional Results Part II. Analysis of the data showed that nematodes, trematodes and cestodes were the most abundant taxonomic groups and were recorded in almost all countries. In addition, 49 percent of the parasite fauna were intestinal, the rest distributed between skin, gills, kidney and swim bladder.

Species richness differed among countries and habitats. The parasitic fauna was more diversified in Algeria with 20 species or taxa, followed by Spain (16) and Tunisia (15), while only one species, the nematode *A. crassus*, was recorded in Greece (Figure 7.14). Eels inhabiting saltwater habitats (lagoons and estuaries) harboured a greater diversity of parasites (69 percent) compared to freshwater habitats (lakes and rivers; 30 percent) (Figure 7.15).

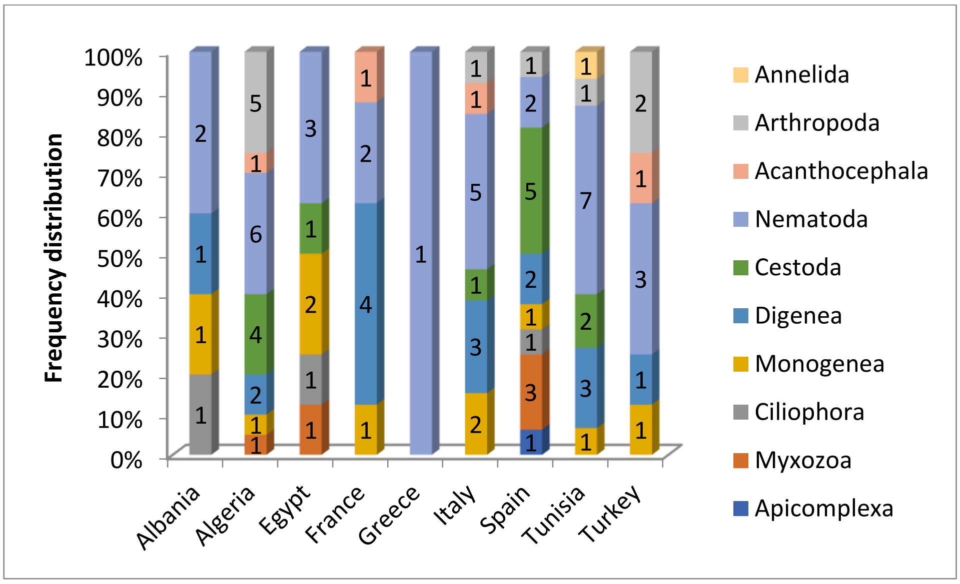

Figure 7.14. Species richness of eel parasites in the Mediterranean region.
Note: Numbers indicate the number of species.

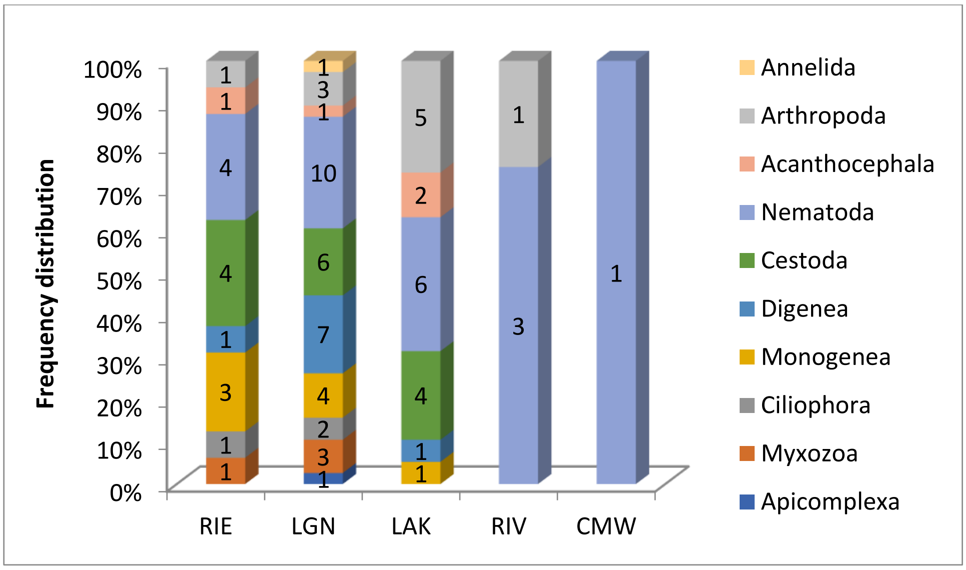

Figure 7.15. Species richness of eel parasites by habitat (RIE = estuary, LGN = lagoon, LAK = lake, RIV = river, CMW = coastal marine waters) in the Mediterranean region.
Note: Numbers indicate the number of species.

Other pathogens

Viruses

Only a few studies have focused on viruses in eels in the Mediterranean. Research in France looked specifically for the EVEX virus. As shown in Figure 7.16 it was present in only 25 percent of sites (one site). Spanish research focused on the herpes virus (Ang HV-1), which was present in 75 percent of sites (three sites), while in Italy researchers looked for the presence of both viruses and it was present in all sites (two sites) (Figures 7.16 and 7.17).

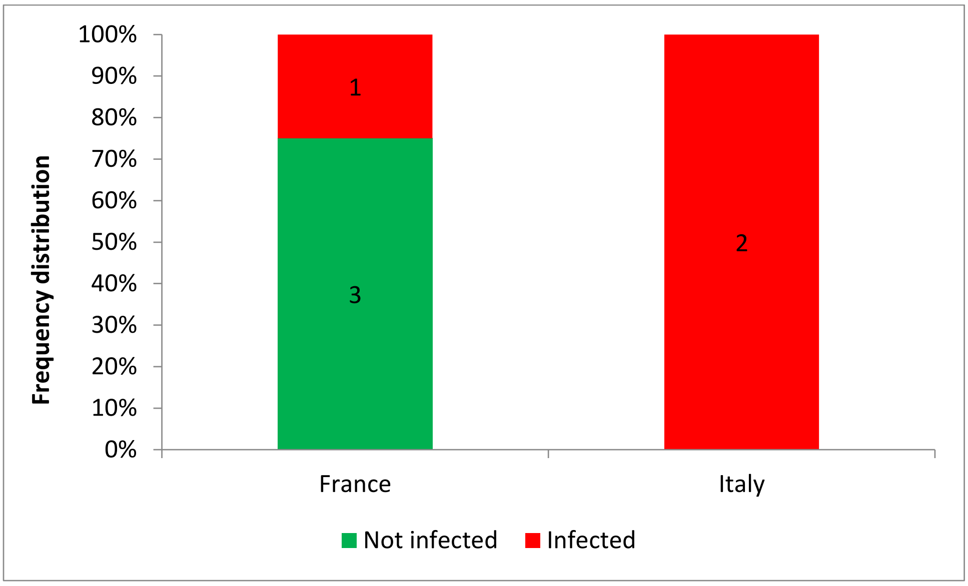

Figure 7.16. Presence and absence of EVEX virus by country in the Mediterranean region. Note: Numbers indicate the number of sites.

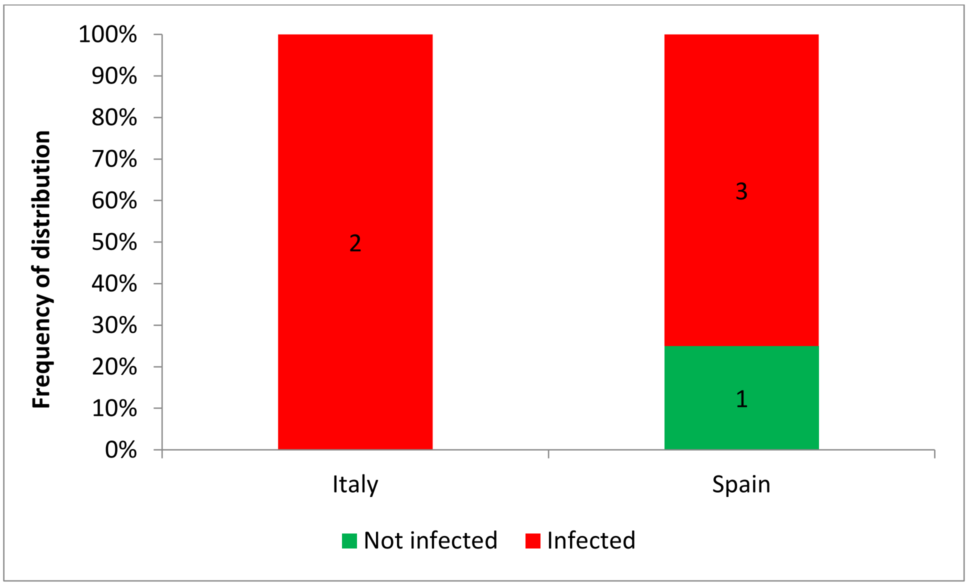

Figure 7.17. Presence and absence of Ang HV-1 virus by country in the Mediterranean region. Note: Numbers indicate the number of sites.

The presence of either one or both of these highly pathogenic viruses, triggered a direct score of 4 leading to the site being classified as strongly infected. Thus, 60 percent of the sites examined, both in lagoons and in estuaries, were classified as strongly infected (Figures 7.18 and 7.19). Additional Results Part III details each site and its classification according to the rate of infestation.

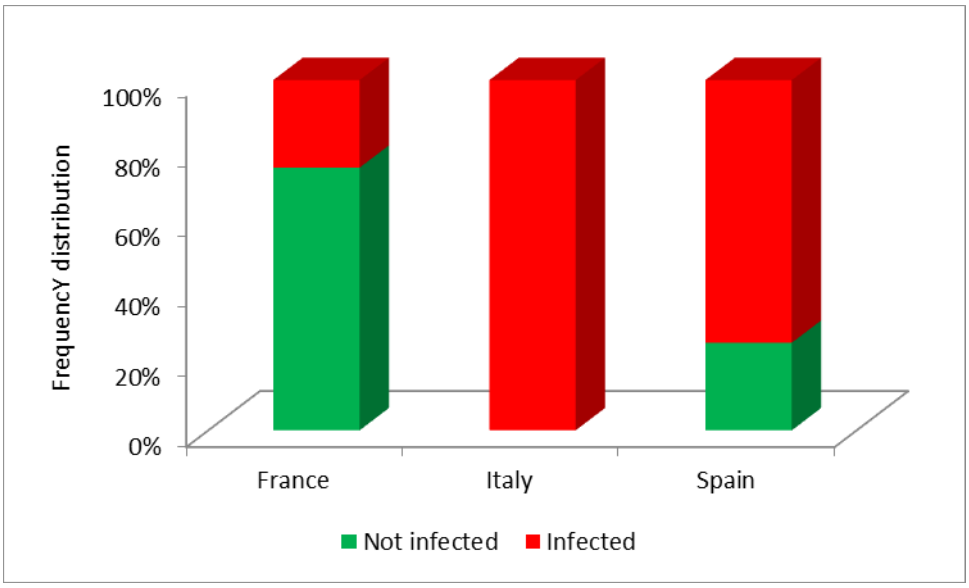

Figure 7.18. Frequency distribution of EVEX and Ang HV-1 viruses' quality class by country in the Mediterranean region.

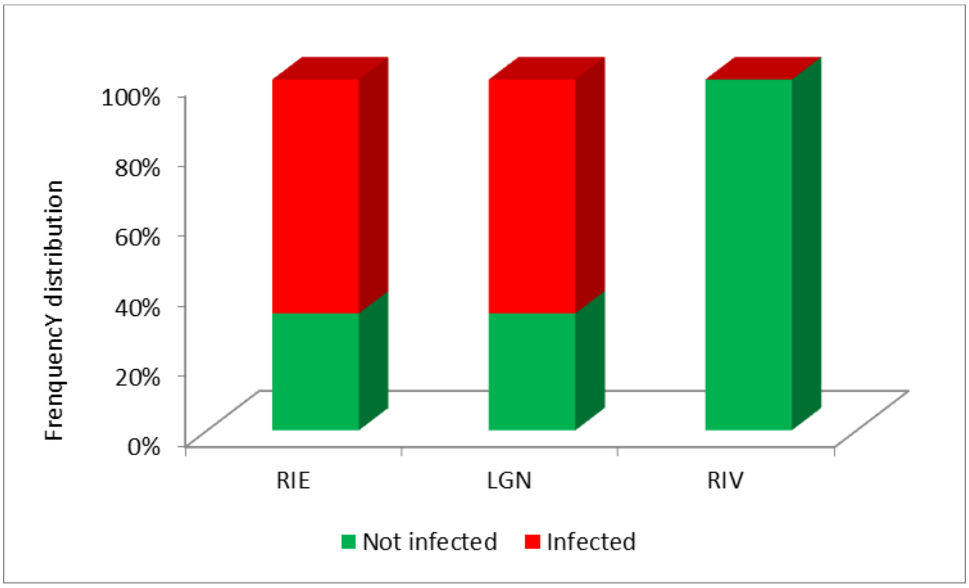

Figure 7.19. Frequency distribution of EVEX and Ang HV-1 viruses quality class by habitat (RIE = estuary, LGN = lagoon, RIV = river) in the Mediterranean region.

In addition, only one site in Spain, the Albufera de Valencia lagoon, was investigated for other viruses in eels. Two viruses not specific to eels, nervous necrosis virus (Betanodavirus) and infectious pancreatic necrosis virus (IPNV), were found.

<u>Bacteria</u>

Research on bacteria in eels was conducted at only one site, the Albufera Lagoon in Valencia, Spain where the following species were identified: *Shewanella putrefaciens*, *Kocuria* sp., *Edwardsiella* sp., *Vibrio* spp., *Pseudomonas* spp., *Aeromonas* spp. *Micrococcus* sp., *Rhodococcus* sp., *Plesiomonas shigelloides* and *Candida sorbophila*.

Eel quality index for diseases (EQIDIS)

EQIDIS allowed the classification of partner country sites the according to their degree of infection by highly pathogenic organisms for eels, namely *A. crassus* and the viruses EVEX and AngHV-1 (Additional Results Part IV). Figure 7.20 shows that sites with healthy eel populations were found in France, Italy and Tunisia while strongly infected sites were found in France, Italy, Spain and Türkiye. Overall, 55 percent of the sites were not infected or slightly infected.

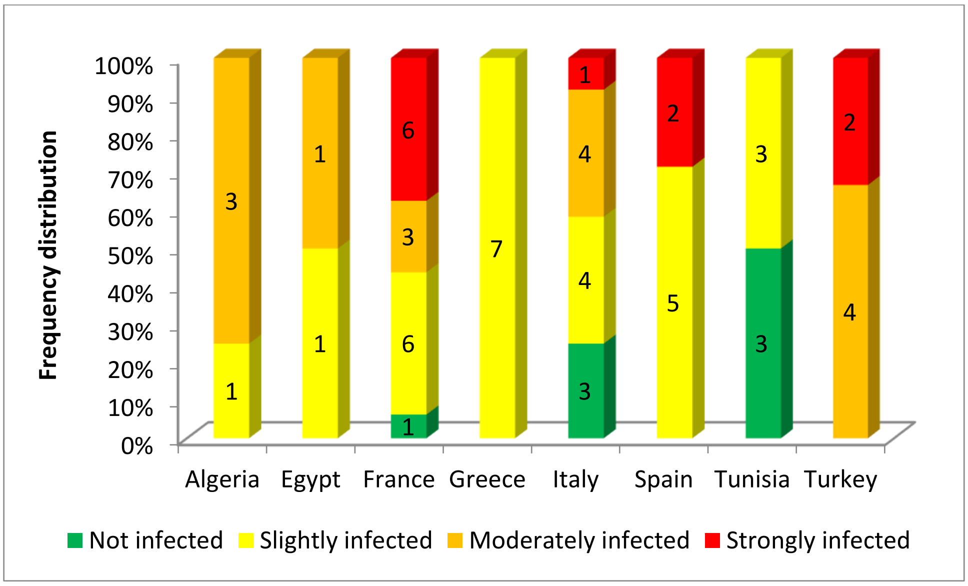

Figure 7.20. Frequency distribution of EQIDIS class by country in the Mediterranean region. Note: Numbers indicate the number of sites.

Figure 7.21 shows that saline habitats presented the healthiest environments for eel populations. Indeed, 70 percent of lagoon and 43 percent of estuary sites were classified as not infected or slightly infected. Freshwater habitats were found to be less healthy for eels where 100 percent of lake sites were classified as moderately infected and 75 percent of river sites were moderately infected to strongly infected.

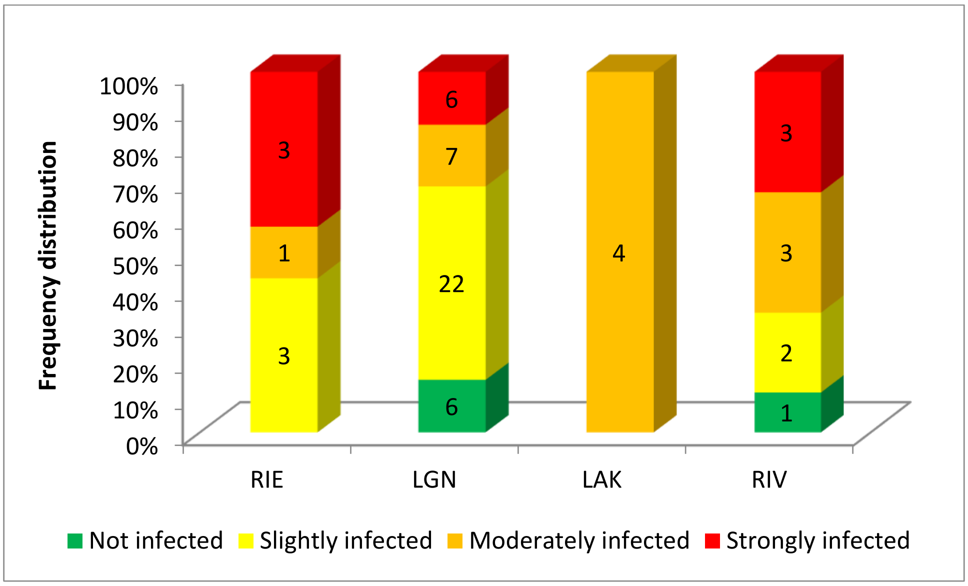

Figure 7.21. Frequency distribution of EQIDIS class by habitat (RIE = estuary, LGN = lagoon, LAK = lake, RIV = river) in the Mediterranean region.
Note: Numbers indicate the number of sites.

Organic pollutants

Information on organic pollutants (seven PCBs and the sum of DDTs) and metals (Hg, Cd, Pb, Cu, Zn and Cr) was retrieved from the habitat database for each country and explored statistically. The results of data deviations were compared to reference values and boundary values of the quality classes presented in Supplementary Material on the Methodolgy. Boxplots have the advantage of providing an overview of the distribution of pollutant levels within a country and between countries. Additionally, significant differences in pollution status between countries was checked by Kruskal-Wallis non-parametric tests. Pollution data from Algeria were not included in this analysis since only one individual measurement was available.

PCBs

PCB levels expressed in total wet weight (sum of the seven congeners: 28, 52, 101, 138, 153, 180 and 118) showed high variability between countries (Figure 7.22). In fact, France recorded the lowest values for all data reported (equal and below the reference value: 29 ng/g). For Spain, it was observed that most data were below the reference value. However, one point measurement deviated slightly (that is it fell within the range 73 ng/mg to less than 183 ng/g) and another was within the first class (less than 73 ng/g). Italy registered the highest contamination rate with data points in the third class (183 ng/g to less than 460 ng/g, two of eight total datapoints) and some sites even classed as strongly polluted (more than 460 ng/g, two of eight data points). The remaining data were either below the reference value (one of eight points), or in the first class (three of eight points). The non-parametric test confirmed these trends (p-value = 0.0080) and designated France and Italy in separate groups (A, B) and Spain in a common group (AB).

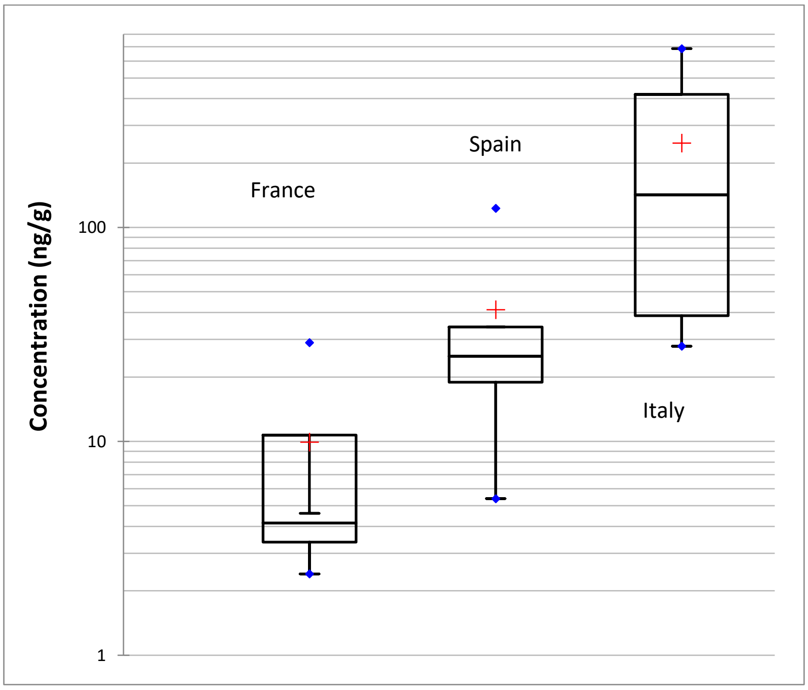

Figure 7.22. Boxplot comparison of the concentrations of the sum of seven PCBs in eel muscle in Mediterranean countries.

Note: Red crosses represent the mean, while the lower and upper blue points represent minimum and maximum values, respectively, and the bottom, medium and top box bars showed the 25th percentile, the median and 75th percentile, respectively.

DDTs

For DDT levels (sum of *p.p'-DDD*, *p.p'-DDT* and *p.p'-DDE*), most of data reported in the three countries registered low values (Figure 7.23), which were considered as not polluted (less than 40 ng/g) below the reference value of 16 ng/g (France and Italy) or slightly polluted (Spain: 40 ng/g to less than 101 ng/g). However, peak concentrations were recorded in France (strongly polluted: greater than 254 ng/g) while Italian sites had the highest frequency categorized in the polluted class (101 ng/g to less than 254 ng/g). A non-parametric Kruskal-Wallis test confirmed that there were no significant differences between countries for DTT contamination (p-value=0.62).

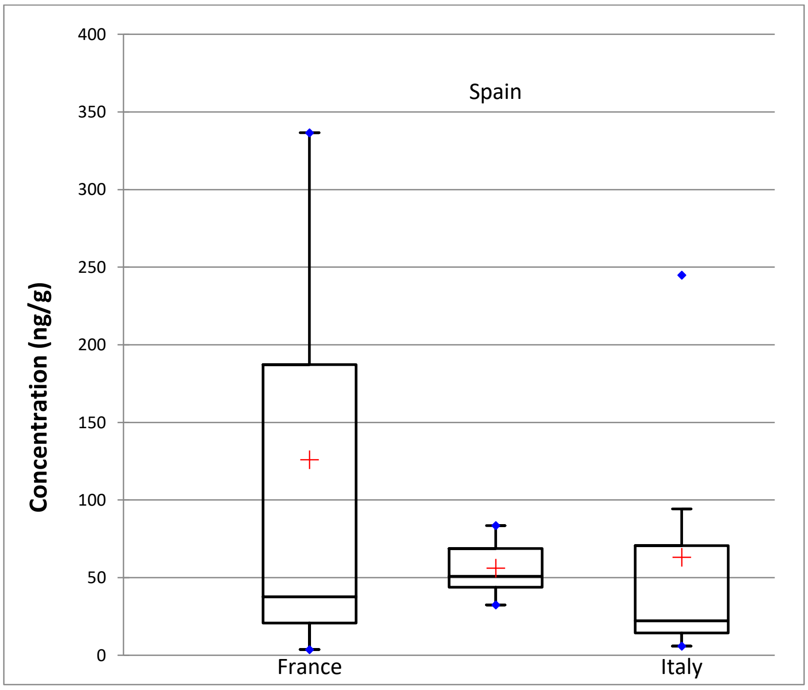

Figure 7.23. Boxplot comparison of sum DDTs concentrations in eel muscle in Mediterranean countries. Note: Red crosses represent the mean, while the lower and upper blue points represent minimum and maximum values, respectively, and the bottom, medium and top box bars showed the 25th percentile, the median and 75th percentile, respectively.

Heavy metals

Mercury (Hg)

Figure 7.24 shows that eels in Algeria had the lowest mercury levels, followed by Spain and Italy. One sample from Türkiye had the highest mercury level (550 ng/g Hg wet weight) and was therefore classified in the deviating class (252 ng/g to less than 634 ng/g). However, statistical analysis (Kruskal-Wallis test) showed no significant differences between countries (p-value = 0.1916). On the other hand, the boxplot of Hg contamination showed a large variability within the data with extremely low and high values for Italy as well as Spain compared to the other countries.

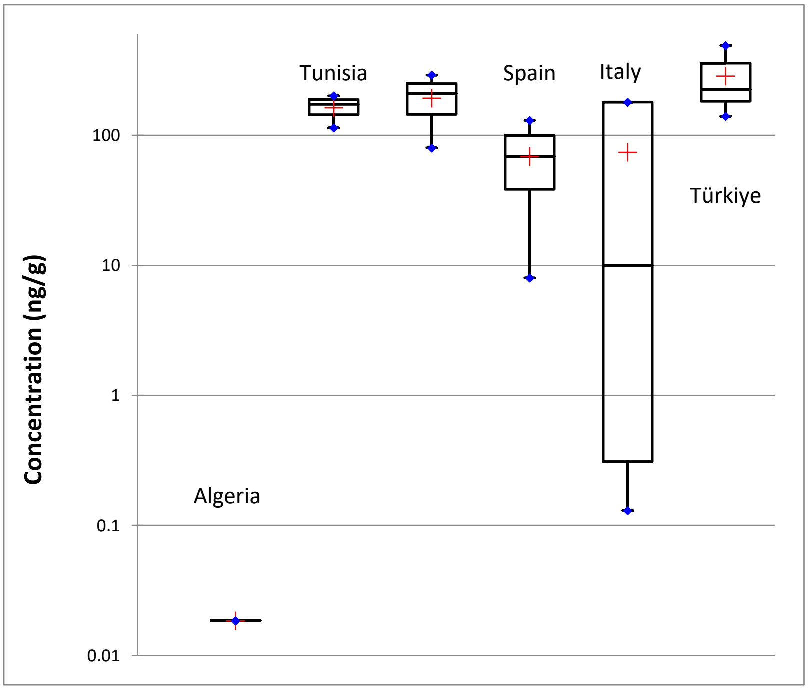

Figure 7.24. Boxplot comparison of mercury concentrations in eel muscle in Mediterranean countries. Note: Red crosses represent the mean, while the lower and upper blue points represent minimum and maximum values, respectively, and the bottom, medium and top box bars showed the 25th percentile, the median and 75th percentile, respectively.

Cadmium (Cd)

The boxplots for cadmium contamination (Figure 7.25) indicated that the majority of countries, apart from Algeria, showed high levels of contamination that exceeded the reference value of two ng/g. Maximum values (in the fourth pollution class, equal or greater than 31.7 ng/g) were recorded for all Cd measurements in Türkiye and two out six total data points in Italy. Tunisia registered all measurements in the third pollution class (12.6 ng/g to less than 31.7 ng/g), while two out of six data points were in the third class for Italy followed by Spain (one data point of three). France recorded homogeneous Cd levels for all reported cases, placing them in the slightly polluted classification. Algeria reported no cadmium polluted eels. A Kruskal-Wallis test, followed by the Dunn procedure, showed significant differences between countries (p-value = 0.0066) which classified sites in France and Spain as the least polluted, in Tunisia and Italy as moderately polluted and Turkish sites as the most polluted. As was seen for mercury contamination, cadmium levels in eels from Türkiye, Italy and Spain showed greater variability than those from France and Tunisia.

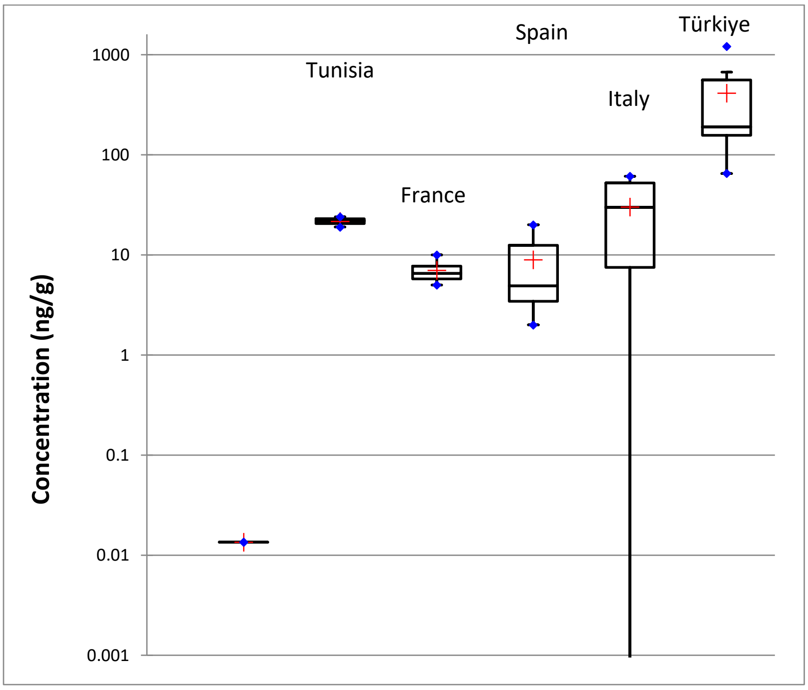

Figure 7.25. Boxplot comparison of cadmium concentrations in eel muscle in Mediterranean countries. Note: Red crosses represent the mean, while the lower and upper blue points represent minimum and maximum values, respectively, and the bottom, medium and top box bars showed the 25th percentile, the median and 75th percentile, respectively.

Lead (Pb)

Lead contamination levels were highest in eel samples from Türkiye, France and Spain. Tunisia and Italy displayed concentrations belonging to the first class (less than 25 ng/g), while Algeria reported contamination levels below the reference value (Figure 7.26). Lead levels in eels from France and Spain were between 63 ng/g and 158 ng/g indicating that they are considered as polluted (in the third pollution class). Türkiye registered high lead values for almost all sites, therefore eels were classified as strongly polluted (greater than or equal to 158 ng/g). Non-parametric analysis of datasets showed significant differences between countries (p-value = 0.0194), especially between Türkiye and Italy classifying Italy as having a low level of pollution, Tunisia, Spain and France as medium and Türkiye as highly polluted. There was high variability of reported lead levels from Türkiye, Italy and France while levels in Tunisia and Spain were more consistent.

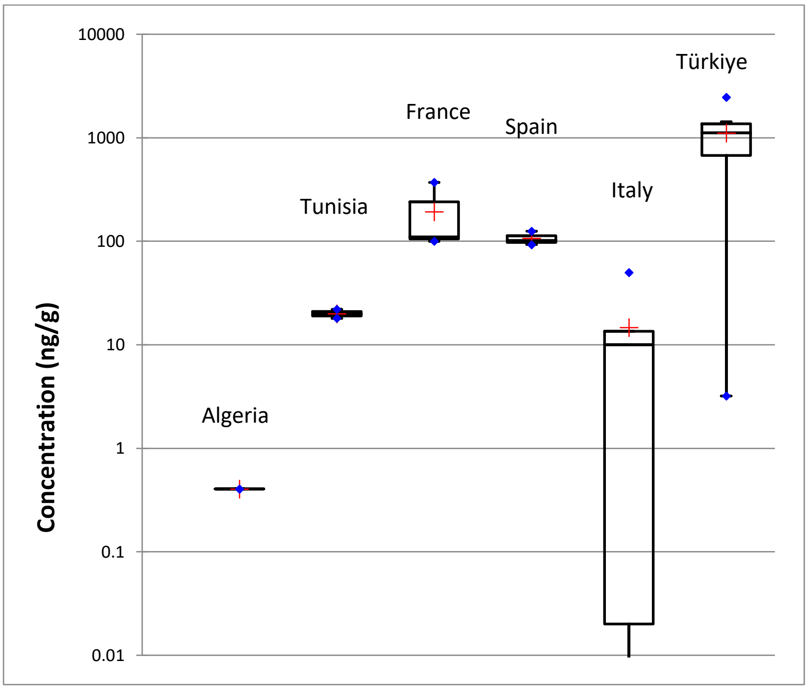

Figure 7.26. Boxplot comparison of Pb concentrations in eel muscle in Mediterranean countries. Note: Red crosses represent the mean, while the lower and upper blue points represent minimum and maximum values, respectively, and the bottom, medium and top box bars showed the 25th percentile, the median and 75th percentile, respectively.

Copper (Cu)

There were relatively few results for copper contamination in eel muscle across all countries and none of countries were grouped in the third class (between 1600 ng/g and 4000 ng/g) or the fourth class (greater than or equal to 4000 ng/g), except for three data points in Türkiye and one in France, as shown in Figure 7.27.

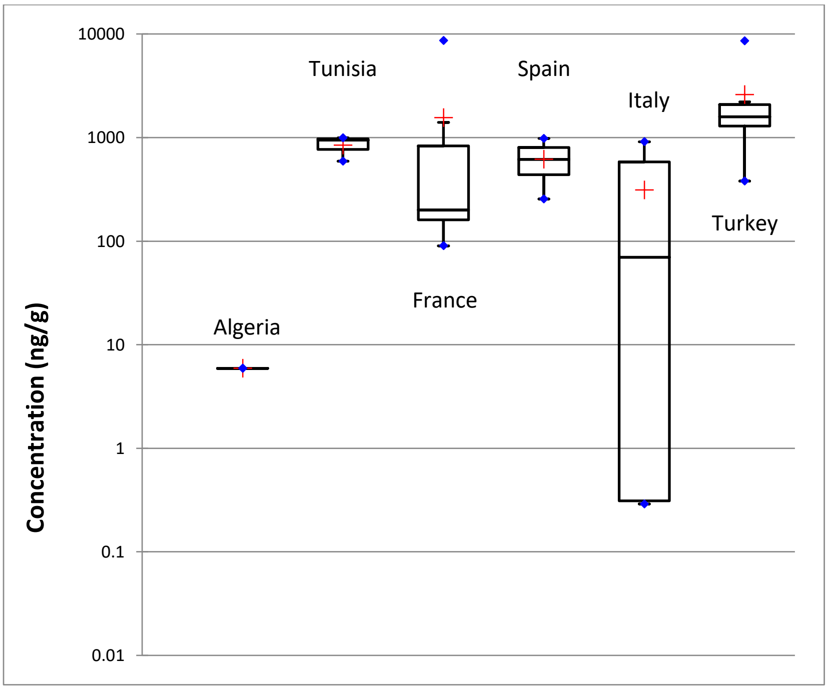

Figure 7.27. Boxplot comparison of Cu concentrations in eel muscle in Mediterranean countries.

Note: Red crosses represent the mean, while the lower and upper blue points represent minimum and maximum values, respectively, and the bottom, medium and top box bars showed the 25^{th} percentile, the median and 75^{th} percentile, respectively.

Results from Tunisia were mostly classified as slightly polluted (600 ng/g to less than 1600 ng/g). Spain reported only two data points (the maximum and minimum values) which belonged to the second and first classes, respectively. Italy and France reported more data in the first class (less than 600 ng/g) or below the reference value of 250 ng/g, while the one data point reported from Algeria was below the reference value. A Kruskal-Wallis test followed by the Dunn procedure determined that there were significant differences (p-value = 0.0479) between Türkiye (the most polluted) and Italy (the least polluted) compared to the other countries (moderately polluted).

Mercury, cadmium, lead and copper were reported in eel samples from the six Mediterranean countries. In order to develop further understanding of this complex matrix, the exploratory statistical procedure, principal component analysis (PCA) was applied to the data which generated one factor (F1) summarizing 77.58 percent of variability with an Eigenvalue greater than one. Three variables Hg, Cu, Pb were strongly positively correlated to F1 (0.9663, 0.9499 and 0.9292), while Cd was moderately correlated to F1 (0.6353). The biplot of observation (countries) scores and the correlation circle of variables (Figure 7.28) led to the separation of one distinct group with high pollution levels due to metals in eels (Türkiye) followed in decreasing order by the pollution levels in eels from sites in France, Tunisia, Spain, Italy and Algeria.

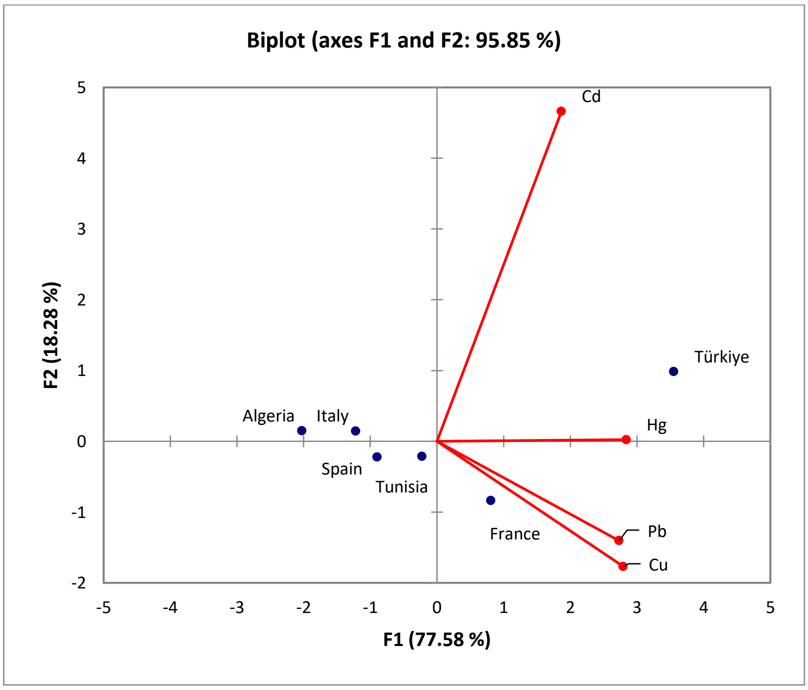

Figure 7.28. Principal component analysis (PCA) of metals in eel muscle in six Mediterranean countries.

Pearson correlation confirmed strong links between metals including, significantly positive correlations between copper and mercury (R^2 = 0.9276) and between copper and lead (R^2 = 0.9276).

Zinc (Zn)

Zinc contamination results (Figure 7.29), showed that sites in all countries were classified in the first group (less than 35000 ng/g) except for the maximum value reported by Türkiye. Zinc is considered as an essential trace metal for aquatic life so the thresholds are higher than for other metals. Non-parametric Kruskal-Wallis testing confirmed this, showing no significant differences between countries (p-value = 0.6931). Data from Italy and Türkiye were distributed over a wide range of concentrations, while French data displayed less variation.

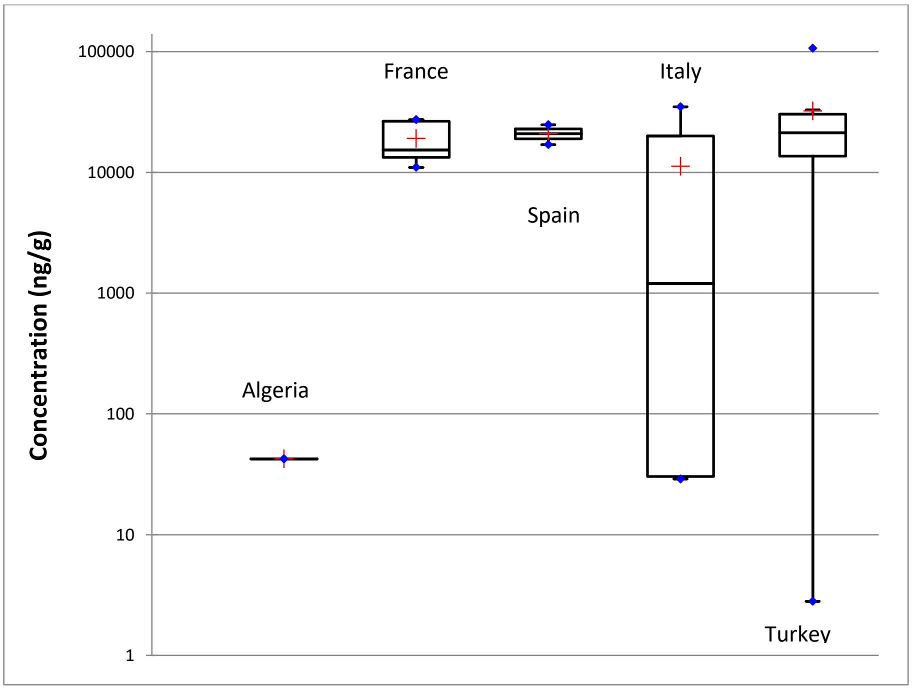

Figure 7.29. Boxplot comparison of zinc concentrations in eel muscle in Mediterranean countries.

Note: Red crosses represent the mean, while the lower and upper blue points represent minimum and maximum values, respectively, and the bottom, medium and top box bars showed the 25th percentile, the median and 75th percentile, respectively.

Chromium (Cr)

There were low levels (below the reference value) of chromium contamination in eels from Italy and Algeria. However, French sites as well as most Turkish sites recorded high levels in all reported data (Figure 7.30), compatible with the third classification level (polluted group: 606 ng/g to less than 1521 ng/g). Turkish data was widely distributed without registering extreme values, while chromium levels were narrowly distributed in samples from France. A Kruskal-Wallis test failed to determine significant differences between countries (p-value = 0.0495).

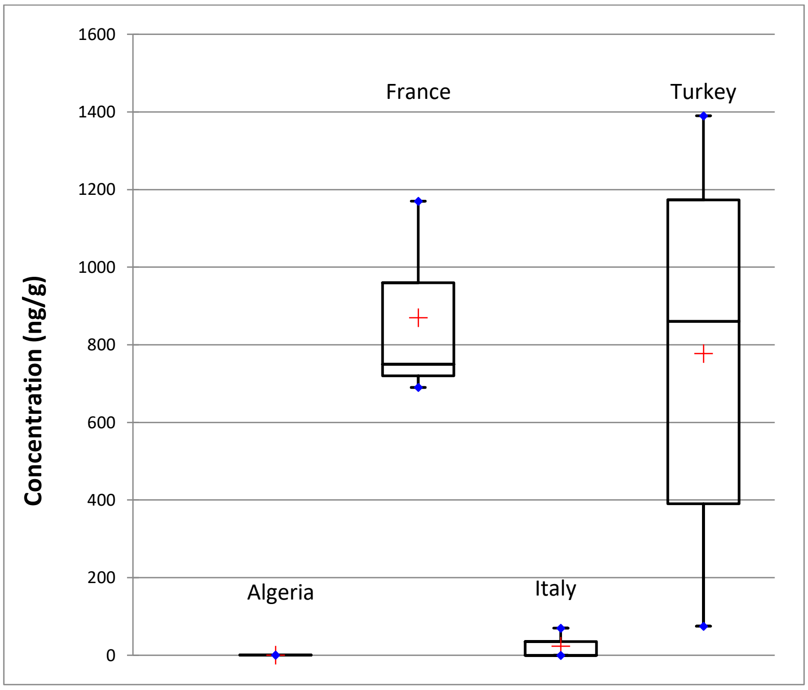

Figure 7.30. Boxplot comparison of chromium concentrations in eel muscle in Mediterranean countries. Note: Red crosses represent the mean, while the lower and upper blue points represent minimum and maximum values, respectively, and the bottom, medium and top box bars showed the 25th percentile, the median and 75th percentile, respectively.

Individual measurements were reported for arsenic (As) in Spain (227.9 ng/g) and Italy (543.5 ng/g) classifying Spain as slightly polluted (within the range, 103 ng/g to less than 259 ng/g) and Italy in the polluted class (259 ng/g to less than 650 ng/g). Only one data point was reported for selenium (Se), from Spain (303 ng/g) classing it as not polluted, (less than 515 ng/g).

Eel quality index for contaminants (EQICONT)

EQICONT by country

The data showed that in the majority of cases, countries did not display high levels of contamination, even if there were large differences in terms of sampling and analysis of pollutants (type of pollutants, number of sampling sites, frequency of analysis). Türkiye registered more sites in the polluted class, followed by Italy, while Algeria, France, Italy and Spain all showed sites with low levels of contaminants (Figure 7.31).

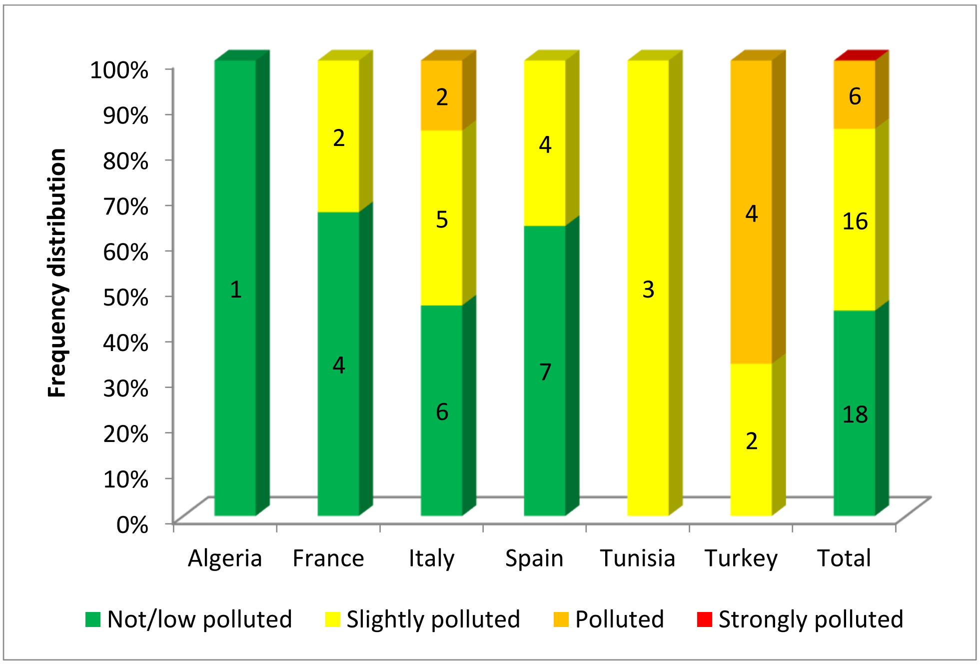

Figure 7.31. Frequency distribution of EQICONT class by country in the Mediterranean region. Note: Numbers indicate the number of sites.

EQICONT by habitat

The eel quality index showed globally clean environments for eel in Mediterranean habitats. No cases of strongly polluted areas were reported. More cases of not or low polluted status were reported in eels inhabiting lagoons, while lakes and estuaries registered relatively similar numbers of cases of clean, slightly polluted and polluted environments while rivers were mostly found to be slightly polluted as there were no strongly polluted river sites (Figure 7.32).

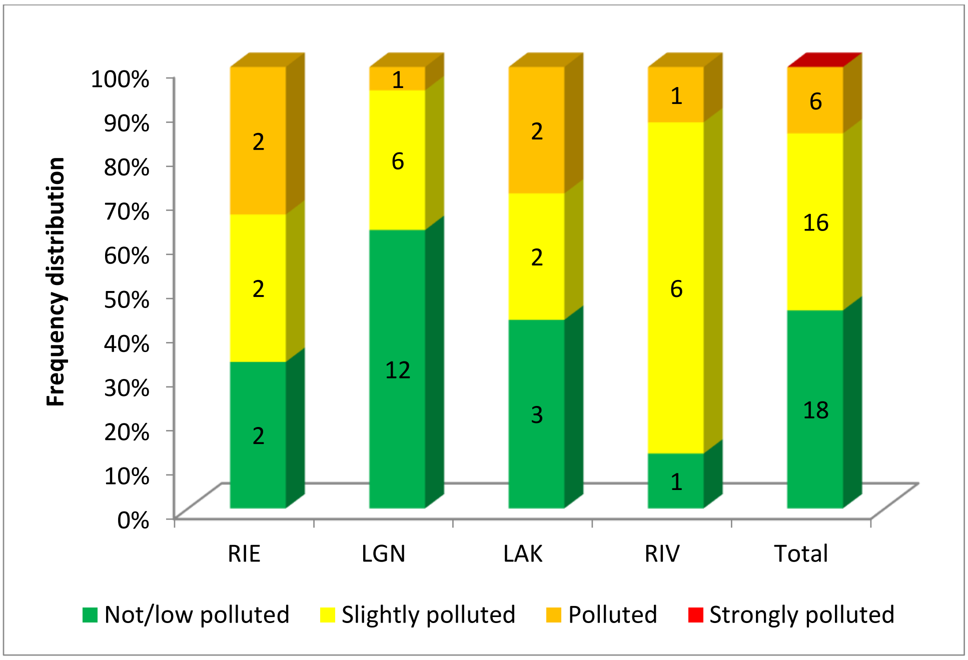

Figure 7.32. Frequency distribution of EQICONT class by habitat (RIE = estuary, LGN = lagoon, LAK = lake, RIV = river) in the Mediterranean region.

Note: Numbers indicate the number of sites.

Additional results on EQICONT are provided in Additional Results Part V.

Identification of key sites (EQITOT)

Data on both pathogen and contaminant stressors used to calculate the total eel quality index, EQITOT, were available only for 19 sites in six partner countries. Most of the sites (84 percent) were classified as not impacted or slightly impacted revealing the good quality status of eels in the Mediterranean region. Only Italy (one site) and Türkiye (two sites) were classified as impacted and no single site was strongly impacted (Figure 7.33). Details on the EQITOT classification by site are presented in Additional Results Part VI.

Concerning habitats, Figure 7.34 shows that all lagoons were not impacted or slightly impacted whereas 33 percent and 66 percent of lakes and rivers, respectively, were impacted.

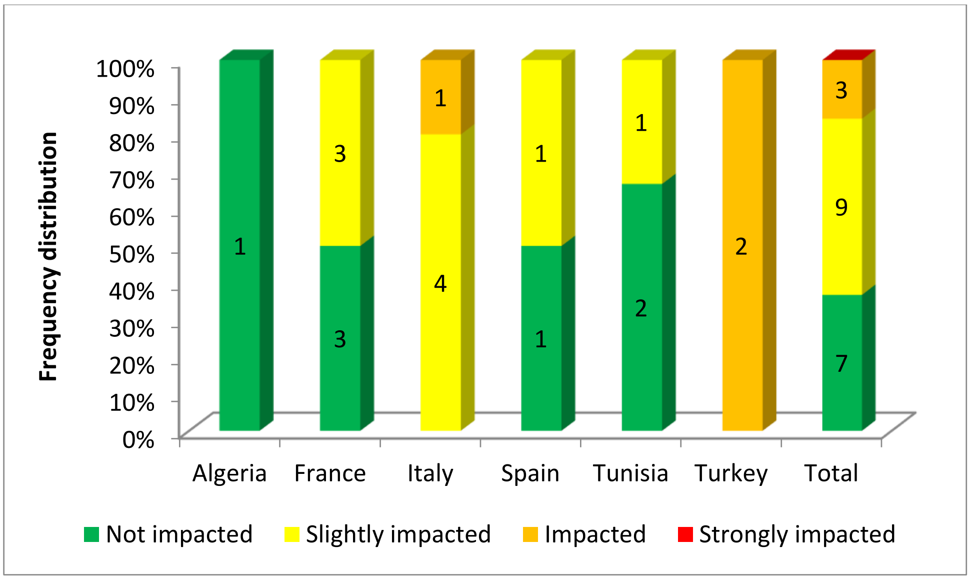

Figure 7.33. Frequency distribution of EQITOT class by country in the Mediterranean region.
Note: Numbers indicate the number of sites.

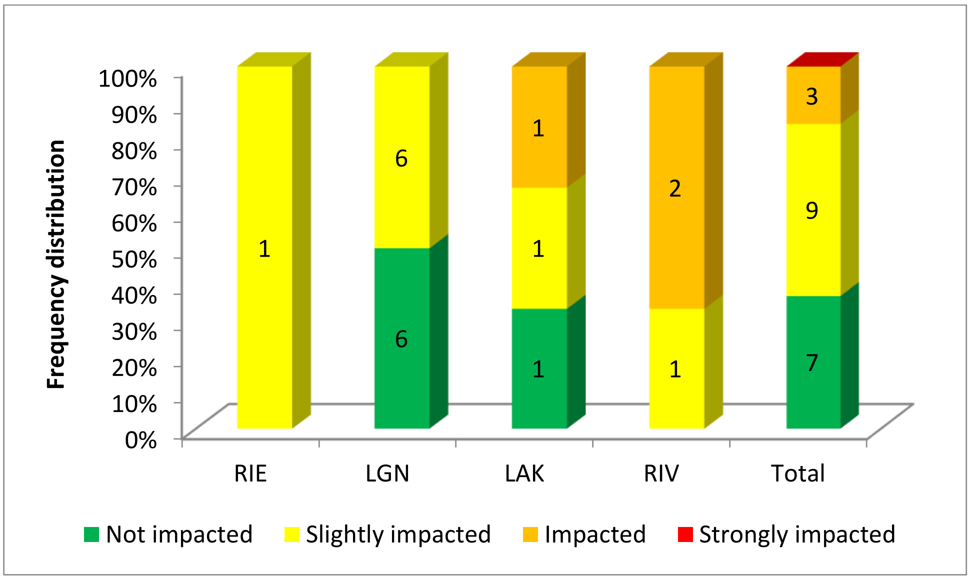

Figure 7.34. Frequency distribution of EQITOT class by habitat (RIE = estuary, LGN = lagoon, LAK = lake, RIV = river) in the Mediterranean region.
Note: Numbers indicate the number of sites.

7.4. DISCUSSION AND CONCLUSIONS

7.4.1. Data availability in Mediterranean countries

Examination of the information on biological and chemical contamination of eels in the nine partner countries revealed great disparity in the availability of data between Mediterranean countries and between habitats. For parasites and pathogens, France, Italy and Spain contributed up to 57 percent of the available data while Albania, Algeria and Egypt contributed only 22 percent and Greece, Tunisia and Türkiye had intermediate levels of data availability. This was probably due to the fact that the north-western European countries have been members of the joint EIFAAC/ICES/GFCM working group on eels (WGEEL) and devoted more effort into monitoring activities within the framework of annual data calls, whereas countries such as Albania, Algeria and Egypt, have only recently joined the WGEEL. Similarly, 68 percent of all sites studied at the regional level were lagoons, as these are the main habitats that have been exploited for eels in the Mediterranean.

Concerning parasites, the nine partner countries were especially interested in the highly pathogenic swim bladder nematode, *Anguillicola crassus* (representing 63 percent of parasite data) and to a lesser extent *Pseudodactylogyrus* spp, while other parasites were studied in only 36 sites across eight countries.

Moreover, few data exist for other pathogens. For viruses, only the three data rich countries provided data, probably because of the high cost of analysis. However, available data remained very scarce compared to the situation in northern European countries and bacteria were the least studied group as only Spain provided data.

Similar disparities in data availability were observed for chemical contaminants such as heavy metals and organic pollutants. Of the 41 studied sites in six partner countries, the majority of data were provided from countries on the north-western side of the Mediterranean (Italy, Spain and France) due to the high cost of such analyses, making it difficult for less developed countries to undertake them.

7.4.2. Parasites and pathogens

Fifty-five parasitic species or taxa were recorded for European eel from the nine partner countries, nematodes, trematodes and cestodes being the most abundant taxonomic groups, recorded in almost all countries. The Mediterranean helminth fauna appeared to be less diverse than elsewhere in Europe where Jakob, Walter and Hanel (2016) listed 161 species.

Moreover, species richness differed between countries and habitats. Algeria reported 20 species or taxa, while only one species, the nematode *A. crassus*, was recorded in Greece. There is a well-developed grey literature on parasites in Algeria, while Greece only focused on the swim bladder parasite. Eels inhabiting brackish environments (lagoon and estuaries) harboured a greater diversity of parasites (54 taxa or species) compared to freshwater environments (lakes and rivers) which only had 23 taxa or species. Although this contrasts with the observations of Køie (1988) and Kennedy *et al*. (1997) who found that parasite diversity decreases with increasing salinity it is due to the fact that most of the Mediterranean data was from lagoons, while freshwater sites were poorly studied, making comparisons difficult.

Most of the helminth fauna of Mediterranean eels were intestinal (49 percent) and autochthonous. They appeared to be of little or no danger to their host, having co-evolved allowing it to acquire immunological protective mechanisms (Vigier, 1997). However, two parasites of allochthonous origin introduced by aquaculture activities or during restocking are particularly harmful for eel populations. The monogene, *Pseudodactylogyrus* spp. parasitizes the gills and can cause stock damage by asphyxiation (Buchmann, 1993; Buchmann, Mellergaard and Kie, 1987; Saraiva, 1995; Kennedy, 2007).

This parasite was found in eight partner countries at 22 sites. However, 24 percent of the Mediterranean sites studied were free of this monogene.

Anguillicola crassus is particularly dangerous for the reproductive capacity of eels. Infection by this swim bladder parasite impairs the silvering process (Fazio *et al*., 2012) and leads to decreased swimming ability (van Ginneken *et al.*, 2004, 2005; Palstra *et al*., 2007) which could result in spawners not being able to migrate and reproduce successfully (Lefebvre, Cantounet and Crivelli, 2002). It is an allochthonous species, originating from southeast Asia and endemic to Japanese eel, that was accidentally introduced into Europe following imports of eels from Taiwan into Germany (De Charleroy *et al*., 1990; Bruslé, 1994). Rahhou *et al*. (2005) highlighted genetic differences between the Mediterranean and Atlantic populations, which, according to these authors, implies several introduction episodes. First documented in the early 1980s (Koops and Hartmann, 1989), it is now considered to have spread across most of the areas where European eel is found (Kennedy, 2007). Data obtained from partner countries showed that *A. crassus* was present in 60 sites in eight countries and had spread to both the northern and southern Mediterranean, in brackish and freshwater habitats. Although it has not yet been demonstrated as present in Albania, its proven presence in Lake Ohrid, a transboundary lake between Macedonia and Albania (Cakic *et al*. 2002), tends to suggest possible spread to the Albanian eel population. However, most of the sites studied were classed as not infected or slightly infected (56 percent). While eight sites (in Italy and Tunisia) were recorded as Anguillicola-free, these results should be taken with caution. For example, sites like Oued Joumine in Tunisia were investigationed some time ago (Ould Daddah, 1995) and this river is one of the tributaries of Ichkeul Lake which was classified as slightly infected through monitoring carried out in 2015. Lagoons accounted for 66 percent of the sites where *A. crassus* was found, again because they are the most studied sites at the Mediterranean level. However, the degree of infection of A. crassus was lower in brackish waters. Indeed, 75 percent of lagoons were classed as not infected or slightly infected while 100 percent of lakes and 78 percent of rivers were moderately or strongly infected. These observations agree with those of Jakob *et al*. (2009), ICES (2013) and Amilhat *et al*. (2014). It is particularly important to identify sites with a high prevalence of *A. crassus* in order to prevent any transfer of eels from these sites and thus avoid further contamination episodes.

Very little information exists in the Mediterranean to have a clear idea on the level of infections caused by other pathogens such as viruses and bacteria. Anguillid herpesvirus 1 (AngHV-1) is one of the major pathogens of European eel (Van Beurden *et al.*, 2012) and has been suggested as one of the causes of its decline (Haenen *et al*., 2002; Haenen *et al*., 2010). It causes skin and gill erythema, as well as necrosis of the skin, gills and liver (Elie and Girard, 2009). Affected eels may not show clinical signs and the virus may remain latent and reactivate under stressful conditions (van Nieuwstadt, Dijkstra and Haenen, 2001). AngHV1 has already been found in several European countries, both in aquaculture and in the wild (Jakob, 2009; van Beurden *et al*., 2012; Kempter, Panicz and Bergmann, 2014; Philippart, 2020).

EVEX virus causes lethargy, haemorrhages, skin lesions, and anaemia. Infected eels died after 1000 km to 1500 km of swimming in an experimental tunnel (van Ginneken *et al*., 2005). In the Mediterranean, EVEX was found to be present in three sites in France and Italy and AngHV-1 in five sites in Italy and Spain. Since these viruses are highly pathogenic and could be a contributing factor to the decline of the European eel stock, more investigations at the Mediterranean level should be undertaken.

Concerning bacteria, several species have been listed in European eels according to Girard and Lefebvre (2001). Elie and Girard (2009) noted the importance of infections and damage caused by bacteria from the genera, Aeromonas, Pseudomonas or Vibrio, especially during the spring and summer periods. Vigier (1997) indicated that bacterial infections only develop in cases of bad environmental conditions such as sudden changes in water temperature and flow. In Mediterranean countries, monitoring and evaluation of bacterial infections in wild eel populations is practically non-existent and only Spain was able to provide data at a single site.

7.4.3 Pollutants and heavy metals

Pollutants, like heavy metals and persistent organic pollutants (POPs), present in the eel habitat could seriously compromise the reproductive success of eels. Despite possessing a permanent detoxification system via the liver and kidneys, the eel has life features that make it particularly vulnerable to pollutants. Its high percentage of lipids, its high trophic level, its lifetime (three to eight years for males, five to 20 years for females) and the fact that it reproduces only once in its life (without being able to evacuate pollution through regular reproduction), mean that it can dramatically accumulate lipophilic, xenobiotic molecules during its long continental journey (Amilhat, 2007).

These pollutants mainly disrupt the endocrine, reproductive, enzymatic, immune, neural and central nervous systems as well as the storage of lipids and the proper functioning of vital organs (Amilhat, 2007). Bioaccumulation of toxic metals in eels has a significant impact on their physiology. Highly toxic metals such as cadmium, lead and mercury can impair the immune, reproductive, nervous, and endocrine systems, thus negatively affecting cellular and organ functions at the individual and even population level (Demirak *et al*., 2022). Corsi *et al*. (2005) reported that PCBs significantly reduce lipid storage and breeding success. Dioxin-like contaminants are strong candidates for causing the decline in eel populations because of their devastating effects on migration and development as well as the survival of eel embryos (Palstra *et al*., 2006; van Ginneken *et al*., 2009). Recent studies have confirmed the presence of heavy metals and POPs in the muscle of eels in Mediterranean countries (Romero *et al*., 2020; Noël *et al*., 2013; Pico *et al*., 2019).

Fish, such as eels, with a high lipid content can be used as good indicators of the presence of organic pollutants rather than direct testing of water since these pollutants are not very water-soluble (Pico *et al*., 2019). It is worth noting that the limits for quality classes in eel muscle presented in Supplemental Material on the MEthodology were established for human consumption-related health risk purposes and are lower than the guide values of most other regulations cited in literature (Linde, Sanchez-Galen and Garcia-Vazquez, 2004; Amilhat, 2007). For example, Amilhat (2007) reported guide values (wet weight) of 1000 ng/g for mercury, 100 ng/g for cadmium and 300 ng/g for lead according to the European Commission (2006). Thus, the health risk effect for consumers may only be relevant for reported values belonging to the fourth class (strongly deviating).

PCB concentrations registered in eel muscle tissue from European Mediterranean countries showed relatively low levels except for some values recorded in Italy. These levels were lower than those reported for other European countries including Poland and Belgium (Szlinder-Richert *et al*., 2014; Bourillon *et al*., 2020). Also, data reported by Van Ael *et al*. (2014) showed high concentrations of six PCBs (median of 2 493 ng/g live weight) in Flanders (Belgium), even higher than those of the above European countries.

Ferrante *et al*. (2010) concluded that the detected PCB levels are likely to contribute to the heavy pollution of the Campania aquatic ecosystem (Italy) and may cause a possible health hazard. The bioconcentration of PCBs in aquatic organisms correlates with the degree of chlorination, as well as stereochemistry and lipophilicity; congeners with low chlorination grades are more readily metabolised and eliminated than highly chlorinated congeners (Bordajandi *et al*., 2003). The large data set generated for the purposes of this project did not allow the reporting of individual concentrations of PCB congeners (as well as DDT congeners and other organic pollutants); future differentiation of congener profiles of each Mediterranean country could be a useful addition to the body of information. Belpaire *et al*. (2011) found a different pattern in the composition of PCB congeners between sites in Flanders (Belgium) that implied different sources of pollution.

The sum of DDTs displayed acceptable values overall, which indicated a not polluted status, with the exception of some peak values recorded in France and Italy. The mean levels of DDTs displayed the

Mediterranean countries were comparable to those found in other European countries such as Belgium and the United Kingdom (Bourillon *et al*., 2020).

The toxic metals, mercury, cadmium and lead were found at different levels across Mediterranean countries. Reported data for mercury did not exceed value limits presented in Supplemental Material on the Methodology for the fourth class (greater than 634 ng/g) for all reported cases and were far from the maximum levels for human consumption as set by Commission Regulation (EC) No. 1881/ 2006 amended by EC 629/2008 at 1000 ng/g wet weight (Noël *et al*., 2013). On the contrary, mean values for cadmium for Turkish eels (413.5 ng/g) exceeded the maximum level set by EU Commission Regulation (EC 629/2008) for eel muscle meat (100 ng/g wet weight) and indicated a strongly polluted status according to ICES (ICES, 2015; Noël *et al*., 2013). Similarly, high lead levels were recorded in some samples in France (mean, 193.33 ng/g) and Türkiye (mean, 1 112.7 ng/g), classifying them as strongly deviating (greater than 158 ng/g). The maximum permitted lead level in Commission Regulation (EC) No. 629/ 2008 for fish muscle meat is 300 ng/g wet weight (Noël *et al*., 2013). In Belgium, Van Ael *et al*. (2014) reported mercury levels comparable to these results (median: 97.3 ng/g, minimum: 10 ng/g and maximum: 708 ng/g), and relatively low levels for cadmium (median: 7.7 ng/g, minimum: 0.25 ng/g and maximum: 554 ng/g) as well as for lead (median: 23.6 ng/g, minimum: 1.0 ng/g and maximum: 669 ng/g). For other fish species in Europe, mercury was found to be between 9.0 ng/g (bream) in the Vestonice reservoir in the Czech Republic and 4 500 ng/g (perch) in the contaminated Nitra River in Slovakia. Cadmium was found to be between 1.0 ng/g (pike) in the Tisza River (Hungary) and 1 780 ng/g (catfish) in the Nitra River in Slovakia. Mean lead levels varied widely between 3.0 ng/g (perch) in the Odra River in Poland and high mean levels were found for common carp in the Nitra River (Slovakia) and the Neretva River (Croatia) (390 ng/g and 317 ng/g, respectively) due to considerable anthropogenic impact (Noël *et al*., 2013).

The metal micronutrients, copper and zinc did not occur at levels that would indicate a polluted status in any of the datasets, as they were lower than 4 µg/g and 222 µg/g, respectively. However, micronutrient concentrations were by far higher than those of the toxic metals mercury, cadmium and lead. These results agree with those of Demirak *et al*. (2022), who found that the accumulation of essential metals (manganese, copper and zinc) in eels was higher than the accumulation of non-essential metals (lead and cadmium). Results from analysis of copper in the contributing Mediterranean countries ranged from between 5.9 ng/g and 1 554.28 ng/g and those zinc varied between 2.8 ng/g and 106 710 ng/g. Higher concentrations were reported in the Flanders region (Belgium) for copper (mean: 909.73 ng/g, minimum: 50 ng/g and maximum: 436 000 ng/g) and zinc (mean: 25 864.79 ng/g, minimum: 1 200 ng/g and maximum: 243 100 ng/g) (Maes, Belpaire and Goemans, 2008). Zinc, copper and selenium (which was not at a toxic level in the single case reported in these datasets) are essential elements. Zinc and copper are involved in many key metabolic processes, while selenium is known to play a key role in the defence against oxidative stress. Unlike zinc, which does not constitute a health risk for eels even at high concentrations, accumulation of copper at high levels is known to disturb the endocrine system, osmoregulation and several other physiological processes. Similarly, at high concentrations, selenium is known for its effects on cardiovascular, hepatic and reproductive functions and for its carcinogenicity (Pannetier *et al*., 2016). However, according to the same authors, selenium toxicity studies have been reported for other fish species but not from specific studies on eels.

Generally, muscle tissue accumulates lower concentrations of metals than the liver (Usero *et al*., 2003; Demirak *et al*., 2022; Pannetier *et al*., 2016). This could be due to the greater tendency of the elements to react with the oxygen carboxylate, amino group, nitrogen or sulphur of the mercapto group in the metal-lothionein protein, whose concentration is highest in the liver (Usero *et al*., 2003).

Metal uptake and internal distribution of metals in aquatic organisms are influenced by many parameters linked to their environment (environmental compartment, pH and temperature), to the nature of the element (physico-chemical characteristics, concentration, speciation and bioavailability) and to the species (absorption, detoxification, feeding, trophic level, gender and life stage) (Lortholarie *et al.*, 2021).

7.4.4 Mediterranean key sites

The health status of the Mediterranean eel population was assessed thanks to EQI indices for contaminants and pathogens. Overall, the environmental quality index for disease, EQIDIS, revealed a high frequency of eels free of pathogens (including *A. crassus*, EVEX and AngHV-1), with 55 percent of the sites in partner countries classified as not infected or slightly infected. Brackish water habitats presented the healthiest environments for eel populations (70 percent of lagoons and 43 percent of estuaries). Strongly infected eels were found in 37.5 percent of French sites, eight percent of Italian sites and 28 percent of Spanish sites. The environmental quality index for contaminants, EQICONT, showed that class 3 (polluted) sites represented 13.6 percent of the total number of sites and were found in Türkiye and Italy while class 1 and 2 sites (not or slightly polluted) represented 43.2 percent and 36.4 percent respectively, mainly in lagoons.

Considering 19 Mediterranean sites from six partner countries, the total environmental quality index, EQITOT, indicated the overall high quality of the eel population with 36.8 percent of sites "not impacted" and 47.3 percent "slightly impacted" while only 15.8 percent of sites (two rivers and one lake) were classified as "impacted" and no single site was classified as "strongly impacted". However, it should be noted that EQI classes are set statistically from field samples of yellow eels from an extensive 12-year study of contaminant monitoring in several sampling sites including heavily polluted sites in Flanders (Belgium) and this may not be suitable for the Mediterranean context. A more appropriate eel quality index for the Mediterranean should be established considering all the habitats in Mediterranean countries, including both presumptive healthy sites and polluted sites, to establish the reference and boundary values for heavy metals and organic pollutants specific to the Mediterranean.

Over the nine partner countries, seven sites were identified as key sites classified as "not impacted" according to their EQITOT classification: Tonga Lake (Algeria), Bages-Sigean, Thau and Camargue lagoons (France), Mar Menor (Spain), Ichkeul and Tunis North lagoon (Tunisia). It is essential to protect key sites through specific management measures to guarantee healthy spawners that can participate effectively towards stock recovery programmes. However, some data are old and must to be used with caution, therefore new research is required to update the available information on key sites.

The overall picture illustrates the good health status of Mediterranean eels, particularly those living in lagoons, demonstrating the importance of these habitats for eel conservation. However, there was very scarce data available compared to the potential number of eel habitats in the Mediterranean. Moreover, most of the data gathered came from France, Italy and Spain and mainly concerned infestation by the parasite *A. crassus*. This implies that with the current state of knowledge, it is difficult to have a comprehensive picture of eel health status at the Mediterranean level. Efforts should be made at the Mediterranean and national level to acquire essential data on *A. crassus*, EVEX, AngHV-1 and pollutants through regular monitoring programmes in order to assess spawner quality.

7.5. RECOMMENDATIONS

The results of this chapter contributed towards updating the state of knowledge about the quality of eels in the Mediterranean. The overall high health status of Mediterranean eel population was highlighted, especially in lagoons, and key sites were identified through quality indices.

However, this work points to the lack of data and the disparities in data availability between countries and sites at the Mediterranean level, probably due to technical difficulties and analytical costs.

The following recommendations can be made:

- Strengthen technical and scientific cooperation for data acquisition through cross-border or Mediterranean-wide projects and the creation of networks to reduce data gaps between countries.
- Harmonize assessment methods at Mediterranean and international levels.
- Encourage countries to carry out regular monitoring of contaminants and pathogens, as well as possibly monitoring lipid levels, in a representative number of sites per country, in accordance with ICES advice on European eel for 2021 (ICES, 2021).
- Establish a more appropriate eel quality index for the Mediterranean.
- Take measures to prohibit any transfer of eels from site to site to avoid transfer of pathogens, especially into sites recognized as free of parasites or viruses.
- Take measures to restore sites identified as polluted and protect others from becoming polluted.
- Propose adequate management measures for key sites identified as having healthy eel populations, such as increasing silver eel escapement to ensure a minimum of spawners that can effectively contribute towards stock recovery.

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Supplementary Material on the Methodology Part I – ReadMe spreadsheet for the WP3 database-eel quality, relative to eel parasites, pathogens and pollutants with the list of variables

Table 7SM1.1. ReadMe spreadsheet for the WP3 database-eel quality relative to eel parasites and pathogens

Country	Site	Area/basin	Longitude	Latitude	Habitat type	*A. crassus* SDI	*A. crassus* prevalence	*A.crassus* score	Quality class *A. crassus*	Other parasites	P(%)	Other parasites score	Bacterias	P(%)	Bacteria score	EVEX prevalence	Ang HV-1 prevalence	Virus score	Other viruses	Other viruses prevalence	Quality class Viruses	EQIdis = Average quality classes *A. crassus*-Viruses	Status	Data source

Table 7SM1.2. ReadMe spreadsheet for the WP3 database-eel quality relative to eel pollutants

Country	Year	Site	Area/basin	Habitat type	Pollutant	Concentration (ng/g)	Concentration µg/g (ng/g entre 1000)	Average	EQI Quality classes by pollutant	Average EQI Quality classes	Total EQI classes (pag. 35 ICES 2015)	EQI classes

Supplementary Material on the Methodology Part II – Eel quality classes, reference values and boundary values of the quality classes for a series of heavy metals, PCB congeners and organochlorine pesticides

Table 7SM2.1 Reference values and boundary values of the quality classes for a series of heavy metals, PCB congeners and organochlorine pesticides as defined in Flanders' Eel Pollution Monitoring Network (EPMN).

Quality classes		1	2	3	4
Contaminant	Reference value (RV)	Not deviating log C/RV < 0.4	Slightly deviating 0.4 ≤ log C/RV < 0.8	Deviating 0.8 ≤ log C/RV < 1.2	Strongly deviating log C/RV ≥ 1.2
Mercury	40	< 100	100 - < 252	252 - < 634	≥ 634
Cadmium	2	< 5	5 - < 12.6	12.6 - < 31.7	≥ 31.7
Lead	10	< 25	25 - < 63	63 - < 158	≥ 158
Cupper[2]	0.25	< 0.6	0.6 - < 1.6	1.6 - < 4	≥ 4
Zinc[2]	14	< 35	35 - < 88	88 - < 222	≥ 222
Nickel	14	< 35	35 - < 88	88 - < 222	≥ 222
Chrome	96	< 241	241 - < 606	606 - < 1521	≥ 1521
Arsenic	41	< 103	103 - < 259	259 - < 650	≥ 650
Selenium	205	< 515	515 - < 1293	1293 - < 3249	≥ 3249
PCB 28	0.12	< 0.3	0.3 - < 0.8	0.8 - < 1.9	≥ 1.9
PCB 31	0.1	< 0.3	0.3 - < 0.6	0.6 - < 1.6	≥ 1.6
PCB 28+31	0.25	< 0.6	0.6 - < 1.6	1.6 - < 4	≥ 4
PCB 52	1	< 2.5	2.5 - < 6.3	6.3 - < 15.8	≥ 15.8
PCB 101	2.5	< 6	6 - < 16	16 - < 40	≥ 40
PCB 105	1.2	< 3	3 - < 7.6	7.6 - < 19	≥ 19
PCB 118	3.5	< 9	9 - < 22	22 - < 55	≥ 55
PCB 138	7.7	< 19	19 - < 49	49 - < 122	≥ 122
PCB 153	10	< 25	25 - < 63	63 - < 158	≥ 158
PCB 156	0.6	< 1.5	1.5 - < 3.8	3.8 - < 9.5	≥ 9.5
PCB 180	4.5	< 11	11 - < 28	28 - < 71	≥ 71
∑ PCBs	29	< 73	73 - < 183	183 - < 460	≥ 460
∑ PCBs[1]	240	< 603	603 - < 1514	1514 - < 3804	≥ 3804
α-HCH	0.05	< 0.1	0.1 - < 0.3	0.3 - < 0.8	≥ 0.8
γ-HCH	1.3	< 3.3	3.3 - < 8.2	8.2 - < 20.6	≥ 20.6
Dieldrin	1.1	< 2.8	2.8 - < 6.9	6.9 - < 17.4	≥ 17.4
HCB	0.5	< 1.3	1.3 - < 3.2	3.2 - < 7.9	≥ 7.9
p.p'-DDD	2.5	< 6	6 - < 16	16 - < 40	≥ 40
p.p'-DDT	0.005	< 0.01	0.01 - < 0.03	0.03 - < 0.08	≥ 0.08
p.p'-DDE	13	< 33	33 - < 82	82 - < 206	≥ 206
∑ DDTs	16	< 40	40 - < 101	101 - < 254	≥ 254

Note: Values are expressed in ng/g wet weight of muscle tissue, unless indicated as 1 in ng/g lipid weight or 2 in µg/g wet weight of muscle tissue. C: concentration; ∑ PCB is indicated for the 7 PCBs indicators (adapted from Belpaire and Goemans, 2007

Additional results Part I – Eel quality classes based on *Anguillicola crassus* infestation by site

Table 7AR1.1. *A.crassus* quality classes by site in the partner countries

Country	Site	Habitat type	SDI	Prevalence P (%)	Score	Status
Algeria	Mafragh	RIE		49.50	3	Infected
	Mellah	LGN		6.70	2	Slightly infected
	Oubeira	LAK		45.74	3	Infected
	Tonga	LAK		40.00	3	Infected
Egypt	Nile delta	RIE		10.7	2	Slightly infected
	Burullus	LGN		54.1	3	Infected
France	Salses-Leucate	LGN	1.20	17.00	2	Slightly infected
	Bages-Sigean	LGN	1.25	30.00	2	Slightly infected
	Vendres	LGN		75.00	4	Strongly infected
	Thau	LGN		4.00	2	Slightly infected
	Or	LGN		25.00	2	Slightly infected
	Gruissan Complex	LGN		69.00	2	Slightly infected
	Palavas Complex	LGN		25.00	2	Slightly infected
	Petite Camargue	LGN		50.00	3	Infected
	Canet	LGN	3.30	38.80	3	Infected
	Berre	RIV	3.70	33.30	3	Infected
	Biguglia	LGN		55.00	3	Infected
	Urbino	LGN		12.90	2	Slightly infected
	Vaccares	LGN		77.27	4	Strongly infected
	Pierre blanche	LGN		5.04	2	Slightly infected
	Grau du roi	LGN		75.00	4	Strongly infected
	Furemorte	RIE		69.19	4	Strongly infected
Greece	Lagoon Amvrakikos	LGN		0.64	2	Slightly infected
	Lagoon Prokopou	LGN		0.18	2	Slightly infected
	Lagoon Porto Lagos	LGN		0.70	2	Slightly infected
	Lake Vistonida	LGN		0.71	2	Slightly infected

	River Evros estuary	RIE		0.20	2	Slightly infected
	Lagoon Klisova	LGN		0.37	2	Slightly infected
	Lagoon Messolonghi-Aitoliko	LGN		0.17	2	Slightly infected
Italy	Bolsena	LAK		57.10	3	Infected
	Lesina	LGN		30.30	2	Slightly infected
	Tevere	RIV		76.40	4	Strongly infected
	Fogliano	LGN	0.00	0.00	1	Not infected
	Capolace	LGN	0.00	0.00	1	Not infected
	Comaccio	LGN	1.44	5.60	2	Slightly infected
	Monaci	LGN		0.00	1	Not infected
	Burano	LGN		37.40	3	Infected
	Aquatina	LGN		0.00	1	Not infected
	Figheri	LGN		9.10	2	Slightly infected
	St. Gilla	LGN		0.00	1	Not infected
Spain	Palmores	RIE		100.00	4	Strongly infected
	Guadalhorce	RIE		100.00	4	Strongly infected
	Guadalfeo	RIE		90.00	4	Strongly infected
	Mar Menor	LGN		3.40	2	Slightly infected
	L'Albufera de Valencia	LGN		66.60	3	Infected
	L'Encanyissada (includes Clot and Noria)	LGN		21.30	2	Slightly infected
	La Tancada, Bassa dels Ouls y Antigues Salines de Sant Antoni	LGN		25.64	2	Slightly infected
	Canal Vell	LGN		0.72	2	Slightly infected
Tunisia	Bizerte	LGN		15.50	2	Slightly infected
	Ghar El Melh	LGN	0.28	3.66	1	Not infected
	Ichkeul	LGN		25.00	2	Slightly infected
	Joumine	RIV		0.00	1	Not infected
	Sejnane	RIV		20.00	2	Slightly infected

	Tunis Lagoon	LGN		0.00	1	Not infected
Turkey	Köyceğiz Gölü	LAK		39.73	3	Infected
	Ceyhan River	RIV		78.13	4	Strongly infected
	Asi River	RIV		61.11	3	Infected
	Goksu	RIV		60.70	3	Infected
	Seyhan	RIV		75.00	4	Strongly infected
	Manavgat River	RIV		63.6	3	Infected

Additional Results Part II – List of protozoan and metazoan parasites of European eel (*Anguilla anguilla*) in the Mediterranean countries based on data from the WP3 database relative to eel habitat and integrated by literature.

Table 7AR2.1 Checklist of protozoan and metazoan parasites of European eel (*Anguilla anguilla*) in the Mediterranean countries

Parasite	Infection site	Habitat	Country	Site	P%
Apicomplexa					
Eimeria anguillae	Intestine	LGN	Spain	L'Encanyissada (includes Clot and Noria)	9.06
		LGN	Spain	La Tancada, Bassa dels Ouls y Antigues Salines de Sant Antoni	7.69
Myxozoa					
Myxidium sp.	Gill, Skin	LGN	Spain	L'Albufera de Valencia	77.08
Myxidium giardi	Gill, Skin	LGN	Spain	L'Encanyissada (includes Clot and Noria)	30.12
		LGN	Spain	La Tancada, Bassa dels Ouls y Antigues Salines de Sant Antoni	17.95
		LGN	Spain	Canal Vell	13.89
		LGN	Algeria	Mellah	81.72
		RIE	Egypt	Nile delta	3.1
Myxobolus sp.	Fin, Intestine, Kidney	LGN	Spain	L'Encanyissada (includes Clot and Noria)	14.72
		LGN	Spain	La Tancada, Bassa dels Ouls y Antigues Salines de Sant Antoni	7.69
Ciliophora					
Glossatella spp.	Skin, Gill	LGN	Albania	ND	2.23
Trichodina pediculus	Gill	LGN	Spain	L'Encanyissada (includes Clot and Noria)	0.02
Trichodina epizootica	Gill, Skin	RIE	Egypt	Nile delta	4.6
Monogenea					
Dactylogyrus sp.	Gill	RIE	Egypt	Nile delta	6.1
Gyrodactylus spp.	Gill	LGN	Albania	ND	12.38
Gyrodactylus anguillae	Gill	LGN	Italy	Figheri	3.00
Pseudodactylogyrus sp.	Gill	LGN	France	Salses-Leucate	10.00
		LGN	France	Bages-Sigean	9.00
		LGN	France	Vendres	100.00
		LGN	France	Thau	0.00

Parasite	Infection site	Habitat	Country	Site	P%
		LGN	France	Or	63.00
		LGN	France	GruissanComplex	50.00
		LGN	France	PalavasComplex	31.00
		LGN	France	Petite Camargue	75.00
		LGN	France	Canet	0.00
		LGN	France	Vaccares	90.91
		LGN	France	Grau du roi	81.25
		LGN	Italy	Aquatina	4.8
		LGN	Italy	Figheri	54.5
		LGN	Tunisia	Ichkeul	14.6
		RIE	Algeria	Mafragh	80.00
		LGN	Algeria	Mellah	0.55
		LAK	Algeria	Oubeira	14.49
		LAK	Algeria	Tonga	80.00
		LAK	Turkey	Köyceğiz Gölü	82.19
Pseudodactylogyrus anguillae	Gill	LGN	Spain	L'Encanyissada (includes Clot and Noria)	75.90
		LGN	Spain	La Tancada, Bassa dels Ouls y Antigues Salines de Sant Antoni	84.62
		LGN	Spain	Canal Vell	1.26
		RIE	Egypt	Nile delta	7.7
Digenea					
Bucephalus sp.	Intestine	LGN	France	Salses-Leucate	16.67
		LGN	France	Bages-Sigean	10.34
Bucephalus anguillae	Intestine	LGN	Italy	Comaccio	2.4
		LGN	Italy	Aquatina	47.6
		LGN	Italy	Figheri	45.4
		LGN	Spain	Mar Menor	60
		LGN	Tunisia	Bizerte	11.8
		LGN	Tunisia	Ghar El Melh	38.00
		LGN	Tunisia	Ichkeul	2.2
		LGN	Tunisia	Tunis Lagoon	2.4
		RIE	Algeria	Mafragh	2.00

Parasite	Infection site	Habitat	Country	Site	P%
		LGN	Algeria	Mellah	47.31
		LAK	Algeria	Oubeira	5.55
		LAK	Turkey	Köyceğiz Gölü	15.07
Deropristis inflata	Intestine	LGN	France	Salses-Leucate	44.44
		LGN	France	Bages-Sigean	81.82
		LGN	France	Thau	94.12
		LGN	France	Palavas Complex	86.36
		LGN	France	Vaccares	45.45
		LGN	France	Pierre blanche	83.33
		LGN	France	Grau du roi	100.00
		LGN	Italy	Comaccio	73.8
		LGN	Italy	Aquatina	19.00
		LGN	Italy	Figheri	93.9
		LGN	Spain	Mar Menor	67
		LGN	Spain	La Tancada, Bassa dels Ouls y Antigues Salines de Sant Antoni	41.03
		LGN	Spain	Canal Vell	1.13
		LGN	Tunisia	Bizerte	11.8
		LGN	Tunisia	Ghar El Melh	58.3
		LGN	Tunisia	Ichkeul	51.00
		LGN	Tunisia	Tunis Lagoon	81.9
		LGN	Algeria	Mellah	9.68
Helicometra sp.	Intestine	LGN	France	Salses-Leucate	11.11
		LGN	France	Bages-Sigean	4.55
		LGN	France	Pierre blanche	16.67
		LGN	France	Grau du roi	6.25
Helicometra fasciata	Intestine	LGN	Italy	Comaccio	73.8
Plagioporus spp.	Intestine	LGN	Albania	ND	9.5
Prosorhynchus aculeatus	Intestine	LGN	France	Salses-Leucate	39.29
		LGN	France	Bages-Sigean	4.55
		LGN	France	Palavas Complex	4.55
		LGN	Tunisia	Bizerte	14.8
Cestoda					
Bothriocephalus sp.	Intestine	LGN	Spain	L'Albufera de Valencia	9.37

Parasite	Infection site	Habitat	Country	Site	P%
Bothriocephalus claviceps	Intestine	LGN	Spain	L'Encanyissada (includes Clot and Noria)	1.40
		RIE	Algeria	Mafragh	10.00
		LGN	Algeria	Mellah	0.30
		LAK	Algeria	Oubeira	32.91
		LAK	Algeria	Tonga	26.00
Ligula intestinalis	Intestine	RIE	Algeria	Mafragh	2.00
		LAK	Algeria	Oubeira	1.38
Parabothriocephalus gracilis	Intestine	LAK	Algeria	Oubeira	0.55
Parabothriocephalus psenopsis	Intestine	RIE	Algeria	Mafragh	7.49
		LAK	Algeria	Oubeira	4.16
Proteocephalidae (larvae)	Intestine	LGN	Spain	Mar Menor	2
Proteocephalus sp.	Intestine	LGN	Spain	L'Albufera de Valencia	6.25
Proteocephalus macrocephalus	Intestine	LGN	Italy	Figheri	9.1
		LGN	Spain	L'Encanyissada (includes Clot and Noria)	2.10
		LGN	Spain	Canal Vell	0.23
		LGN	Tunisia	Ichkeul	16.8
		RIE	Egypt	Nile delta	1.5
Scolex pleuronectis (larvae)	Intestine	LGN	Tunisia	Ichkeul	4.3
Nematoda					
Camallanus lacustris	Intestine	RIE	Algeria	Mafragh	2.00
		LGN	Albania	ND	3.23
Capillaria brevispicula	Intestine	LGN	Albania	ND	7.52
Contracaecum sp. (larvae)	Intestine	LGN	Italy	Comaccio	9.8
		LGN	Italy	Aquatina	61.9
		LGN	Italy	Figheri	69.7
		LGN	Spain	Mar Menor	46
		LGN	Tunisia	Ghar El Melh	13.00
		LGN	Tunisia	Ichkeul	20.9

Parasite	Infection site	Habitat	Country	Site	P%
		LGN	Tunisia	Tunis Lagoon	38.7
Cosmophalus obvelatus	Intestine	LGN	Italy	Comaccio	4.8
Cucullanus sp.	Intestine	RIE	Algeria	Mafragh	4.30
		LAK	Algeria	Oubeira	3.60
Pseudoterranova decipiens	Intestine	LAK	Algeria	Oubeira	41.10
Hysterothylacium sp.	Intestine	LAK	Algeria	Oubeira	53.56
Lasiotocus longicystis	Intestine	LGN	Tunisia	Bizerte	2.10
Lecithchirium priacanthi	Intestine	CMW	Egypt	Alexandria	40
Lecithochirium gravidum	Intestine	LGN	France	Salses-Leucate	83.33
		LGN	France	Bages-Sigean	22.73
		LGN	France	Pierre blanche	83.33
		LGN	France	Grau du roi	6.25
		LGN	Tunisia	Bizerte	14.8
		LGN	Egypt	Burullus	41.66
Lecithochririum musculus	Intestine	LGN	Italy	Comaccio	69.00
		LGN	Italy	Aquatina	4.8
		LGN	Italy	Figheri	36.4
Paraquimperia sp.	Intestine	RIV	Tunisia	Joumine	
Paraquimperia tenerrima	Intestine	RIE	Algeria	Mafragh	4.99
		LAK	Algeria	Oubeira	1.66
Spinectus sp.	Intestine	RIV	Tunisia	Joumine	6.60
Tertraphyllidea (larvae)	Intestine	LGN	Italy	Aquatina	4.8
		LGN	Tunisia	Bizerte	29.5
		LAK	Turkey	Köyceğiz Gölü	1.37
Anguillicola crassus	Swimbladder	LGN	France	Salses-Leucate	17.00
		LGN	France	Bages-Sigean	30.00
		LGN	France	Vendres	75.00
		LGN	France	Thau	4.00
		LGN	France	Or	25.00
		LGN	France	Gruissan Complex	69.00
		LGN	France	Palavas Complex	25.00
		LGN	France	Petite Camargue	50.00
		LGN	France	Canet	38.80
		RIV	France	Berre	33.30

Parasite	Infection site	Habit at	Count ry	Site	P%
		LGN	France	Biguglia	55.00
		LGN	France	Urbino	12.90
		LGN	France	Vaccares	77.27
		LGN	France	Pierre blanche	5.04
		LGN	France	Grau du roi	75.00
		RIE	France	Furemorte	69.19
		LGN	Greece	Lagoon Amvrakikos	0.64
		LGN	Greece	Lagoon Prokopou	0.18
		LGN	Greece	Lagoon Porto Lagos	0.70
		LGN	Greece	Lake Vistonida	0.71
		RIE	Greece	River Evros estuary	0.20
		LGN	Greece	Lagoon Klisova	0.37
		LGN	Greece	Lagoon Messolonghi-Aitoliko	0.17
		LAK	Italy	Bolsena	57.10
		LGN	Italy	Lesina	30.30
		RIV	Italy	Tevere	76.40
		LGN	Italy	Fogliano	0.00
		LGN	Italy	Capolace	0.00
		LGN	Italy	Comaccio	5.60
		LGN	Italy	Monaci	0.00
		LGN	Italy	Burano	37.40
		LGN	Italy	Aquatina	0.00
		LGN	Italy	Figheri	9.10
		LGN	Italy	St. Gilla	0.00
		RIE	Spain	Palmores	100.00
		RIE	Spain	Guadalhorce	100.00
		RIE	Spain	Guadalfeo	90.00
		LGN	Spain	Mar Menor	3.40
		LGN	Spain	L'Albufera de Valencia	66.60
		LGN	Spain	L'Encanyissada (includes Clot and Noria)	21.30
		LGN	Spain	La Tancada, Bassa dels Ouls y Antigues Salines de Sant Antoni	25.64
		LGN	Spain	Canal Vell	0.72
		LGN	Tunisia	Bizerte	15.50
		LGN	Tunisia	Ghar El Melh	3.66
		LGN	Tunisia	Ichkeul	25.00

Parasite	Infection site	Habitat	Country	Site	P%
		RIV	Tunisia	Joumine	0.00
		RIV	Tunisia	Sejnane	20.00
		LGN	Tunisia	Tunis Lagoon	0.00
		RIE	Algeria	Mafragh	49.50
		LGN	Algeria	Mellah	6.70
		LAK	Algeria	Oubeira	45.74
		LAK	Algeria	Tonga	40.00
		LAK	Turkey	Köyceğiz Gölü	39.73
		RIV	Turkey	Ceyhan River	78.13
		RIV	Turkey	Asi River	61.11
		RIV	Turkey	Goksu	60.70
		RIV	Turkey	Seyhan	75.00
		RIV	Turkey	Manavgat River	63.60
		RIE	Egypt	Nile delta	10.7
		LGN	Egypt	Burullus	54.1
Acanthocephala					
Acanthocephala (larvae)	Intestine	LGN	Italy	Figheri	12.1
Acanthocephalus anguillae	Intestine	LGN	France	Salses-Leucate	3.57
Acanthocephalus clavula	Intestine	LAK	Turkey	Köyceğiz Gölü	6.85
Echinorhynchus sp	Intestine	RIE	Algeria	Mafragh	2.25
		LAK	Algeria	Oubeira	0.27
Arthropoda					
Argulus sp.	Skin	LAK	Algeria	Tonga	2.00
Argulus foliaceus	Skin	LAK	Algeria	Oubeira	15.89
Ergasilus sp.	Gill	RIE	Algeria	Mafragh	14.00
		LGN	Algeria	Mellah	11.83
		LAK	Algeria	Tonga	1.11
Ergasilus lizae	Gill	RIV	Tunisia	Joumine	6.60
		LAK	Turkey	Köyceğiz Gölü	26.03
Ergasilus gibbus	Gill	LGN	Italy	Figheri	3.00
		LGN	Spain	Canal Vell	0.59

Parasite	**Infection site**	**Habitat**	**Country**	**Site**	**P%**
		LAK	Algeria	Oubeira	83.40
		LAK	Turkey	Köyceğiz Gölü	52.05
Gnathiidae (larvae)	Gill	LGN	Algeria	Mellah	4.30
Anellida					
Batracobdella algira	Skin	LGN	Tunisia	Ghar El Melh	0.9

Additional results Part III – Eel Quality classes based on highly pathogen EVEX and Ang HV-1 viruses by site in partner countries

Table 7AR3.1. Highly pathogenic EVEX and Ang HV-1 viruses quality classes by site in the partner countries

Country	Site	Habitat type	EVEX prevalence	Ang HV-1 prevalence	Score	Satus
France	Salses-Leucate	LGN	17.00		4	Strongly infected
	Bages-Sigean	LGN	0.00		1	Not infected
	Canet	LGN	0.00		1	Not infected
	Berre	RIV	0.00		1	Not infected
Italy	Fogliano	LGN	5.00	25.00	4	Strongly infected
	Capolace	LGN	9.50	43.00	4	Strongly infected
Spain	Palmores	RIE		16.70	4	Strongly infected
	Guadalhorce	RIE		62.50	4	Strongly infected
	Guadalfeo	RIE		0.00	1	Not infected
	L'Albufera de Valencia	LGN		53.00	4	Strongly infected

Additional Results Part IV – Eel Quality classes based on EQDIS (Eel Quality Index for diseases, ICES, 2015) by site in partner countries

Table 7AR4.1. EQIDIS classes by site in partner countries

Country	Site	Habitat type	EQIDIS score	Status
Algeria	Mafragh	RIE	3.00	Moderately infected
	Mellah	LGN	2.00	Slightly infected
	Oubeira	LAK	3.00	Moderately infected
	Tonga	LAK	3.00	Moderately infected
Egypt	Nile delta	RIE	2.00	Slightly infected
	Burullus	LGN	3.00	Moderately infected
France	Salses-Leucate	LGN	3.00	Moderately infected
	Bages-Sigean	LGN	1.00	Not infected
	Vendres	LGN	4.00	Strongly infected
	Thau	LGN	2.00	Slightly infected
	Or	LGN	2.00	Slightly infected
	Gruissan Complex	LGN	4.00	Strongly infected
	Palavas Complex	LGN	2.00	Slightly infected
	Petite Camargue	LGN	3.00	Moderately infected
	Canet	LGN	1.50	Slightly infected
	Berre	RIV	1.50	Slightly infected
	Biguglia	LGN	3.00	Moderately infected
	Urbino	LGN	2.00	Slightly infected
	Vaccares	LGN	4.00	Strongly infected
	Pierre blanche	LGN	2.00	Slightly infected
	Grau du roi	LGN	4.00	Strongly infected
	Furemorte	RIE	4.00	Strongly infected
Greece	Lagoon Amvrakikos	LGN	2.00	Slightly infected
	Lagoon Prokopou	LGN	2.00	Slightly infected
	Lagoon Porto Lagos	LGN	2.00	Slightly infected
	Lake Vistonida	LGN	2.00	Slightly infected
	River Evros estuary	RIE	2.00	Slightly infected
	Lagoon Klisova	LGN	2.00	Slightly infected
	Lagoon Messolonghi-Aitoliko	LGN	2.00	Slightly infected
Italy	Bolsena	LAK	3.00	Moderately infected
	Lesina	LGN	2.00	Slightly infected
	Tevere	RIV	4.00	Strongly infected
	Fogliano	LGN	2.50	Moderaltely Infected
	Capolace	LGN	2.50	Moderaltely Infected
	Comaccio	LGN	2.00	Slightly infected
	Monaci	LGN	1.00	Not infected
	Burano	LGN	3.00	Moderately infected
	Aquatina	LGN	1.00	Not infected

Country	**Site**	**Habitat type**	**EQIDIS score**	**Status**
	Figheri	LGN	2.00	Slightly infected
	Lesina	LGN	2.00	Slightly infected
	St. Gilla	LGN	1.00	Not infected
Spain	Palmores	RIE	4.00	Strongly infected
	Guadalhorce	RIE	4.00	Strongly infected
	Guadalfeo	RIE	2.00	Slightly infected
	Mar Menor	LGN	2.00	Slightly infected
	L'Albufera de Valencia	LGN	3.50	Strongly infected
	L'Encanyissada (includes Clot and Noria)	LGN	2.00	Slightly infected
	La Tancada, Bassa dels Ouls y Antigues Salines de Sant Antoni	LGN	2.00	Slightly infected
	Canal Vell	LGN	2.00	Slightly infected
Tunisia	Bizerte	LGN	2.00	Slightly infected
	Ghar El Melh	LGN	1.00	Not infected
	Ichkeul	LGN	2.00	Slightly infected
	Joumine	RIV	1.00	Not infected
	Sejnane	RIV	2.00	Slightly infected
	Tunis Lagoon	LGN	1.00	Not infected
Turkey	Köyceğiz Gölü	LAK	3.00	Moderately infected
	Ceyhan River	RIV	4.00	Strongly infected
	Asi River	RIV	3.00	Moderately infected
	Goksu	RIV	3.00	Moderately infected
	Seyhan	RIV	4.00	Strongly infected
	Manavgat River	RIV	3.00	Moderately infected

Additional results Part V – Eel Quality classes based on EQICONT (Eel Quality Index for Contaminants, ICES, 2015) by site in partner countries

Table 7AR5.1. EQICONT quality classes by site in partner countries

Country	Site name	Habitat type	EQICONT score	Status
Algeria	Tonga	LAK	1	Not/low polluted
France	Bage Sigean	LGN	1,4	Not/low polluted
	Berre	RIV	2	Slightly polluted
	Canet	LGN	2	Slightly polluted
	Salses	LGN	1,2	Not/low polluted
	Thau	LGN	1	Not/low polluted
	Rhône	RIV	1,33	Not/low polluted
	Camargue	LGN	1	Not/low polluted
Italy	Garigliano	RIE	2,43	Slightly polluted
	Bolsena	LAK	2	Slightly polluted
	Santa Giusta	LGN	1	Not/low polluted
	Orbetello	LGN	1	Not/low polluted
	Varano	LGN	1,25	Not/low polluted
	PO Delta	RIE	2,75	Polluted
	Bracciano	LAK	2	Slightly polluted
	Trasimeno	LAK	1	Not/low polluted
	Caprolace coastal lake	LGN	1,33	Not/low polluted
	Fogliano	LGN	1,35	Not/low polluted
	Lesina	LGN	1,84	Slightly polluted
	Tevere	RIV	2,46	Slightly polluted
	Venezia	LGN	3,33	Polluted
Spain	Albufereta de Pollensa	LGN	1,33	Not/low polluted
	Albufera de Mallorca	LGN	1,66	Slightly polluted
	Albufera des Grau	LGN	1	Not/low polluted
	Guadalfeo	RIV	1,5	Not/low polluted
	Mar menor	LGN	1,5	Not/low polluted

Country	Site name	Habitat type	EQICONT score	Status
	Guadalhorce	RIE	1,5	Not/low polluted
	Ebro	RIE	2,5	Slightly polluted
	Palmones	RIE	1,5	Not/low polluted
	La Albufera	LAKE	1,5	Not/low polluted
	Turia	RIV	1,71	Slightly polluted
	Ferrerias	RIV	2,5	Slightly polluted
	Raices	RIV	1,5	Not/low polluted
Tunisia	Ghar El Melh	LGN	2	Slightly polluted
	Ichkeul	LGN	1,75	Slightly polluted
	Tunis North Lagoon	LGN	2	Slightly polluted
Turkey	Asi River	RIV	2,33	Slightly polluted
	Dalyan Estuary	RIE	3	Polluted
	Tersakan Stream	RIV	3,17	Polluted
	Gediz	RIV	1,83	Slightly polluted
	Bafa	LAK	2,66	Polluted
	Köycegiz	LAK	3,5	Polluted

Additional Results Part VI – Eel quality classes based on EQITOT (Eel Quality Index Total, ICES, 2015) by site in partner countries

Table 7AR6.1. EQITOT quality classes by site in partner countries

Country	Site name	Habitat type	EQITOT score	Status
Algeria	Tonga	LAK	1.38	Not impacted
France	Bage Sigean	LGN	1.20	Not impacted
	Berre	RIV	2.50	Slightly impacted
	Canet	LGN	2.50	Slightly impacted
	Salses	LGN	1.60	Slightly impacted
	Thau	LGN	1.13	Not impacted
	Camargue	LGN	1.38	Not impacted
Italy	Caprolace coastal lake	LGN	1.67	Slightly impacted
	Fogliano	LGN	1.68	Slightly impacted
	Lesina	LGN	1.92	Slightly impacted
	Tevere	RIV	3.23	Impacted
	Bolsena	LAK	2.50	Slightly impacted
Spain	Guadalhorce	RIE	2.50	Slightly impacted
	Mar menor	LGN	1.38	Not impacted
Tunisia	Ghar El Melh	LGN	1.63	Slightly impacted
	Ichkeul	LGN	1.50	Not impacted
	Tunis North Lagoon	LGN	1.38	Not impacted
Turkey	Asi River	RIV	2.67	Impacted
	Köycegiz	LAK	2.63	Impacted

CHAPTER 8. EEL FISHING GEAR AND METHODOLOGIES IN THE MEDITERRANEAN COUNTRIES

ABSTRACT

The European eel (*Anguilla anguilla*) is an emblematic Mediterranean species, especially in coastal lagoons. It is widely exploited commercially on both sides of the Mediterranean basin, as well as by recreational fishers in some countries. A large variety of methods and fishing gear types are used to catch this species. The main objective of this chapter is to describe the types of fishing gear and methods employed, including the technical characteristics for both recreational and professional fishing in the nine partner countries of the research programme.

For this purpose, a questionnaire was developed and sent to data collection authorities in each country. The form contained questions concerning the different types of gear used for European eel fishing by life stage, in addition to the technical characteristics of each gear type.

In total, eight types of professional fishing gear were identified: three types of gear are used for glass eels in only two countries (glass eel gear, GEG). With the exception of Algeria, baited longlines (ELL) are used in all countries while eel pots (EPO) are used in only two countries. Four types of fixed gear are used: fyke nets (FYK) and fences (FEN) are used in seven countries, barriers(BAR) are used in six countries and pound nets (PON) in only one country. Meanwhile, gillnets (NTS), in which European eel is caught as a bycatch, are used in three countries.

Analysis of the technical characteristics of fishing gear revealed a lack of data in the majority of countries and many different shapes, materials, structures and mesh sizes used, adapted to the habitat or to the fishing traditions of particular sites.

Only four countries were able to provide data on recreational fisheries and six types of gear were identified. The most popular is the fishing rod, (FRD) used in all four countries. Longlines (ELL) are used only in Türkiye; pots (EPO) only in France; spearfishing(SPF), shore lift net (SNL) with its large and small variants and snigging (SNI) are used only in Italy.

HIGHLIGHTS

- Eight types of professional European eel fishing gear were identified across the nine Mediterranean countries.
- Longlines and fyke nets are the most popular types of gear in the Mediterranean.
- Only Spain and Italy target glass eels.
- Data and knowledge on the technical characteristics of fishing gear are lacking in most of the countries.
- A great variety of materials, shapes and structures was evident between countries, sites and habitats.
- Six types of gear were identified for recreational fishing and were used only in four countries.
- Data for recreational fishing gear are lacking.

8.1 INTRODUCTION

In the Mediterranean, European eel fishing is an ancestral activity that has been practiced for thousands of years, as evidenced by the mosaics found in many countries such as Tunisia and Italy. It is mainly carried out using two methods, according to the life stage of the European eel. The first method involves intercepting and guiding European eels to a pocket or terminal capture chamber in which they will be trapped. This method mainly targets the migratory stages (glass eels and silver eels). However, yellow eels can also be caught, but in smaller quantities. The second method involves attracting yellow eels with different types of baits to capture them with hooks or pots. To a lesser extent, silver eels can also be caught with this method.

Various types of fishing gear are used in the Mediterranean for the exploitation of European eel at a commercial scale or for recreational purposes. The characteristics of these gear types are adapted to the environment (lagoons, estuaries, rivers and lakes), to the environmental conditions (including depth and currents), to the ecobiology of the species and sometimes to the traditions and local habits of the fishing communities, including culinary habits.

The main objective of this chapter is to list and categorize European eel fishing gear types and methods in the nine Mediterranean partner countries, for both recreational and professional fishing, and to collect information on their technical characteristics in order to detect points of similarity and divergence at the regional level.

8.2 METHODOLOGY

Within the WP3-Data collection in the framework of the GFCM research programme, a questionnaire in MS Word format (Supplemental Material on the Methodology Part I) was prepared and sent to the nine partner countries (see Supplementary Material on the Methodology Part II). Partners were invited to identify and describe the main types of fishing gear and methods used in professional and recreational European eel fisheries by life stage (glass eel, yellow eel, silver eel) and habitat type (estuary, lagoon, lake, river, coastal marine waters).

Additionally, partner countries were requested to complete an MS Excel file containing additional information related to the technical characteristics of the most frequently used types of fishing gear (fyke net, fence, barrier, baited longlines) at each site, including the following information:

- Country, site, fishing gear, European eel stage targeted.
- Gear dimensions:
    - ELL: hook dimensions.
    - FEN/FYK: diameter of hoops, minimum mesh size of codend (pocket).
    - BAR: dimension of the room (last part of the gear where fish are caught), mesh size (mesh opening for diamond/ mesh bars for other shape), mesh geometry (square, triangular, rectangular or diamond).
- Number of units:
    - ELL: total number of hooks per licence.
    - FEN/FYK: total number of codends (pockets) per licence.
    - BAR: total number of rooms per licence.

8.3 RESULTS

8.3.1 Commercial fishing gears and methods

Nine different types of fishing gear were identified from the questionnaire responses by the nine partner countries. One is specific to the capture of glass eels (GEG), two are specific to yellow eels (eel long line, ELL and eel pots, EPO), four are designed for the capture of silver eels (fyke net, FYK, fence, FEN, barrier, BAR and pound net, PON) and a last category which is not specific to the eel (gill net, NTS and other, OTH). Each category includes a multitude of different shapes, materials, structures and meshes, also adapted to the habitat or sometimes to the fishing traditions in a site.

Table 8.1 shows that longlines are the most frequently used gear in partner countries (eight countries) followed by fyke nets (FYK; seven countries), fences (FEN) and barriers (BAR) in six countries. On the other hand, glass eel gears (GEG) are only used in two countries (Italy and Spain).

Table 8.1. Eel commercial fishing gears categories used in Partner Countries

Country	GEG	FYK	FEN	ELL	BAR	EPO	PON	NTS	OTH
Albania			X	X	X			X	
Algeria		X							
Egypt			X	X					
France		X	X	X		X			
Greece		X		X	X				
Italy	X	X	X	X	X	X		X	
Spain	X	X	X	X	X		X		
Tunisia		X	X	X	X			X	X
Türkiye		X		X	X	X			

Glass eel gear (GEG)

GEG is a specific gear for the glass eel life stage. In the Mediterranean, the glass eel fishery is presently banned with the exception of two countries (Italy and Spain) where it is permitted under strict regulations in estuaries, lagoons and rivers (Table 8.2)

In Italy, it is a cylindrical fyke net wedged on the bottom which includes two chambers constituting a funnel that leads to the last part of the gear having the shape of a pocket (codend) characterized by a tiny mesh size (1-2mm) (Table 8.3). the shape of the net is maintained by three hoops with two wings and two central net leaders directing the glass eels towards the entrance of the gear (Plate 8.1).

Table 8.2. Glass eel gear used in Partner Countries by habitat (RIE = estuary, LGN = lagoon, RIV = river. LAK = lake, CMW = coastal marine waters)

Country	RIE	LGN	RIV	LAK	CMW
Italy	X	X	X		
Spain	X	X			

Table 8.3. Glass eel gear characteristics in Partner Countries

	Gear dimension		Number of units
Country	Diameter of hoops (cm)	Minimum mesh size of codend (mm)	
Italy	na	1-2	na
Spain	na	1	1

na: data not available

Plate 8.1. Fyke-net used for a glass eel fishery in Italy; photo by C. Leone

In Spain, two different types of gear are used to catch glass eels, with the local names, "*Bussó*" and "*Monot de goleró*".

Bussó is a kind of glass eel weir (BAR) net used in transitional waters, mainly set close to the river mouth, next to the shore and facing the current. This gear is composed of a polyhedral receptacle, made of wood or iron and plastic or iron mesh (1 mm mesh opening), the base of which has a funnel pointing inwards, through which the glass eels enter (Plate 8.2). It may be fitted with a stopper wing and the whole gear must not exceed 25 percent of the width of the river. *Bussó* is only used in the Autonomous Community of Catalonia according to strict rules where the use of water pumps, light sources and modification or variation of the nets is forbidden. Fishing shifts are organized for each fishing point in each river, which are drawn between pairs of fishers from the Fisher Association at the beginning of each campaign. Fishing days are distributed so that each pair of fishers exploits a different fishing area that rotates alternately on a daily basis and all fishers carry out the activity in all the authorized fishing areas of the basin.

Monot de goleró is used in the Autonomous Community of Valencia. It has a maximum surface area of 1.5 m^2 at the entrance opening and an entrance to the net with a maximum width of four centimetres and meshes between 0.5 centimetres and 0.8 centimetres on the side, in order to prevent the entry of non-target species (Figure 8.1). Fishing licenses are awarded for each fishing area (89 in total) for a period of five years. Fishers interested in fishing for glass eels must submit an application including a certificate of approval of the *Monot* characteristics and a catch logbook.

Plate 8.2. "*Bussó*" Catalonia, Spain; photo by E. Diaz

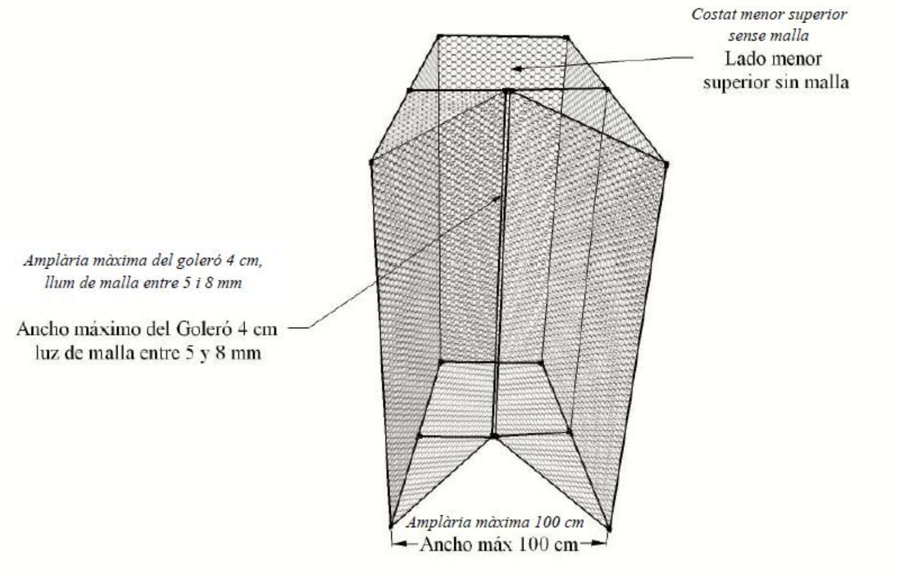

Figure 8.1. "*Monot de goleró*" used in Valencia, Spain

Fyke nets (FYK)

A fyke net is a trap made of netting, oriented upstream, that must be deployed in areas with weak water flows. It is used in shallow water in estuaries, rivers, lagoons and lakes to catch both yellow and silver eels in seven of the Mediterranean countries (Table 8.4).

It consists of a series of covered cylindrical funnels and a series of hoops that decrease in diameter. Hoops are made of various types of rigid materials such as iron or plastic. A funnel-shaped net favours fish entry but prevents their escape and leads them to a closed terminal space, the pocket or "codend".

Fyke nets have extremely variable dimensions, shapes and structures depending on habitat type, region and country (Table 8.5). The mouth is generally cylindrical in lagoons and lakes (Plate 8.3) and semi-circular in rivers (Plate 8.4). The diameter of the hoops and mesh sizes are generally larger in lakes (Plate 8.5).

Table 8.4. Fyke nets used in Partner Countries by habitat (RIE = estuary, LGN = lagoon, RIV = river. LAK = lake, CMW = coastal marine waters) and eel life stage (Y = yellow eel, S = silver eel)

Country	RIE	LGN	RIV	LAK	CMW
Algeria		Y, S		Y, S	
France	Y, S	Y, S	Y		
Greece	S		S		
Italy	Y, S	Y, S	Y, S	Y, S	
Spain	Y, S	Y, S			
Tunisia				Y, S	
Türkiye	Y, S	Y, S	Y, S	Y, S	

Table 8.5. Fyke net characteristics in Partner Countries

Country	Gear dimension: Diameter of hoops (cm)	Gear dimension: Minimum mesh size of codend (mm)	Number of units
Algeria	ND	10	ND
France	50-100	10	ND
Greece	ND	16-20	12
Italy	45-1000	6-40	4-8
Spain	30-80	15-22	1
Tunisia	ND	ND	ND
Türkiye	30-48	24	ND

Number of units= total number of codends per license

Plate 8.3. Fyke nets used in Italian lagoons; photo by C. Leone

Plate 8.4. Semi-circular mouth of a fyke net used in Italian rivers, photo by E. Ciccotti

Plate 8.5. A fyke net used in Italian lakes; photo by google

Fyke nets may be used alone or assembled in pairs. When alone, it may have one vertical net wing to divert eels into the net, held in the water by means of an upright wooden pole planted in the bottom of the water body (called in Spain a “Mornell”, in Türkiye and Greece a “Söke”) (Figure 8.2). In some cases there are two barrier nets or wings, placed in a V-shape (Figure 8.3). This two-winged type is used in France and Algeria.

Fyke nets may be coupled together, in which case, two fyke nets are held together by one medium-sized, leading panel of variable length that leads to two terminal chambers (Figure 8.4). This double-chambered type is used in France and Algeria.

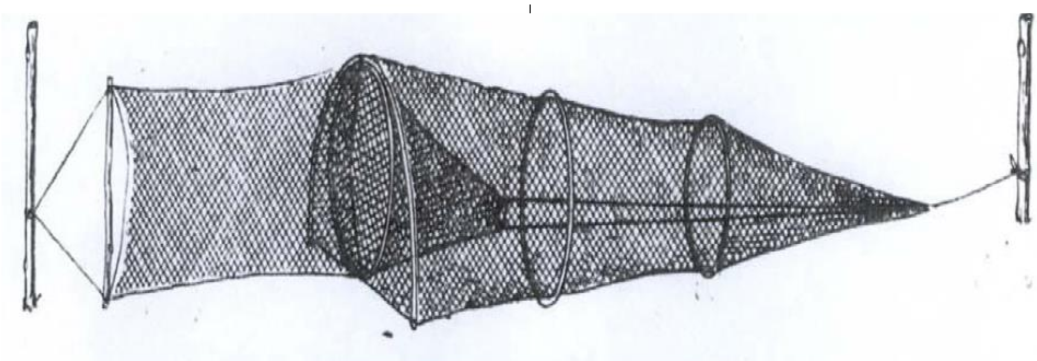

Figure 8.2. Fyke net with one wing “mornell” used in Spain

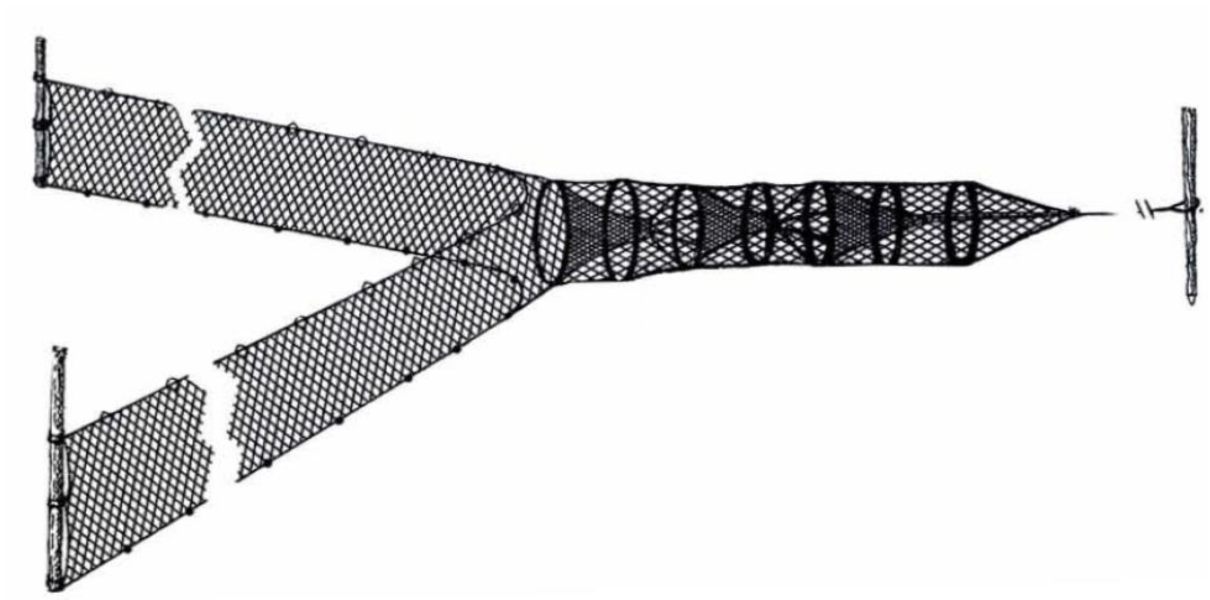

Figure 8.3. Fyke net with two wings used in France and Algeria

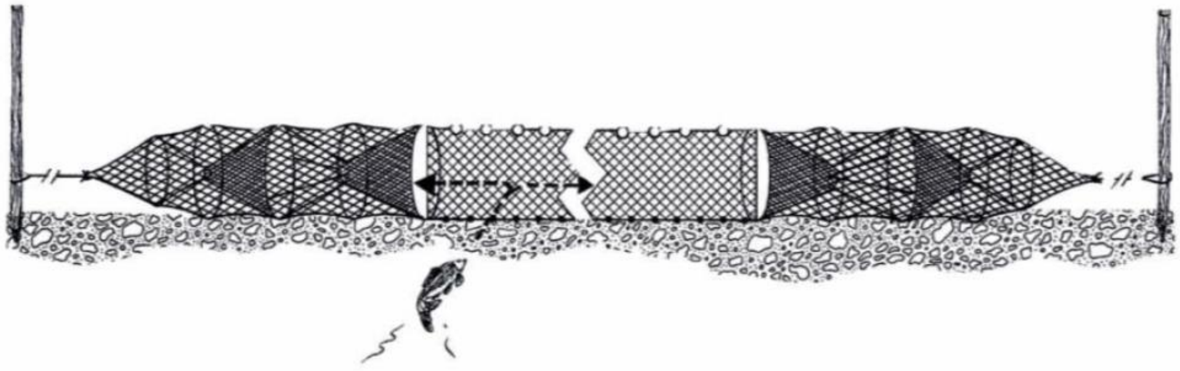

Figure 8.4. Fyke net with two chambers used in France and Algeria

Fence (FEN)

An eel fence can be considered as a structure based on multiple fyke nets fixed in position using stakes. This gear is installed permanently and fixed in a single location during the fishing season. Unlike fyke nets that are generally used in shallow water, fences can be installed in deeper waters (one to ten metres depth).

It consists of a leading net barrier of variable length and mesh size, fixed to the bottom and perpendicular to the shore, which has several secondary arms ending in an assemblage of three or more fyke nets arranged to form an arrow at the extremity in a more or less complex system depending on the site (Figure 8.5; Plate 8.6). The net barrier leads eels toward the fyke net opening and when they find their way into the end of the fyke net, they cannot turn back. This gear is known in France as "*Capétchade*", in Italy as "*Giostra*", "*Paranza*", "*Tresse*" and "*Cogolli*", in Spain as "*Gánguil*", in Egypt as "*Dourah*" and in Tunisia as "*Nassa*". It is designed to catch migrating silver eels mainly in lagoons but can also catch yellow eels and can be used in other habitats , including lakes and river estuaries (Table 8.6). The number, layout, gear dimensions and materials used vary depending on site, region and country (Table 8.7).

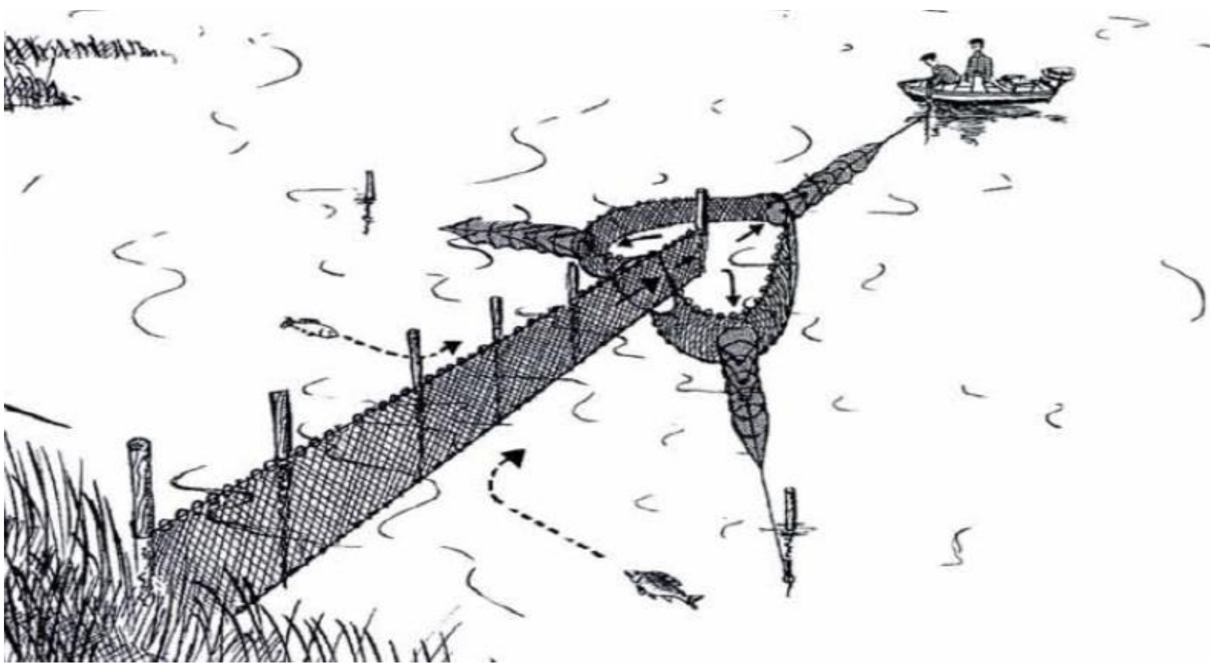

Figure 8.5. Fence with three fyke nets

Plate 8.6. Fence used in Tunis South Lake (Tunisia); photo by E.Derouiche

Table 8.6. Fence use in partner countries by habitat (RIE = estuary, LGN = lagoon, RIV = river. LAK = lake, CMW = coastal marine waters) and eel life stage (Y = yellow eel, S = silver eel)

Country	RIE	LGN	RIV	LAK	CMW
Albania		Y, S		Y, S	
Egypt	Y, S	Y, S			
France	Y, S	Y, S			
Italy	Y, S	Y, S			
Spain		Y, S			
Tunisia		Y, S			

Table 8.7. Fence characteristics in partner countries

Country	Gear dimension		Number of units
	Diameter of hoops (cm)	Minimum mesh size of codend (mm)	
Albania	na	14	0.8-52
Egypt	na	50	na
France	na	6-12	na
Italy	30-200	7-16	2-75
Spain	30-50	16	3
Tunisia	30	24 STR mesh	na

na: data not available
Number of units= total number of codends per license
STR= stretched

Longlines (ELL)

Bottom longlines are designed to catch yellow eels since they are baited with small fish fingerlings and worms but they can sometimes also catch silver eels. They are used in all the countries except Algeria, and in all habitat types but mainly in lagoons (Table 8.8). Lines are mainly formed by nylon or monofilament of very variable length to which a large number of baited hooks of variable dimensions are attached (Table 8.9). Longlines are weighted at the bottom and attached to the shore by a wooden or a bamboo stick (Figure 8.6; Plate 8.7).

Table 8.8. Longlines used in partner countries by habitat (RIE = estuary, LGN = lagoon, RIV = river. LAK = lake, CMW = coastal marine waters) and eel life stage (Y = yellow eel, S = silver eel)

Country	RIE	LGN	RIV	LAK	CMW
Albania		Y		Y	
Egypt	Y, S	Y, S			
France		Y	Y		
Greece				S	
Italy		Y, S	Y, S	Y, S	
Spain		Y, S			
Tunisia		Y, S			Y, S
Türkiye	Y, S	Y, S			

Table 8.9. Longline characteristics in partner countries

Country	Gear dimensions		Number of units
	ELL length (m)	Hook dimensions	
Albania	50	na	50-200
Egypt	na	3, 5, 11, 12, 13	na
France	na	na	na
Greece	na	na	na
Italy	50-1700	na	30-500
Spain	200	12	100
Tunisia	na	14-16	250-350
Türkiye	na	4-6	100-150

na: data not available

Number of units= total number per license

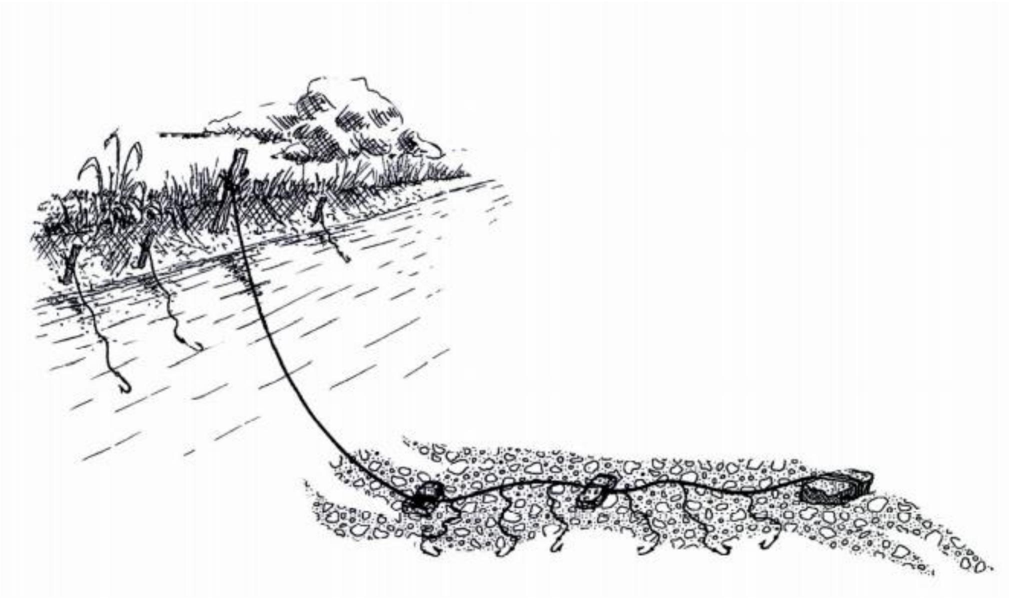

Figure 8.6. Bottom baited longlines

Plate 8.7. Longlines used in Tunisia; photo by M. Bdioui

Fixed Barrier (BAR)

The fixed barrier is a typical eel fishing gear mainly used in lagoons to intercept silver eels migrating downstream when returning to the sea in Albania ("*Dajlan"*), Greece, Italy ("*Lavoriero"*), Spain ("*Pantena"*), Tunisia ("*Bordigue"*) and Türkiye ("*Kuzuluk"*). In Albania, they are also used in the Buna River (Table 8.10). It is a fixed barrier built of wire mesh panels, positioned along the tidal inlet between the lagoon and the sea. These panels are vertically removable, with more or less complex different shapes, mainly "V"- or "W"-shaped, and capture chambers at the end of the sides (Plate 8.8 and Plate 8.9). The fishing unit in this gear consists of a main chamber (Plate 8.10) and two return chambers. Eels that go upstream enter the capture chambers where they are trapped. The barrier is made of reed, concrete, wood or metal, and mounted permanently during the year or only during the fish escapement phases (Plate 8.11 and Plate 8.12). The number of gears, dimensions and number of chambers vary depending on the site (Table 8.11).

Table 8.10. Fixed Barrier used in partner countries by habitat (RIE = estuary, LGN = lagoon, RIV = river. LAK = lake, CMW = coastal marine waters) and eel life stage (Y = yellow eel, S = silver eel)

Country	RIE	LGN	RIV	LAK	CMW
Albania		S	S		
Greece		S			
Italy		S			
Spain		Y, S			
Tunisia		Y, S			
Türkiye	Y, S	Y, S			

Table 8.11. Barrier characteristics in partner countries

Country	Number of gears/site	Gear dimensions	Number of units
Albania	1-4	12	3
Greece	1	na	na
Italy	1	5-30	1-3
Spain	na	16	2
Tunisia	1	10X20 REC	5
Türkiye	na	30	na

na: data not available
Gear dimension= mesh size of the chamber (mm); Number of units= total number of rooms per license
REC= rectangular

Plate 8.8. Wire structured W-shaped barriers in (Buna/Bojana river) Albania; photo by E. Hala

Plate 8.9. V- and W-shaped wooden barriers in Ichkeul Lake, Tunisia; photo by E. Derouiche

Plate 8.10. Capture chamber, Italy; photo by C. Leone

Plate 8.11. Metal structure fixed barrier in Spain; photo by C. J. Marcet

Plate 8.12. Reed structure fixed barrier at Enez lagoon system- Türkiye; Photo by N. Partal

Eel pot and traps (EPO)

Eel pots and traps are used in France and Italy. They are enclosed structures with a funnel-shaped entrance submerged in the water and fixed on the bottom of lagoons, estuaries and rivers (Table 8.12). They are baited with worms, small shells or small fishes to catch mainly yellow eels. They are made with different types of material (plastic, galvanised metal, wood) and have different shapes (cylindrical, D-shape) and dimensions and may be composed of one or two chambers (Plate 8.13).

Table 8.12. Eel pots used in partner countries by habitat (RIE = estuary, LGN = lagoon, RIV = river. LAK = lake, CMW = coastal marine waters) and eel life stage (Y = yellow eel, S = silver eel)

Country	RIE	LGN	RIV	LAK	CMW
France	Y, S	Y	Y		
Italy		Y, S			

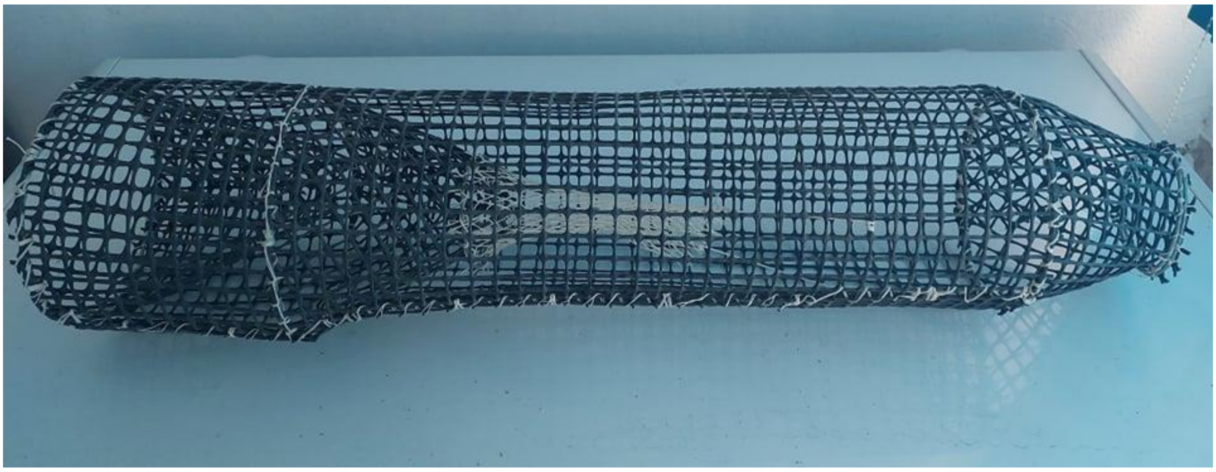

Plate 8.13. Cylindrically shaped eel pot; Photo by E. Derouiche

Pound net (PON)

A pound net consists of net walls anchored or fixed on stakes, reaching from the bottom to the surface. The nets are open at the surface and include various types of fish herding and retaining devices. They are mostly divided into chambers closed at the bottom by netting. It is a fishing method typical of the Mar Menor in Spain where two types exist:

The "*paranza del seco*" is a fixed gear that has a codend in the shape of a net box, which can keep the fish alive for several days. This gear consists of a net of a maximum length of 100 metres and a circular-shaped net with a codend or proper fence (Figure 8.7). The dimensions of the codend and the height of the net are optional. The mesh size of the codend is 1.5 cm.

The "*paranza del hondo*" is similar to the *paranza del seco*, but with more depth and are arranged from the shore into the sea. This gear consists of a 120 metre-long net and a circular-shaped net of the same length. The dimensions of the codend or fence and the height of the net can vary. The mesh size of the codend is 1.5 cm. The "*paranzas del hondo*" can have two heads (Figure 8.8).

Figure 8.7. “*Paranza del seco*” used in Mar Menor (Spain)

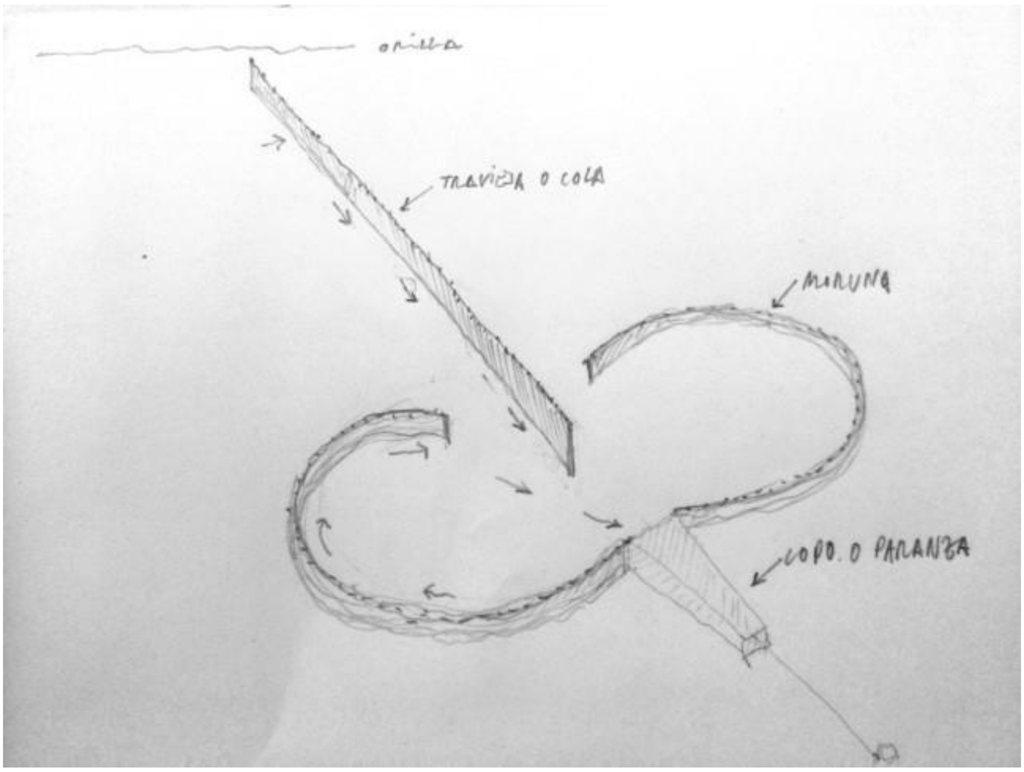

Figure 8.8. “*Paranza del hondo”* used in Mar Menor (Spain)

Nets (NTS)

Trammel nets and gill nets are not set specifically to catch eels. However, they can catch both yellow and silver eels as a bycatch (Plate 8.14). They are used in lagoons, lakes or coastal areas in Albania, Italy, Spain and Tunisia (Table 8.13).

Plate 8.14. Nets used in Lebna dam lake (Tunisia); photo by E. Derouiche

Table 8.13. Nets used in Partner Countries by habitat (RIE = estuary, LGN = lagoon, RIV = river. LAK = lake, CMW = coastal marine waters) and eel life stage (Y = yellow eel, S = silver eel)

Country	RIE	LGN	RIV	LAK	CMW
Albania		Y, S			
Italy		Y			
Spain		Y, S		Y, S	
Tunisia		Y, S		Y, S	Y, S

Other (OTH)

"*Rrahça*" is a special passive eel fishing gear in Albania, comprising of a pyramid about 20 metres in diameter with a rectangular entrance (Figure 8.9). The rest of this fishing gear is the form of funnel. It was used to catch eels until 2019 in Buna/Bojana river. Since 2020, this artisanal fishing gear is considered to be illegal.

In addition, another type of fixed gear is used in Tunisia in the coastal marine waters of the Chebba region and Kerkennah Islands, called "*Charfia*" (Plate 8.15). It is a passive fishing gear made up of palm branches planted on or close to the shore in such a way as to form paths, at the end of which the fish are trapped. Eels are not targeted by this fishing gear but are regularly found among the catch.

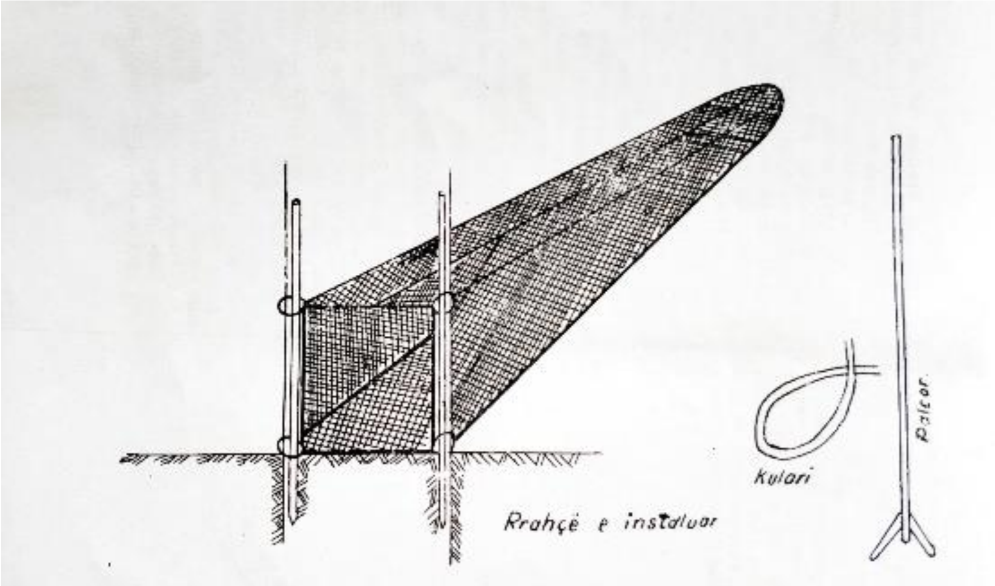

Figure 8.9. “*Rrahça*” in Albania

Plate 8.15. “*Charfia*” in Kerkennah Islands (Tunisia); Photo by P. Gassin

8.3.2 Eel recreational fishing gears and methods

The recreational fishery for eel is practiced in only four countries (France, Italy, Spain and Türkiye) using 6 different fishing gears (fishing rod, FRD; longline, ELL; pots, EPO; shore lift net, SLN; snigging, SNI and spearfishing, SPF) (Table 8.14). Other Mediterranean countries did not report recreational eel fisheries, even though they may exist.

Table 8.14. Recreational eel fishing gears used in partner countries

Country	FRD	ELL	EPO	SLN	SNI	SPF
France	X		X			
Italy	X			X	X	X
Spain	X					
Türkiye	X	X				

FRD = fishing rod, ELL = longline, EPO = pots, SLN = shore lift net, SNI = snigging, SPF = spearfishing

Fishing rod (FRD)

A fishing rod is a springy, tapered, typically jointed, rod made of wood, split bamboo, fibreglass, graphite or steel fitted with a handle and line guides and used to capture fish, including eels, using a fishing line and reel. It was reported as being used in the four countries. Anglers use two to three hooks in one line for eel fishing.

Longlines (ELL)

Previously described, this fishing gear is only used in Türkiye to capture yellow and silver eels in rivers.

Pots and traps (EPO)

Previously described, this fishing gear is only used in French rivers.

Shore lift net (SNL)

This type of gear, often called a Chinese net, is used only in Italy and is allowed in many rivers and channels in most regions (Emilia Romagna, Veneto, Friuli Venezia Giulia, Toscana, Lazio and Campania). It targets nektonic species that perform regular migrations (seasonal or tidal) between the lagoon or river and the sea. It consists of a metal structure in the shape of an "X" that supports and stretches a horizontal net. A rope fixes the metal structure to a rod that allows it to be lowered to the bottom and quickly raised. The relatively small mesh size, at least in the central portion of the gear, makes the juvenile forms and undersized individuals vulnerable to capture. Two types of SNL exist:

- The small shore lift net "*Bilancia*" (Plate 8.16) has a side of 1.5 m (10 mm mesh size). It is mounted on a pole, operated manually and can be moved easily. The diameter of the net must not exceed one-third of the width of the waterbody measured at medium-low tide level and located no less than 500 metres from other gears.
- -Big shore lift net "*Bilancioni*" (Plate 8.17): it is usually placed strategically inside the tidal channels. It consists of a quadrangular-shaped net mounted on a lifting system with a handling platform. The net width is five to 15 metres maximum (mesh size ranging from six mm to 50 mm). The net diameter must not exceed one-third of the width of the river or channel or at least half of the width of the waterbody measured at medium-low tide level and located no less than 500 meters from other gears. It is a fixed emplacement located along the tide channels or in the terminal stretch of river, no less than 500 meters from other fixed gears.

Plate 8.16. Small shore lift net "*Bilancia*” in Italy; photo by Google

Plate 8.17. Big shore lift net "*Bilancioni*" in Italy; photo by Google

Snigging (SNI)

SNI is a bait-equipped hook usually used in Italy and associated to shore lift nets.

Spearfishing (SPF)

Spearfishing is used in Italy and is a fishing technique that is nonspecific to eels. It entails impaling the fish with a straight-pointed instrument such as a spear, gigs, or harpoon.

8.4 DISCUSSION AND CONCLUSIONS

Analysis of the questionnaires shows that eel fishing in the Mediterranean is carried out mainly in lagoons. Longlines are the most common fishing gear in the partner countries, as it is an old technique used since the prehistory.

Fyke nets and fences are the most suitable fishing gears for eels from the point of view of design in relation to the behaviour of the species. Fences are, in general, a gathering of many FYKs with the addition of leading panels. Thus, the gear covers a larger catch area and may offer a larger catch. This gear is common in seven countries with some differences in design and materials and is used mainly in lagoons and estuaries, but also in lakes and rivers. Fyke nets have two main configurations; fyke nets with two wings and a single pocket (codend) and fyke nets with two pockets and a central leading panel. The first offers a better drawdown while the latter has the advantage of a larger number of pockets allowing the capture of eels moving in both directions. The latter seems to be more adapted to yellow eels which move frequently, including for trophic reasons, whereas the silver eel only moves in one direction towards the open sea. Fyke nets can be set in various locations in the same fishing season while fences are fixed throughout the season by stakes fixed into the substrate. Although the general appearance is similar for all countries, the mesh, the number of gears and pockets used and their dimensions differ from one country to another and from one habitat to another. For example, in Italy, the diameter of FYK hoops is larger in lakes than in the other habitats.

Barriers are permanent constructions targeting different species, including eels and are installed in estuaries and lagoon outlets. This gear is used in six partner countries. They could be a problem for seasonal exploitation of eels as they may operate all year round.

In general, the characteristics of many key elements of several fishing gears are not known in the majority of countries (for example, number of hooks, number of pockets, and number of codends) which makes it difficult to consider them as a unit of effort and adopt technical management measures.

Other gears are used in the Mediterranean but remain limited to a few countries or are specific to a single country (pots in France and Italy, pound net in Spain, *Charfia* in Tunisian coastal marine waters). Moreover, Italy and Spain are the only two countries in the Mediterranean exploiting glass eels due to their socio-economic importance, but also owing to their culinary habits. Glass eels are caught by three different gears.

Concerning recreational fishing, which is generally carried out in freshwater habitats (rivers and lakes), data could only be collected in four countries: Spain, France, Italy and Türkiye. Six gears were identified. The most popular is the simplest one: the fishing rod used in all four countries. Longlines are used in Türkiye only, pots in France only and spearfishing, shore lift nets with large and small variants and snigging are used only in Italy. Despite being considered as recreational fisheries, the scale of exploitation of snigging in Italy seems to be important for some localities.

The other countries did not provide data on recreational fishing, but this does not mean that it does not exist there.

8.5 RECOMMENDATIONS

Eels are caught by several type fishing gears depending on habitat and life stage. The commercial eel fishery generally employs passive gears, based on knowledge of the species behaviour. Thus, the eel can be attracted by a baited gear or by a trap offering refuge during its growth phase (yellow eel) or caught by devices that block its route to the sea during its migratory phase (silver eel).

This chapter gives a general perspective on the different types of fishing gear used in the Mediterranean for professional and recreational eel fishing. However, it also points to the lack of knowledge regarding the technical characteristics of these gears, which are key elements that need to be known for better management of eel fisheries.

Recommendations are as follows:

- Elaborate a detailed catalogue of eel fishing gears taking into account all specific technical details.
- Take into consideration the management of fishing gears in national eel management plans.
- Avoid the use of multispecies fishing gears installed permanently such as barriers for better management of this critically endangered species.
- Consider the number, position, and installation of gears, particularly those that constitute permanent obstacles (barriers, fences, fyke nets) to allow the free migration of potential spawners towards the sea
- Agree on minimum mesh sizes and minimum hook sizes for exploitation of eels at national and regional levels.
- Pay particular attention to the collection of data from the recreational fishery, especially those targeting eels, and study appropriate management measures for its exploitation by this fishery (including quotas per fisher, fishing gear used).

Quantify the eel by-catch in the other fisheries, including those that are carried out in coastal marine waters.

Supplementary Material on the Methodology Part I – Questionnaire for the collection of descriptive information on eel fishery methods in Mediterranean partner countries

The objective of the fishery method questionnaire is to complete the overall description of eel fisheries present in every Country. This request is the first step towards describing the diversity in fishing methods and developing the most appropriate and efficient metrics to describe the eel fishing effort at the Regional level.

What are the main fishing methods for eel used in freshwater habitat (lake and river), transitional (lagoon estuary) or marine water of your Country?

Please list them separately for eel life stage.

Eel life stage	Transitional		Freshwater		Marine
	Estuary	Lagoon	River	Lake	
G	*Glass eel fyke net*	*Glass eel fyke net*	*Glass eel fyke net*	*np*	*np*
Y	*Fyke net, pot*	*Fyke net, pot, "Paranza"*	*Fyke net*	*Fyke net*	*np*
S	*Fyke net*	*"Lavoriero"*	*Fyke net*	*Longline*	*np*

Describe active and passive fishing gears and the related fishing techniques from around your Country.

For each type of fishing gear, please provide information such as:

- A general description of the gear in terms of dimensions of the nets, mesh size, length, wide, number of chambers, etc.
- The methodology of use of the instruments, e.g. single or collective use.
- Use from the land or the boat, day or night use, single or multiple fishing trips at day/night

Report any other information you think could be useful.

Provide a picture of the fishing gears.

Supplementary Material on the Methodology Part II – Questionnaire for the collection of additional information on eel fishery methods (technical features) in Mediterranean partner countries

Please insert the technical characteristics of each fishing gear (ELL, FEN, FYK, BAR) used in your country

Country	Site name	Habitat type	Gear code	Eel stage targeted	Gear dimension (1)	Number of units (2)	Number of licences

(1) ELL: hook dimensions
(1) FEN+FYK: diameter of hoops, minimum mesh size of codend (mesh opening)
(1) BAR: dimension of the room (last part of the gear where fish are caught), mesh size (mesh opening for diamond/ mesh bars for other shape), mesh geometry (square, triangular, rectangular or diamond)
(2) ELL: total number per licence
(2) FEN+FYK: number of codends (pockets) per licence
(2) BAR: number of rooms per licence

CHAPTER 9. EEL FISHING EFFORT IN MEDITERRANEAN COUNTRIES

ABSTRACT

Fishing effort is one of the most important parameters used for fishery management. According to FAO, it is defined as the amount of fishing gear of a specific type used on the fishing grounds over a given unit of time, such as hours trawled per day, number of hooks set per day or number of hauls of a beach seine per day. It is the fishing capacity multiplied by the activity. It takes into account the fishing time, the number of fishers involved, the gears used and their characteristics.

In the case of eel, where there are various habitats and it is caught by various fishing gears or by the same gear at different life stages, it is difficult to choose a common unit to measure fishing effort. An ambitious but unsuccessful attempt has already been made by the joint EIFAAC/ICES/GFCM working group on eels (WGEEL) in 2019 to quantify the effort in commercial eel fisheries around Europe.

The aim of this chapter is to report as much information as possible on eel fisheries from the nine partner countries in order to harmonize the information on fishing effort at the Mediterranean basin level. For this purpose, the data contained in the WP3-Fishery database were used for the time period, 2015–2020, corresponding to the GFCM Data Collection Reference Framework (DCRF) timeframe (see Chapter 16).

Results showed a high level of variability between countries and a significant lack of data. None of the nine countries considered were able to provide sufficient data for comprehensive estimation of eel fishing effort, while some countries could not obtain any data. Since there was great variability between countries in terms of the number of fishers, fishing times or the number of fishing gears used at a given site, and each country reported information in their own way, it was impossible to compute and compare fishing effort.

Thus, a simplified method, taking into consideration fishing gear characteristics, was suggested for the DCRF in order to standardize fishing effort data collection for eels in Mediterranean countries.

HIGHLIGHTS

- Great variability was found between countries coupled with a lack of data.
- No standardization was evident among countries, with each one reporting the data in their own way.
- No consistency of data in a given site across time could be found, with disparities within and between countries in terms of the data provided on the number of fishers, fishing times or number of fishing gears used, as well as catches reported by life stage.
- Low availability of reliable data on fishing effort at the site level was evident.
- It was not possible to detect changes in fishing effort over time at the site level or to compute and compare catch per unit of effort.
- A simplified method based on the characteristics of fishing gears is proposed to standardize estimation of eel fishing effort in Mediterranean countries.

9.1 INTRODUCTION

Fishing effort is one of the fundamental ways of regulating the impacts of fisheries on both target stocks and the wider ecosystem.

It is often described as the amount of time spent searching for fish or the amount of certain kinds of fishing gear used on the fishing grounds over a specified unit of time, such as a fishing operation, fishing activity, day or fishing trip. The unit of fishing effort varies depending on the fishery and the type of gear employed. The impact of a unit of fishing effort on fish populations and the environment in general varies depending on the vessel and fishers, as well as the gear used.

Thus, the evaluation of fishing effort of a critically endangered species such as the European eel is of paramount importance in order to choose the most effective management scenarios to ensure both the conservation of the species and the sustainability of its fishery, which is the main source of income for some fishers.

However, this species is caught in all its life stages (glass eel, yellow and silver eel), in various habitats (transitional waters, freshwater and marine waters) using numerous gears with varied characteristics and this diversity constitutes an obstacle to the standardization of fishing effort in the region.

The aim of this chapter was to collect as much information as possible on the eel fisheries from the nine partner countries to attempt harmonization of fishing effort across partner countries for both commercial and recreational fisheries.

9.2 METHODOLOGY

A database "commercial fishery DB" (Excel format) was created under WP3 of the GFCM eel research programme. In addition to time series for commercial landings data, scientific partners were asked to report information at the site level on both nominal and effective fishing effort, fishing gear type, mean number of fishing gears per day per fisher, potential capacity, months in the fishing period, number of effective fishing days and mean number of fishing hours per day (ICES, 2019). Furthermore, the database for recreational fishing gathered information on site level fishing effort metrics.

The quality of information was ensured by a data reliability score, asking partners to give their expert judgment on a scale of one to three where 1 = high quality/reliable data, 2 = use data with care and 3 = low quality or data not validated.

For the specific aims of this task, all data were used to report fishing effort data from a qualitative point of view. On the other hand, only data with score of 1 were used for the calculation of fishing effort. Furthermore, due to wide variability in the data provided by each country, only the most recent five years of data, corresponding to the GFCM-DCRF timeframe of 2015–2020 (see Chapter 15), were selected for further analysis.

9.3 RESULTS

9.3.1 Commercial fishery

Qualitative analysis

Table 9.1a provides a qualitative summary of the main information collected on eel fishing effort metrics. With the aim of correlating catches to fishing effort, fishing effort metrics at the site level such as, i) the number of effective eel fishers, ii) the number of fishing gear used per day by the individual fisher and, iii) the number of effective fishing days in a fishing season, were collected by time and fishing gear. In most cases the availability of the data was very poor (Table 9.1b).

Table 9.1a and Table 9.1b show the wide variability between countries in reporting of data on fishing effort as well as a general and significant lack of data. Indeed, all nine countries were not able to provide full details for comprehensive estimation of eel fishing effort, while some provided no data.

Table 9.2 reports specific information on the nature of the data collected and on fishing effort data availability with respect to catches, fishing gears, number of fishers and fishing time. The nature of the data provides information about how the original data were modified to be included in the WP3 fishery database. "Raw" indicates that data have been used as they are. "Aggregated" indicates a simple sum of the data per year, habitat or fishing gear, with no modification. “Processed” means that, in cases of scattered or incomplete sources or data recorded at different temporal and spatial scales, data had to be processed and validated before inclusion in the database. Table 9.2 also includes information on whether it was possible to separate the catches by life stage and the percentage of fishing metrics available for each country, such as the number of gears per day and per fisher, the potential capacity (intended as total number of fishers, cooperatives, boats or licences) and the recorded fishing times. Availability of fishing time is the percentage of records that report this information, specifying whether the time is expressed in months, days or hours of fishing (in brackets). The general reliability percentage of the fishing effort, was calculated from the number of records with reliable fishing effort data.

There were great disparities between countries in terms of the data provided on the number of fishers, fishing time or the number of fishing gears used, as well as catches reported by life stage, which resulted in a lack of consistent data at a given site across time. Most of the commercial catch series were missing data or information on effort, while some had unreliable data on effort at the site level, or did not report on changes in fishing effort over time.

The inconsistencies, which were dictated by the data collection methodologies used in each country, made it difficult to analyse data reliability and use and compare data over time and space. Therefore it was not possible to evaluate catch per unit of effort (CPUE). Also, only the last five years of data corresponding to the GFCM-DCRF timeframe of 2015 to 2020, were selected for subsequent qualitative and quantitative analyses.

Table 9.1a. Availability of data on eel fishing capacity and fishing effort by country.

Fishing capacity metrics	**Albania**	**Algeria**	**Egypt**	**France**	**Greece**	**Italy**	**Spain**	**Tunisia**	**Turkey**
Number of cooperatives	NA	Yes	NA	NA	Yes	NA	NA	Yes	NA
Number of licences	Yes	NA	NA	NA	NA	Partially	NA	Yes	NA
Number of fishers	Site level	NA	NA	Site level	Partially	Partially	Site level	Partially	Partially
Fishing effort metrics									
Number of fishing months	Yes	Yes	Yes	NA	Yes	Yes	Yes	Yes	Yes
Number of effective fishing days	Yes	NA	Yes	NA	Yes	Yes	NA	NA	Yes
Fishing hours/day	NA	NA	NA	Yes	Yes	NA	NA	NA	NA
Number of gears/day/man	Yes	NA	NA	NA	NA	Yes, partially	NA	NA	NA
Metrics for fixed barriers									
Number of fixed barriers	Yes	NP	NP	NP	Yes	Yes	NP	NP	Yes
Number of fishing months	Yes	NP	NP	NP	Yes	Yes	NP	NP	Yes
Number of effective fishing days	Yes	NP	NP	NP	Yes	Yes	NP	NP	Yes

Yes: Data available at the site level
NA: data not available
Partially/Site level: Data not fully available or data available at a different spatial level (for example, site/EMUs/country)
NP: not pertinent

Table 9.1b. Availability of data on eel fishing metrics at the site level for the Mediterranean

Metric	**Data availability (percent of total sites)**	**Number of sites**
Number of fishers	57.6	188
Number of gears/day/fisher	36.4	143
Number of effective fishing days	39.4	137
All fishing metrics available	29.7	107

Table 9.2. Availability of eel fishing effort information by country (percent of total sites in each country)

Country	Nature of the data	Catches per life stage	N° of gears/day /fisher	Potential capacity	Fishing time (in months, days or hours)	Reliable data
Albania	raw	Y, S, mixed	100%	100%	100% (in months and days)	100%
Algeria	aggregated	NO	ND	ND	100% (in months)	100%
Egypt	raw	NO	ND	ND	100% (in months and days)	100%
France	processed	Y, S, mixed	ND	100% *	100% (in hours) *	75%
Greece	raw	S	98.2%	3%	95% (in months, days and hours)	98.2%
Italy	raw	Y, S, mixed	50%	77.8%	54.7% (months and days)	66%
Spain	raw, processed	Y, S, mixed	ND	45.4%	85.4% (in months)	2.8%
Tunisia	aggregated	NO	ND	19.6%	27% (in months)	34.4%
Turkey	raw	NO	12.6%	60.4%	47% (in months and days)	83.5%

Eel life stages: Y = yellow eel, S = silver eel, NO = not available

ND = no data reported

* **France**: Potential capacity refers to the number of fishers in coastal waters. The number of fishing days is unknown: the fishers usually leave fyke nets for 24 hours before collecting the eels.

Albania, France, Greece, Italy and Tunisia were able to provide data covering almost all of the time period, 2015 to 2020, while Egypt provided data until 2018. Algeria provided data starting from 2017 while Spanish data covered the years 2019 to 2020 and Turkish data was only for 2020 (Table 9.3). Countries contributing to the DCRF provided data from this source, while Albania, Algeria, Egypt and Greece provided data dependent on the specific fishery. It should be noted that Tunisia used data from the DCRF in 2018 and 2019.

Table 9.3. General overview of the data sources obtained from countries during the period, 2015 to 2020 (DCRF=Data Collection Reference Framework)

Country	Years	Information source
Albania	2015–2019	National statistics
Algeria	2017–2019	National statistics
Egypt	2015–2018	National statistics (GAFRD)
France	2015–2019	GFCM-DCRF
Greece	2015–2019	National statistics
Italy	2015–2019	GFCM-DCRF
Spain	2019–2020	GFCM-DCRF
Tunisia	2015–2019	National statistics and GFCM-DCRF (2018 and 2019)
Turkey	2020	GFCM-DCRF

9.3.2. Fishing gears

Data on the fishing gears used in commercial eel fisheries were reported by all nine countries. Figure 9.1 shows that the fyke net (FYK) was the most frequently used gear as it was employed in 35.5 percent of all fishing sites. Italy used fyke nets more than any other country where it was used in 32 fishing sites. Eel fences (FEN) were used in 31.7 percent of the total number of sites and barriers (BAR) in 24.2 percent with usage over six and four countries respectively. Longlines (ELL) and nets (NTS) were the least used gears among the partner countries.

However, it should be noted that it was not possible to discriminate fishing gear type in about 26 percent of the sites. These mixed gears (MIX) were present in four countries, but mainly in Tunisia and France, and mean that eel fishers were using sets of gears that differed from one country to another and sometimes from one site to another. Finally, Italy reported 91 sites with, for some years, non-determined fishing gears (ND).

The most frequently fished habitat for eels across the Mediterranean was lagoons with 157 sites. Fences (FEN), barriers (BAR) and fyke nets (FYK) were used in 51, 44 and 31 of these lagoon sites, respectively. Furthermore, barriers were only used in transitional waters, such as estuaries (RIE) and lagoons (LGN) while fyke nets were used across a wider range of habitats. Mixed gears were used in lagoons as well as in coastal marine waters (CMW) and to a lesser extent in the other habitats (Figure 9.2).

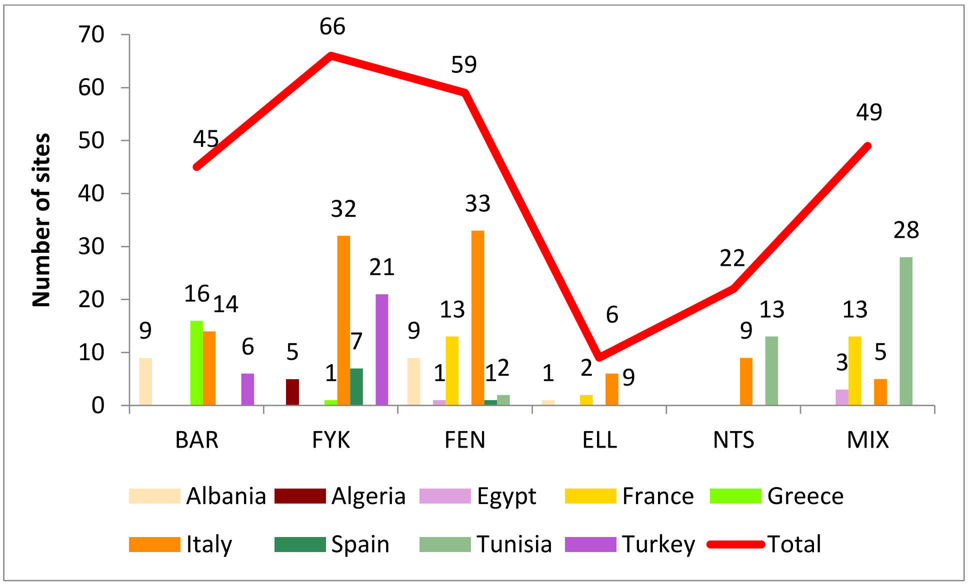

Figure 9.1. Fishing gear types by country and number of sites where specific gears (BAR = barrier, FYK = fyke net, FEN = fence, ELL = longline, NTS = nets, MIX = mixed gears) were used over the period, 2015–2020. Red line: total number of Mediterranean sites where specific gears are used .

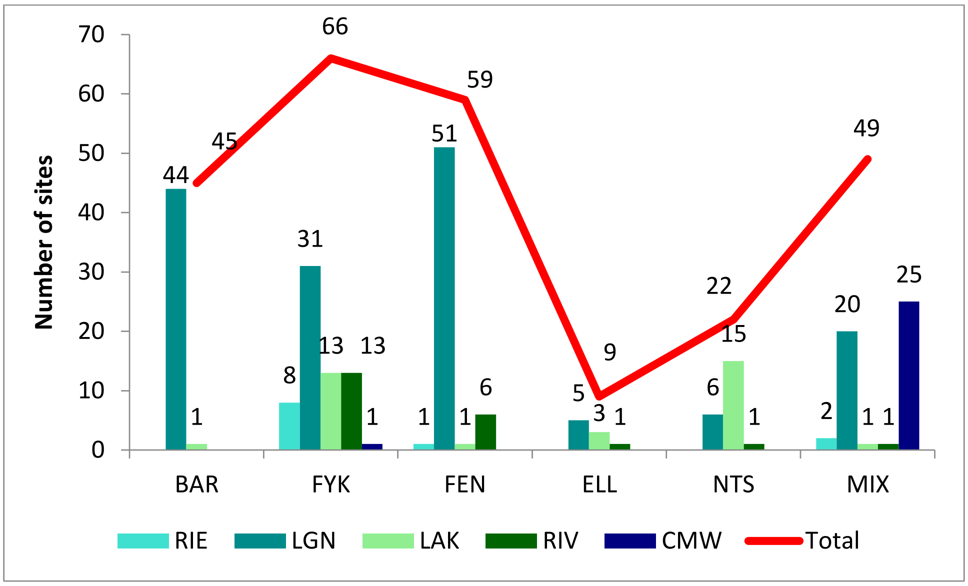

Figure 9.2. Fishing gear types by habitat RIE = estuary, LGN = lagoon, LAK = lake, RIV = river, CMW = coastal marine waters) and number of sites where specific gears (BAR = barrier, FYK = fyke net, FEN = fence, ELL = longline, NTS = nets, MIX = mixed gears) were used over the period, 2015–2020). Red line: total number of Mediterranean sites where specific gears were used.

9.3.3. Fishing capacity

Determining the number of fishers is an essential first step towards defining fishing capacity. Data were provided by seven out of the nine partner countries (Figure 9.3). Among these countries, only Albania reported the number of all the commercial fishers for each site. France, Greece, Italy, Tunisia and Turkey reported some sites with an exact number of fishers, while Algeria, Egypt and Spain were not able to provide data at all. Overall, no information was available (ND) in 49.5 percent of Mediterranean sites.

The number of cooperatives was reported only by Algeria in four fishing sites, by Greece in 16 sites out of 17 and by Tunisia in only one site out of 43. In total, eel fishing was carried out by fisher cooperatives in 21 of the 247 Mediterranean fishing sites (Figure 9.4).

Five out of the nine participant countries reported data on the number of eel fishing licences. In Albania there were 188 licences distributed over the nine fishing sites, issued for commercial fishing activities including eel. In Tunisia, data were reported only for four sites out of 43 (77 licences in total). Algeria, Italy, Spain and Turkey reported one, four, six and four sites with licences respectively, without reporting the number of licences while the remaining partner countries did not provide data for the number and distribution of licences (Figure 9.5).

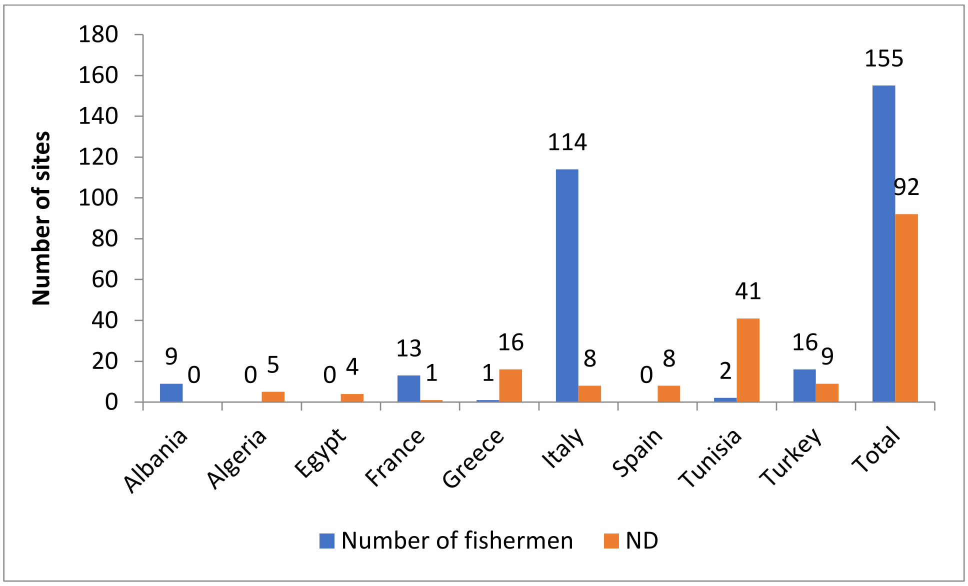

Figure 9.3. Number of sites where number of fishers were provided by country, 2015–2020. ND = no data reported

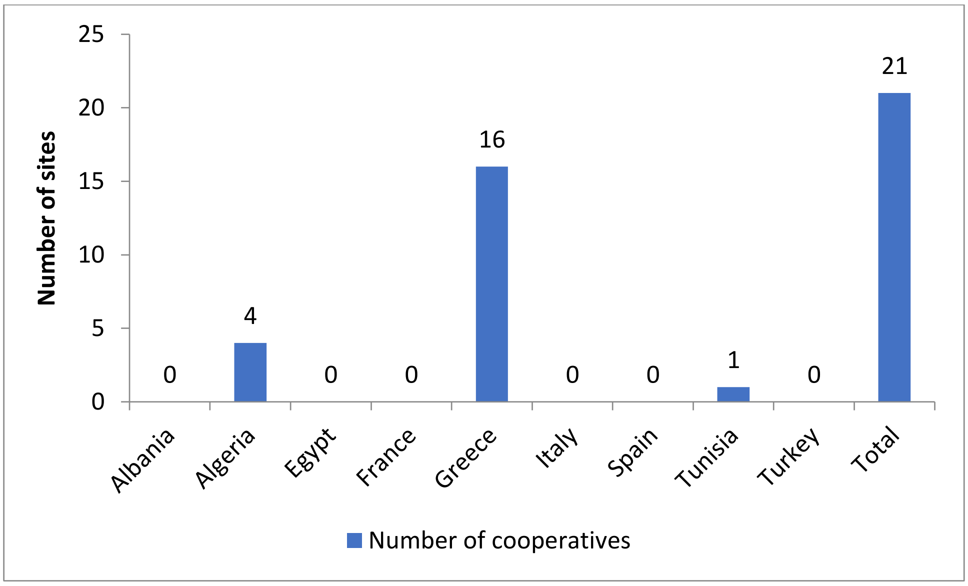

Figure 9.4. Eel fishing sites with fishing cooperatives by country, 2015–2020.

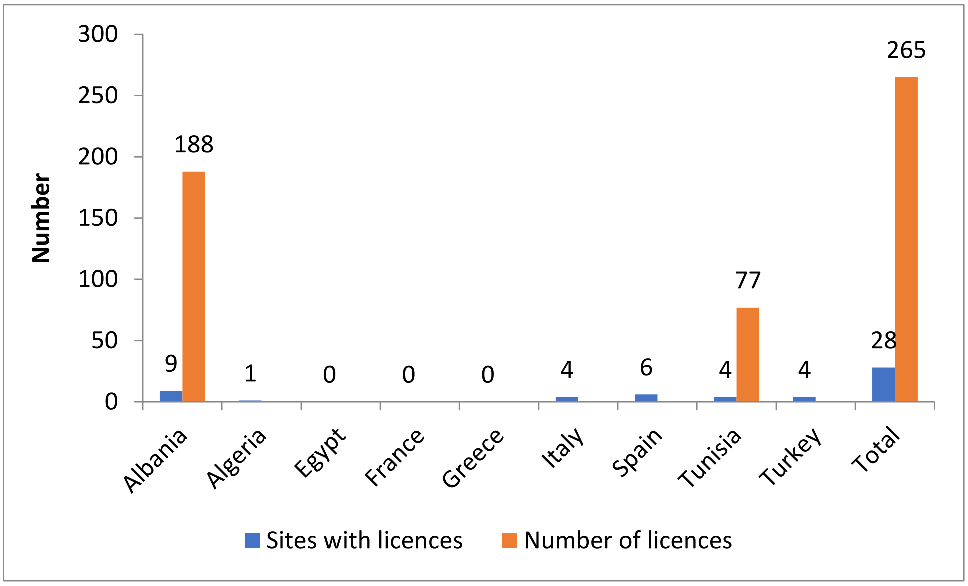

Figure 9.5. Eel fishing sites with licences and number of licences by country, 2015–2020.

9.3.4. Eel life stage

At the Mediterranean level, yellow eels (Y) were caught in 111 sites in four countries while silver eel catches were reported in 131 sites across five countries. However, there was no discrimination between eel life stages in a further 158 sites. These mixed life stage eels (YS) were reported as being caught in all partner countries except Greece, while Algeria, Egypt, Tunisia and Turkey provided only YS data (Figure 9.6). It should be noted that France started reporting the ratio between yellow and silver eels from 2017 onwards in the database.

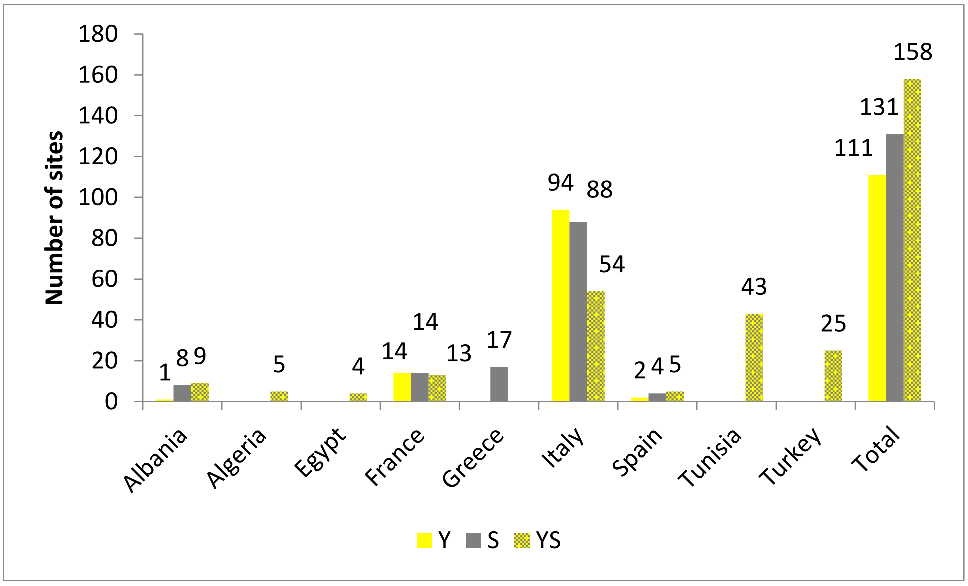

Figure 9.6. Number of eel fishing sites reporting catches according to eel life stage (Y = yellow eel, S = silver eel, YS = mixed yellow and silver eel) by country, 2015–2020.

9.3.5. Fishing time

Eight of the nine partner countries reported fishing months across 176 sites. Five countries reported data on fishing days in 107 sites, while three countries were able to provide data on fishing days across 30 sites. Greece and Egypt provided all three time-based fishing metrics (fishing months, fishing days and fishing hours), Italy, Albania and Turkey reported data on fishing months and fishing days data while Algeria, Spain and Tunisia only provided fishing months data (Figure 9.7).

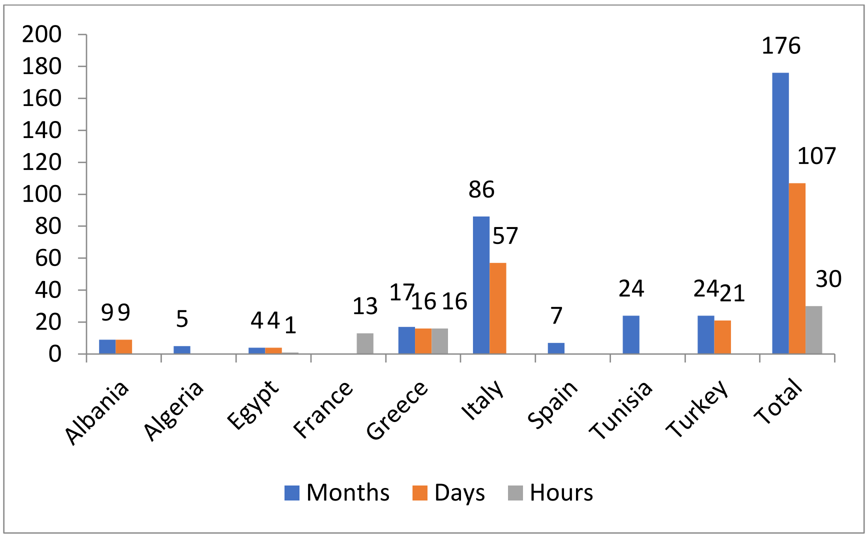

Figure 9.7. Number of eel fishing sites reporting fishing time data (fishing months, fishing days and fishing hours) by country, 2015–2020.

9.3.6. Number of gears per day per fisher

Site level data on the number of gears per day per fisher was provided for 41.7 percent of Mediterranean sites by four partner countries: Albania (nine sites), Greece (17 sites), Italy (56 sites out of 121) and Turkey (21 sites out of 25). In total, these data were missing for 144 Mediterranean sites (Figure 9.8).

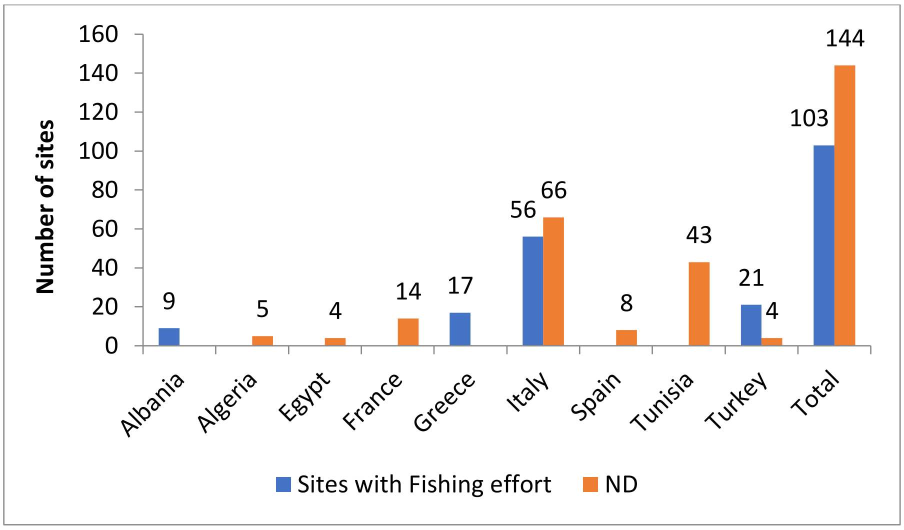

Figure 9.8. Number of eel fishing sites where data on the number of gears per day per fisher were reported, 2015–2020. ND = no data reported

9.3.7. Quantitative analysis of the commercial fishery

The following section reports the fishing effort metrics calculated as number of gears, number of fishers, number of fishing months, number of fishing hours, and number of effective fishing days reported by countries in the period, 2015–2020. All data were considered to give an overview of the current fishing effort employed on eel, irrespective of the reliability of the data. Results are presented in Tables 9.4, 9.5, 9.7, 9.9, and 19.3. The mean number of gears per day per fisher by site, by habitat and by country are presented in Tables 9.6, 9.8, 9.10, and 9.12. As the quality of data did not allow the detection of changes in fishing effort over time, fishing effort (number of gear/day × number of effective fishing days × number of fishers) and catch per unit of effort were not calculated.

Fixed barriers (BAR)

Fixed barriers were reported by Albania, Greece, Italy and Turkey in lagoon habitats and in one Albanian lake (Shkodra).

Albania had a total number of 18 fixed barriers in nine sites, operating over a period of six months and with 178 days of average fishing activity. Italy reported 13 sites with barriers and a total number of 17 fixed barriers. On average, there was one barrier per site, working over a period of five months and 129 effective fishing days. Barriers were reported at 16 sites in Greece that were operated for an average of three months per year and 90 days of fishing activity. Barriers were also present at six sites in Turkey with an average of one gear per site working over a period of five months and 145 days on average per year.

A total of 57 fixed barriers were reported as operating during the selected timeframe in the Mediterranean. However, fixed barriers were also included in the mixed fishing gear category (MIX), therefore the total number of fishing gears reported in Table 9.4 has to be taken with caution and should not be considered as exhaustive, while data reliability also needs to be taken into account.

Table 9.4. Fishing effort metrics (total number, mean, range) for fixed barriers (BAR) by country, and reliability of data, averaged over the five year period, 2015–2020.

Country	Number of sites	Fishing gears*			Number of fishing months		Number of effective fishing days		Hours/day	Data reliable
		Total	Mean	Range	Mean	Range	Mean	Range	N	percent
Albania	9	18	2	1–4	6	3–6.5	178	76–200	np	100
Greece	16	16	1	-	3	-	90	-	24	100
Italy	13	17	1	1–2	5	3–6	129	48–180	np	79
Turkey	6	6	1	-	5	4–6	145	120–180	np	100
Total	44	57	-	-	-	-	-	-	-	-

* numbers not exhaustive, fishing gear also included in the MIX category
np = not pertinent

Eel longlines (ELL)

Eel longlines were reported as being used in three Mediterranean countries, employing 50 fishers in Albania, 42 fishers in France and just three fishers in Italy (Table 9.5). Table 9.6 shows the mean number of fishing gears per day per fisher (N gear/day/fisher) for Albania and Italy, while fishing months and fishing days are comparable between the two countries. In contrast, France reported the standardized number of fishing hours per day (24 hours). A total of 104 eel longlines were reported as operating during the selected timeframe in the Mediterranean, although longlines were also included in the mixed fishing gear category and some of the data may not be reliable.

Table 9.5. Fishing effort metrics (total number, mean, range) of eel longlines (EEL) reported by country and reliability of data (percent), averaged over the five year period, 2015–2020.

Country	Number of sites	Fishing Gear*			Fishers*			Fishing months		Fishing days		Hours/day	Data reliable
		N Tot	Mean	Range	N Tot	Mean	Range	Mean	Range	Mean	Range	N	percent
Albania	1	50	1	-	50	50	-	3	-	91	-	np	100
France	2	nd	nd	nd	75	42	18-60	nd	nd	nd	nd	24	100
Italy	6	54	5	1–20	49	3	1-8	5	4–12	84	15–150	np	67
Total	9	104	-	-	-	-	-	-	-	-	-	-	-

* numbers not exhaustive
nd = not determined
np = not pertinent

Table 9.6. Mean number of fishing gears per day per fisher of EEL "Longlines" reported by country, by site and by habitat (LAK = lake, RIV = river, LGN = lagoon) averaged over the five year period, 2015–2020.

Country	Number of sites	Habitat	Site	Number of gear/day/man		Number of gear/day/man by habitat	
				Mean	Range	Mean	Range
Albania	1	LAK	Shkodra	1	-	-	-
Italy	6	LAK	Bolsena	3	1–5	7	1–20
		LAK	Trasimeno	10	4–20		
		RIV	Coghinas	6	3–20	-	-
		LGN	Santa Gilla	1	-	1	1–3
		LGN	Marano	nd	nd		
		LGN	San Puoto	3	-		

Fyke nets (FYK)

Fyke nets were reported as being used in five partner countries. Fishing capacity was higher in Spain with an average of 145 fishers compared to the other countries. Information on gears was available for Algeria, Greece, Spain, Italy, and Turkey, with Italy reporting the highest mean number of fishing gears at 54 gears per site, while average fishing time varied between the countries (Table 9.7). Over 18 000 eel fyke nets were reported as operating during the survey period in the Mediterranean. However, there may be under-reporting as fyke nets were also included in the mixed fishing gear category, while some of the data may not be reliable. The mean number of fishing gears per day per fisher (Table 9.8) was highly variable between countries due to a range of factors including the characteristics of gears, sites and habitats.

Fences (FEN)

Six partner countries provided data on fishing effort metrics for fences, although the majority of fishing metrics were not reported (Table 9.9). Fishing capacity data in terms of total number of fishers were not comparable between countries, but Italy and France reported an average of 18–19 fishers per site using fences. The estimated total number of fences operating in the Mediterranean during the survey period cannot be considered as comprehensive given the paucity of available data, while fences may also have been included in the mixed fishing gear category and some of the data may be unreliable. Table 9.10 shows the mean number of fishing gears per day per fisher for fences, only for Italy.

Nets (NTS)

Only Italy and Tunisia reported data on nets, although this did not include the majority of fishing metrics. In Italy, this gear was used in nine lagoons during an average of five months and 103 of effective fishing days (Table 9.11). No data on fishing effort parameters for nets were reported from Tunisia. There was insufficient data to the estimate of total number of nets operating in the Mediterranean, while the usual caution has to be taken as nets might have been reported in the mixed fishing gear category, and some of the data may have not been reliable. The mean number of fishing gears per day per fisher for Italy ranged from five to 150 with an average Figure 9.of 66 nets per lagoon (Table 9.12).

Table 9.7. Fishing effort metrics (total number, mean, range) of fyke nets (FYK) reported by country, and data reliability (percent), averaged over the five year period, 2015–2020.

Country	Number of sites	Fishing Gear*				Fishers*				Fishing months			Fishing days		Hours/day	Data reliable
		N	Mean	Range		N	Mean	Range	N	Mean	Range		Mean	Range	N	percent
Algeria	5	na	na	na		na	1 Cooperative	na		7	-		na	na	np	100
Greece	1	30	6	-		5	5	4–5		3	-		na	na	np	75
Italy	31	8 019	54	1–600		313	9	1–125		4	1–10		86	10–222	np	35
Spain	6+1**	na	na	na		458	145	6–414		6	5–7		na	na	np	20
Turkey***	16	10 063	24	8–60		443	29	3–90		4	2–8		132	60–240	np	100
Total	*51+1*	*18 112*	-	-	-	-	-	-	-	-	-	-	-	-	-	-

* numbers not exhaustive
**complex of « Other lagoons »
*** One year: 2020
na = data not available
np = not pertinent

Table 9.8. Mean number of fishing gears per day per fisher for fyke nets (FYK) by country, by site and by habitat (LAK = lake, LGN = lagoon, RIV = river, RIE = estuary, CMW = coastal marine waters), averaged over the five year period, 2015–2020.

Country	Number of sites	Habitat	Site	(Number of gear/day/fisher) by site		(Number of gear/day/fisher) by habitat	
				Mean	Range	Mean	Range
Italy	31	LAK	Bolsena	9	6–15	15	5–50
			Bracciano	21	10–50		
			Iseo	5	-		
			Trasimeno	22	17–30		
		LGN	Calich	5	-	37	2–150
			Colostrai	10	-		
			Comacchio	32	30–35		
			Fondi	19	2–28		
			Goro	28	17–35		
			Lesina	60	34–77		
			Lungo	117	3–150		
			Orbetello	14	9–24		
			Pauli Bianco Turri	6	-		
			San Giovanni Muravera	8	-		
			San Puoto	6	-		
			Valle Fattibello	25	24–26		
			Varano	28	9–38		
		RIV	Cedrino	4	-	102	1–600
		RIV	Flumendosa	2	-		
		RIV	Garigliano. Ofanto. Minturno	1	-		
		RIV	Po di Goro	15	-		
		RIE	Po di Goro Sacca di Goro	25	-		
		RIE	Po di Volano Mesola	36	35–38		
		RIE	Po di Volano Sacca di Goro	35	-		
		RIE	Po Berra	77	70–80		
		RIV	Po Bondeno	11	10–15		
		RIE	Sile	na	na		
		RIV	Tevere	256	20–600		
		RIV	Tevere Aniene	267	200–400		
		RIV	Tevere Arrone	200	-		
		RIV	Tevere e canali minori	47	6–150		
Spain	6+1*	LGN	Albufera de Valencia	na	na	na	na
		CMW	Ebro	na	na	na	na
		LGN	Ebro Delta	na	na	na	na
		LGN	Lagune del Hondo	na	na	na	na
		RIE	Marjal de Pego Oliva	na	na	na	na
		LGN	Other lagoons	na	na	na	na
		LGN	Santa Pola	na	na	na	na
Turkey	16	LGN	Akgöl-Paradeniz	30	-	24	10–30
		LGN	Akköy	30			
		LGN	Dipsiz	30			
		LGN	Enez	30			
		LGN	Güllük	20			
		LGN	Karina	20			
		LGN	Misakça	10			
		LGN	Poyraz-Arapçiftliği	20			
		LAK	Yarseli	15		22	8–60
		LAK	Bafa	34	8–60		
		LAK	Belevi	25			
		LAK	Gala	10			

Country	Number of sites	Habitat	Site	(Number of gear/day/fisher) by site		(Number of gear/day/fisher) by habitat	
				Mean	Range	Mean	Range
		LAK	Gölbaşı	15			
		LAK	Köyceğiz	20			
		RIV	Asi	30		30	-
			Meriç	30			

*complex of « Other lagoons »
na = data not available

Table 9.9. Fishing effort metrics (total number, mean, range) for fences (FEN) by country, and data reliability (percent), averaged over the five year period, 20152020.

Country	Number of sites	Fishing gears*			Fishers*			Number of fishing months		Number of fishing days		Hours/day	Data validated percent
		N Tot	Mean	Range	N Tot	Mean	Range	Mean	Range	Mean	Range	N	
Albania	9	1 029	10	1–25	141	16	4–40	6	3–7	171	76–200	np	100
Egypt	1	na	na	na	na	na	na	12	-	365	-	np	100
France	12	na	na	na	221	18	4–60	na	na	na	na	24	100
Italy	33	3 406	10	0.04–40	536	19	1–146	5	1–8	108	20–200	np	89
Spain	1	na	na	na	35	-	-	6	6–8	na	na	np	0
Tunisia	2	na	na	na	19	9	9–10	4	3–6	na	na	np	100
Total	*58*	*4 435*	-	-	-	-	-	-	-	-	-	-	-

* numbers not exhaustive
na = data not available
np = not pertinent

Table 9.10. Mean number of fishing gears per day per fisher for fences (FEN) by country, by site and by habitat (LAK = lake, LGN = lagoon, RIV = river, RIE = estuary, CMW = coastal marine waters), averaged over the five year period, 2015–2020.

Country	Number of sites	Habitat	Site	Number of gears/day/man by site		Number of gears/day/man by habitat	
				Mean	Range	Mean	Range
Albania	8	LGN	Butrinti	1	-	11	1-25
		LGN	Karavasta	3	-		
		LGN	Kune	25	-		
		LGN	Narta	7	-		
		LGN	Orikumi	13	-		
		LGN	Patoku	10	-		
		LGN	Vain	4	-		
		LGN	Viluni	25	-		
	1	LAK	Shkodra	5	-	5	-
France	12	LGN	Bage-Sigean	na	na	na	na
			Berre	na	na	na	na
			Canet	na	na	na	na
			Complexe de Petit Camargue	na	na	na	na
			Complexe Palavisien	na	na	na	na
			Gruissan	na	na	na	na
			Lagunes de Corse	na	na	na	na
			Or	na	na	na	na
			Salses-Leucate	na	na	na	na
			Thau	na	na	na	na
			Vaccares	na	na	na	na
			Vendres	na	na	na	na
Italy	22	LGN	Arenario Su Graneri	6	6–8	9	0.04–40
			Boi Cervus	8	6–13		
			Cabras	8	3–11		
			Calich	9	6–16		
			Casaraccio	10	-		
			Colostrai	3	2–3		
			Corru S'Ittiri - Corru Mannu	4	0.04–10		

			Feraxi	1	1–2		
			Goro	14	10–16		
			Gravile	5	4–8		
			Is Benas	2	-		
			Longu Posada	10	-		
			Marceddì	10	9–11		
			Mistras	5	2–7		
			Pauli Bianco Turri	5	2–10		
			Pilo	40	-		
			Porto Pino	9	-		
			Sa Praia	4	4–6		
			San Giovanni Muravera	2	-		
			San Teodoro	10	8–15		
			Santa Gilla	16	12–19		
			Santa Giusta	25	-		
			S'Ena Arrubia	7	6–8		
			Su Pedrosu Avalè	5	3–8		
			Su Stangioni Pula	16	6–19		
			Tortolì	16	5–24		
			Valle Fattibello	10	8–10		
		RIV	Cedrino	5	3–8	14	3–40
			Coghinas	24	10–30		
			Flumendosa	5	4–6		
			Flumini Durci	3	-		
			Pramaera	15	-		
		RIE	Po di Volano Sacca di Goro	40	-	-	-
Spain	1	LGN	Mar Menor	na	na	na	na
Tunisia	2	LGN	Tunis North	na	na	na	na
			Tunis South	na	na	na	na

na = data not available

Table 9.11. Fishing effort metrics (total number, mean, range) for nets (NTS) by Country, and data reliability (percent), over the five year period, 2015–2020.

Country	Number of sites	Fishing gears*			Fishers			Fishing months		Fishing days		Hours/day	Data reliable percent
		N	Mean	Range	N	Mean	Range	Mean	Range	Mean	Range	N	
Italy	9	na	na	na	65	6	1–35	5	3–8	103	28–200	np	100
Tunisia	13	na	na	na	na	na	na	na	na	na	na	np	na
Total	*22*	*na*	-	-	-	-	-	-	-	-	-	-	-

* numbers not exhaustive, fishing gear also included in the MIX category
na = data not available
np = not pertinent

Table 9.12. Mean number of fishing gears per day per fisher for nets (NTS) by country, by site and by habitat (LAK = lake, LGN = lagoon, RIV = river, RIE = estuary, CMW = coastal marine waters), averaged over the five year period, 2015–2020.

Country	Number of sites	Habitat	Site	Number of gears/day/man by site		Number of gears/day/man by habitat	
				Mean	Range	Mean	Range
Italy	9	LGN	Corru S'Ittiri - Corru Mannu	150	-	66	5–150
			Gravile	na	na		
			Longu Posada	40	-		
			Malfatano	28	10-83		
			Santa Gilla	100	-		
			Su Pedrosu Avalè	5	-		
		LAK	Como	na	na	na	na
			Varese	na	na	na	na
		RIV	Pramaera	10	-	-	-
Tunisia	13	LAK	Abid	na	na	na	na
			Bezirk	na	na	na	na
			Bir M'Cherga	na	na	na	na
			Chok El Felfel	na	na	na	na
			Hjar	na	na	na	na
			Jouline	na	na	na	na
			Maseri	na	na	na	na
			Mellegue	na	na	na	na
			Sejnane	na	na	na	na
			Sidi El Barrak	na	na	na	na
			Sidi Saad	na	na	na	na
			Sidi Salem	na	na	na	na
			Smati	na	na	na	na

na = data not available

Mixed gears (MIX)

Table 9.13 shows cases in which countries were unable to discriminate catches according to which specific fishing gears had been used so catches were reported as a mix of gears (MIX). Egyptian eel fishers used other methods (OTH) and longlines (ELL) in three sites. Eel pots (EPO), fences (FEN), fyke nets (FYK) and longlines (ELL) were used in 12 sites in France. Italian eel fishers used longlines (ELL), fyke nets (FYK) and fences (FEN), and Tunisia used longlines (ELL), nets (NTS), barriers (BAR), fyke nets (FYK), and *charfia*, classed as other methods (OTH), mainly in coastal marine waters where eel is a by-catch. The majority of fishing parameters were not available.

Table 9.13. Fishing effort metrics (n tot, mean, range) for mixed fishing gears (MIX) by country, and reliability of data (percent), averaged over the five years, 2015–2020.

Country	Number of sites	Gear type	Number of gears		Number of fishers		Number of fishing months		Number of fishing days		Hours/day	Data reliable
			Mean	Range	Mean	Range	Mean	Range	Mean	Range	N	percent
Egypt	3	ELL, OTH	na	na	na	na	12	-	365	-	10	100
France	12	EPO, FYK, FEN, ELL	na	na	20	4–60	na	na	na	na	24	99
Italy	5	FYK, ELL, FEN	na	na	2	1-3	4	2-7	104	65-150	np	4.5
Tunisia	28	ELL, NTS, BAR, FYK, OTH	na	na	na	na	na	na	na	na	np	7
Total	*48*		na	-	na	-	-	-	-	-	-	-

na = data not available

np = not pertinent

9.3.8 Recreational fishery

Qualitative analysis of the recreational fishery

Little information was obtained on recreational eel fisheries in Mediterranean countries with only France, Italy, Spain and Turkey providing some data. Table 9.13 shows that unlike the commercial fishery, recreational fishing is mainly practiced in freshwater habitats (59 sites in rivers and eight in lakes). It should be noted that there are some additional sites in Italy where an eel recreational fishery exists but their names and numbers are unknown (ND). Thus Table 9.14 should be taken with caution and not be considered exhaustive.

Italy and Spain provided data covering the five years from 2015 to 2019, while France and Turkey provided data only for 2015 and 2020, respectively. France provided data from the French Office of Biodiversity (OFB), while Italy provided data collected under the Data Collection Framework (DCF) - Decision EU 2016/1251, Spain from official regional statistics and Turkey provided data from the GFCM-DCRF.

Table 9.14. General overview of the data source obtained from partner countries: number of sites by country and habitat (RIE = estuary, LGN = lagoon, LAK = lakes, RIV = rivers, CMW = coastal marine waters), during the five years, 2015 to 2020.

		Number of sites						
Country	Total number	RIE	LGN	LAK	RIV	CMW	**Year**	**Source**
France	2	0	0	0	2	0	2015	OFB - SNPE
Italy*	42	1	0	7	35	0	2015–2019	DCF (EU 2016/1251)
Spain	1	0	1	0	0	0	2015–2019	Reg. Fishery Stat.
Turkey	23	0	0	1	22	0	2020	GFCM-DCRF
Total	*68*							

* numbers not exhaustive

<u>Fishing gears</u>

Figure 9.9 shows that fishing rods (FRD) were the most frequently used recreational fishing gear in the partner countries (used in 62.3 percent of all fishing sites), with the prevalence of use highest in Italy (used in 42 of fishing sites). Longlines (ELL) were used only in Turkey and eel pots (EPO) only in France. Italian recreational fishers also used shore lift nets (SLN), snigging (SNI) and spearfishing (SPF), mostly in rivers (Figure 9.10).

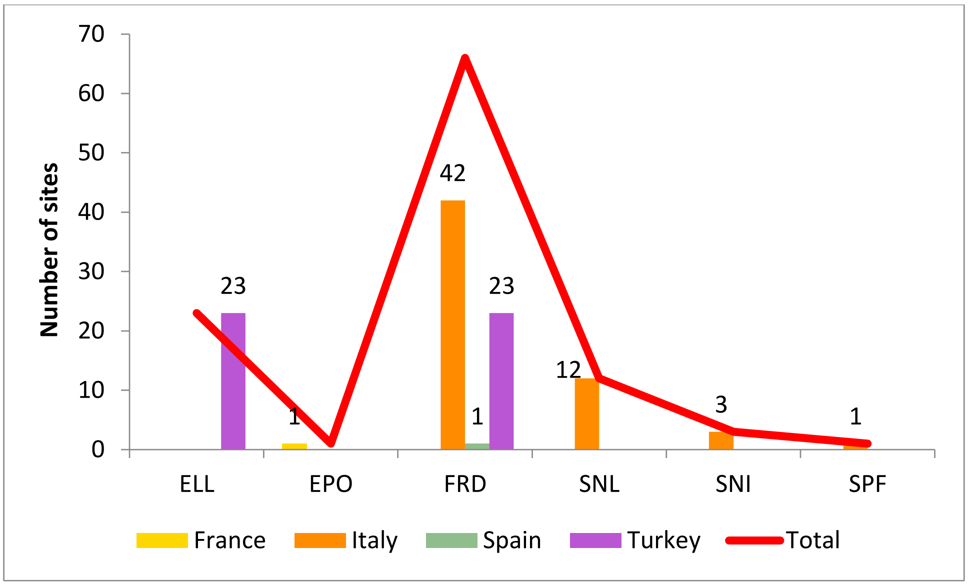

Figure 9.9. Recreational eel fishing gear types by country and number of sites where specific gears were used over the five years, 2015–2020. Red line: total number of Mediterranean sites where specific gears were used.

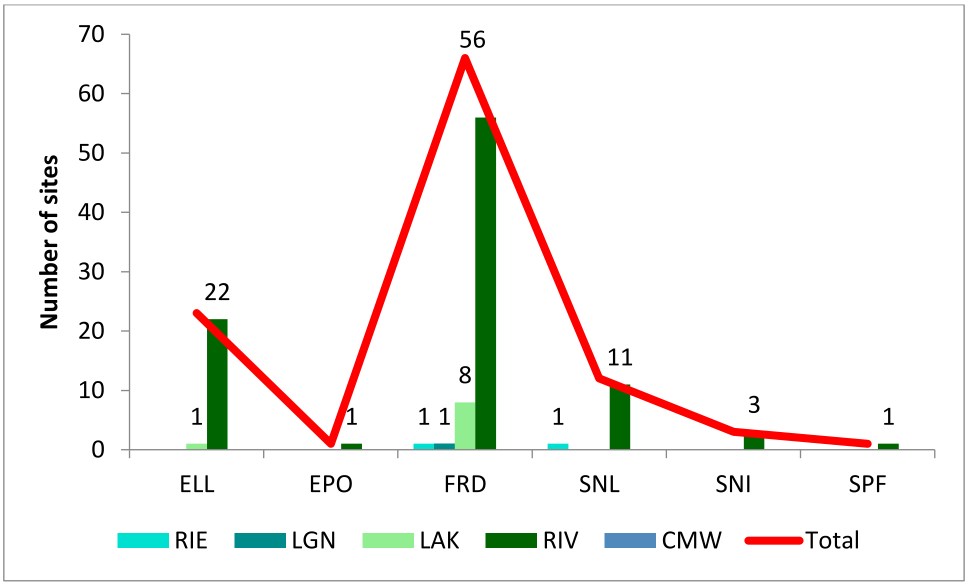

Figure 9.10. Recreational fishing gear types by habitat (LAK = lake, LGN = lagoon, RIV = river, RIE = estuary, CMW = coastal marine waters) and number of sites where specific gears were used over the five years, 2015–2020. Red line: total number of Mediterranean sites where specific gears were used.

Fishing capacity

All partner countries reported the number of anglers per licence according to the site, except France (Figure 9.11). Overall, information was available in 97.1 percent of Mediterranean sites.

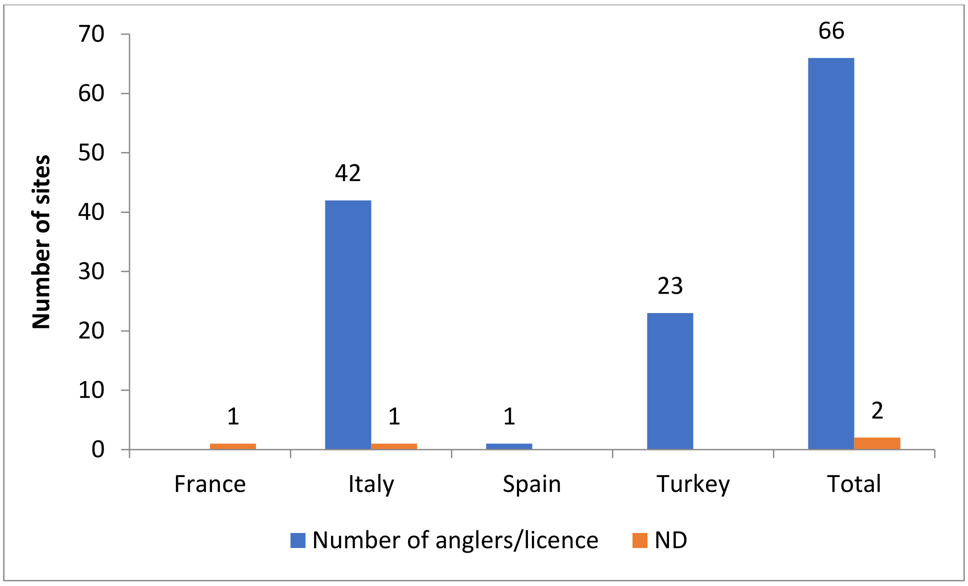

Figure 9.11. Number of sites where number of anglers per licence was provided by country during the five year period, 2015–2020. ND = no data reported

Eel life stage

Across the Mediterranean, yellow eels (Y) were reported as being caught in 42 recreational fisheries sites, all in Italy, while silver eels were reported from 13 sites, also in Italy. It was not possible to discriminate between eel life stages in 24 sites where Turkey and Spain provided only YS data while France did not report data on eel life stage (Figure 9.12).

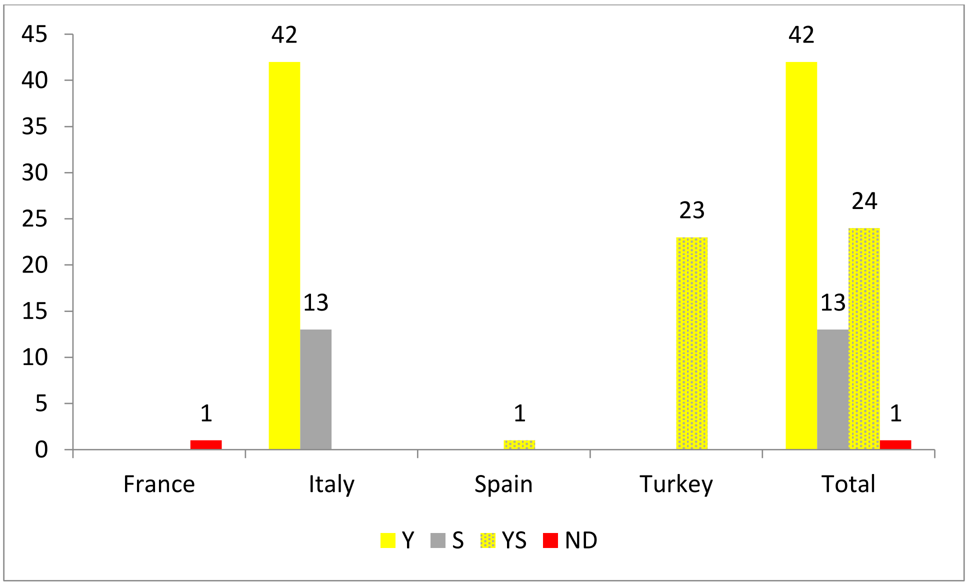

Figure 9.12. Eel fishing sites according to eel life stages (Y = yellow eel, S = silver eel, YS = mixed yellow and silver eel) by country during the five year period, 2015–2020. ND = no data reported.

Fishing time

Italy and Turkey reported fishing months and days over 67 sites while Spain provided data only on fishing months and France did not report any data (Figure 9.13).

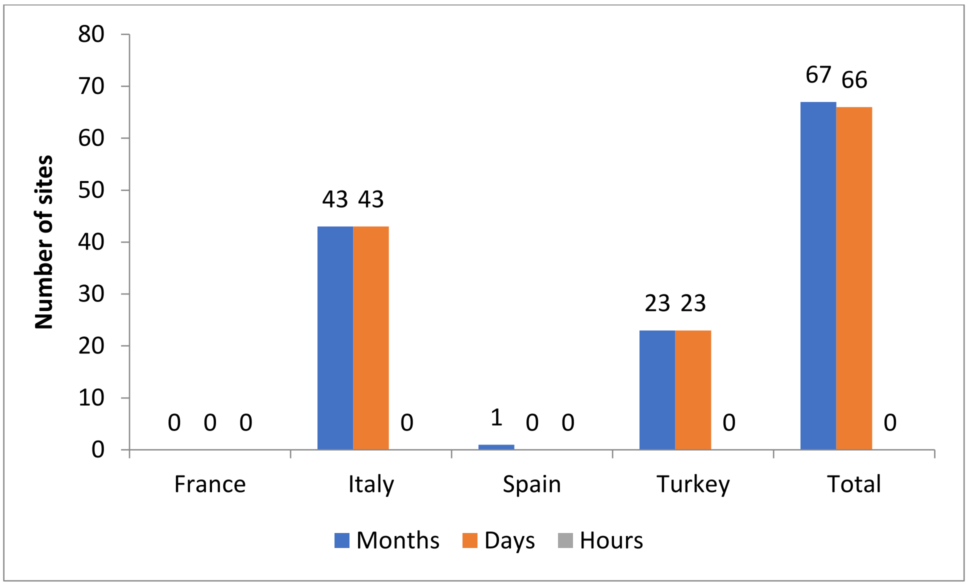

Figure 9.13. Eel fishing sites according to fishing time (months, days, hours) by country during the five year period, 2015–2020.

Number of fishing gears

Turkey was the only country that provided data on the number of fishing gears, which it did for all of its 23 sites, but only for eel longlines (Figure 9.14). No country provided data on fishing effort.

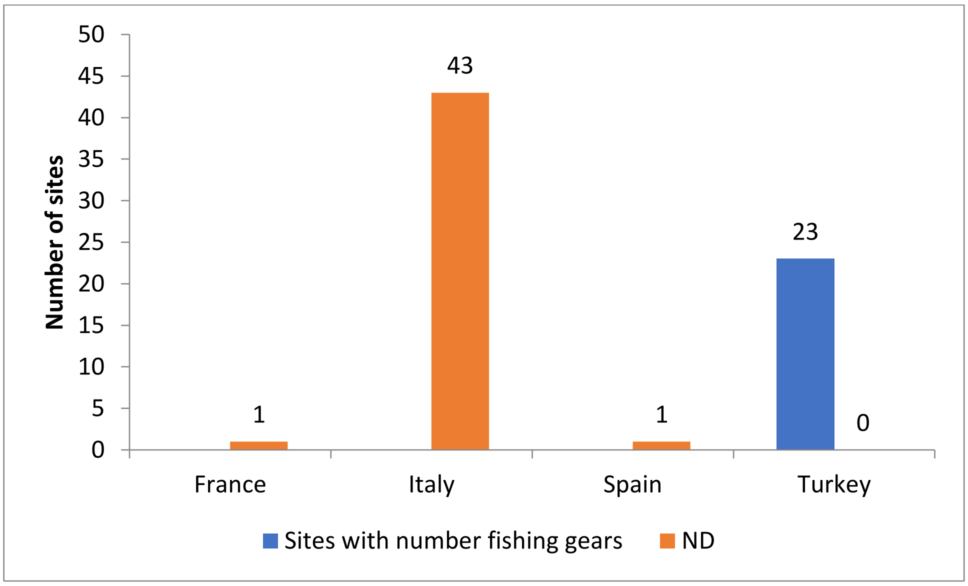

Figure 9.14. Number of eel recreational fishing sites and number of fishing gears by country over the five year period, 2015–2020.

Quantitative analysis of the recreational fishery

Longlines (ELL)

Longlines were only used in 23 sites in Turkey with an average of two gears per licence. The number of anglers varied between two and 1 020 and the average fishing time was three months (Table 9.15).

Table 9.15. Fishing effort metrics (total number, mean, range) for recreational longlines (EEL) reported by country over the five years, 2015–2020.

Country	Number of sites	Fishing gears			Anglers/licence		Fishing months		Fishing days	
		N	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Turkey	23	4–2 040	2	-	160	2–1020	3	3–5	104	90–150

* numbers not exhaustive

Fishing rod (FRD)

Fishing rods were reported as being used in three partner countries. In Italy there was an average of 102 anglers per licence while the average fishing time was longest in Spain (eight months) (Table 9.16).

Table 9.16. Fishing effort metrics (total number, mean, range) for fishing rods (FRD) by country, averaged over the five year period, 2015–2020.

Country	Number of sites*	Fishing gears*			Anglers/licence*		Fishing months		Fishing days	
		N	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Italy	42		na	-	102	2–540	5	2–8	13	5–32
Spain	1		na	-	23	13–35	8		na	
Turkey	23		na	-	na		na		na	
Total	*76*									

* numbers not exhaustive
na = data not available

Shore lift net (SNL)

Shore lift nets were only reported from Italy where, on average, 25 anglers practiced this type of recreational fishing over a five month period (Table 9.17).

Table 9.17. Fishing effort metrics (total number, mean, range) for shore lift nets (SNL) by country, averaged the five year period, 2015–2020.

Country	Number of sites*	Fishing gears*			Anglers/licence*		Fishing months		Fishing days	
		N	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Italy	12	na	na		25	2–214	5	2–7	17	5–58

* numbers not exhaustive
na = data not available

Snigging (SNI)

Snigging was also used only in Italy where there were, on average, 136 anglers and fishing times varied between five and 26 days (Table 9.18).

Table 9.18. Fishing effort metrics (mean, range) for snigging (SNI) by country, averaged over the five year period, 2015–2020.

Country	Number of sites*	Fishing gears*			Anglers/licence*		Fishing months		Fishing days	
		N	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Italy	3	na	na		136	8–382	6	4–7	14	5–26

* numbers not exhaustive
na = data not available

Spearfishing (SPF)

Spearfishing was used by 14 anglers to catch eels at only one site in Italy during eight months of the year (Table 9.19).

Table 9.19. Fishing effort metrics (mean, range) for spearfishing (SPF) by country, averaged over the five year period, 2015–2020.

Country	Number of sites*	Fishing gears*			Anglers/licence*		Fishing months		Fishing days	
		N	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Italy	1		ND	-	14	-	8	-	15	-

* numbers not exhaustive

ND = no data available

9.4 DISCUSSION AND CONCLUSIONS

Within the framework of this project, data on the number of fishers, licences, gears and fishing time (months, days, and hours) were requested from partner countries and all the countries provided the data that they had available. An attempt was made to quantify fishing effort for both commercial and recreational eel fisheries. However, it was difficult to calculate fishing effort and make comparisons because the data were disparate, scattered and in different formats as well as there being differences in data collection administrative procedures and the units used were not suitable for eel fisheries. It was not possible to use these data for fishing effort calculations due to the absence of standardized units that could be commonly interpreted.

In the data call, the countries were requested for any type of potential capacity under the condition of specifying the unit. The provided data were a mixture of total number of fishers, number of interviewed fishers, number of cooperatives, as well as number of licences. Also, the data did not cover all sites where eels are caught and many data remain unavailable. Licences for commercial eel fisheries can be issued to individual fishers, to boats or to companies, therefore, the number of licences does not reflect the actual number of fishers operating in a site, with a fishing gear.

Fishing time was not available for all countries and was sometimes confused with the fishing season or the allowable fishing period and effective fishing time was only provided by few countries. The provided data were in hours, days or months depending on the protocol of data collection adopted by the national or local administration.

Moreover, eel fishery data collection in many countries does not take into consideration the segregation between life stages, especially for yellow and silver eels, as well as the type of gears used or they report landings caught by mixed gears, thereby increasing the complexity.

Only a few countries provided data concerning the number of fishing gears and key elements of the gears such as the number of pockets or number of hooks. The use of many different types of fishing gears was reported by many countries (see Chapter 8 on eel fishery methodology) while the catches do not exist in the fisheries database (see Chapter 10 on eel landings).

For all these reasons, it was not possible to standardize these data and even when data were provided, they were impossible to compare. For example, the mean number of fishing gears per day per fisher were very different for fyke nets (Table 9.8) and fences (Table 9.10), even if habitat was taken into consideration. Also, data seem to be calculated according to different approaches which returned different results. Thus, the fishing effort calculation should be completely reviewed for eventual standardization by selecting suitable effort units per gear type taking into consideration their characteristics and units of fishing time.

Ideally, it is recommended that the following parameters should be collected by habitat and life stage, in all sites where the eel is caught, either as a target or as by-catch:

- Longline: total number of hooks per licence, distance between hooks, hook size, soak time per fishing operation, number of fishing operations per day, number of fishing days per trip, number of licences, and landings per trip.
- Eel pots: total number of used pots per licence, distance between pots, mesh size, soak time per fishing operation, number of fishing operation per day, number of fishing days per trip, number of licences, and landings per trip.
- Fyke nets and fences: minimum mesh opening, number of pockets (cod-ends) per gear, pocket dimensions (diameter, length), number of gears per licence, total gear dimensions, landings per effective fishing operation, soak time, number of licences.
- Barriers: number of rooms, dimension of rooms, minimum mesh size, landings per fishing operation, effective number of fishing days

Concerning recreational fisheries, data were provided by only four countries (France, Italy, Spain and Turkey), while it was completely absent for the others. The data provided were not complete and only Turkey provided data related to the number of fishing gears. Calculation of fishing effort was not possible for this kind of fishery.

9.5 RECOMMENDATIONS

This chapter highlights the wide variability in the quality of data provided by partner countries on eel fishing effort. None of the nine countries provided sufficient data for a comprehensive estimation of eel fishing effort and some countries provided no data. This information gap is not limited to the Mediterranean region, but to the entire range of the species as similar situations have been reported in other countries and regions (ICES, 2020).

This work is a first attempt at quantifying fishing effort for eel in the Mediterranean region. However, due to the lack of complete and precise information, this evaluation was not successful.

Therefore, it is highly recommended to:

- Review the requested data in the DCRF in accordance with the possible common parameters to all the CPCs.
- Include all eel fisheries and landings by fishing gear type, habitat and life stage in the GFCM-DCRF data call
- Collect data on recreational fishing.
- Take into consideration eel by-catch in data collection.

9.6 REFERENCES

ICES. 2020. Joint EIFAAC/ICES/GFCM Working Group on Eels (WGEEL), and Country Reports 2019–2020. *ICES Scientific Reports*, 2:85. 223 pp. doi:10.17895/ices.pub.5982

CHAPTER 10. EEL LANDINGS

ABSTRACT

Eel exploitation in the Mediterranean region was investigated, collecting detailed information and data on eel fisheries and landings. Eel catches from nine countries (Albania, Algeria, France, Greece, Italy, Spain, Tunisia, Egypt and Türkiye) out of 12 where significant eel fisheries exist were gathered, when possible, with site level data. Data collection relied on national fishery statistics, fishing reports, grey and scientific literature and logbooks. A multi-step quality check was carried out, that also involved an expert judgement approach by scientific partners and national focal points in validating data. Information was gathered for 366 fishing sites. Data on recreational fisheries were limited to four out of nine countries and indicated that there were significant recreational catches, while recreational fisheries are known to take place in other countries as well.

In total, 93 percent of commercial catches (considering all countries and all years) occurred in lagoons while the remainder occurred in rivers and lakes. In most cases, catches were reported as mixed eel life stages, that is, yellow and silver eel together (YS, 92 percent of total catch). Fishing effort information and data were not reported in 50 percent of cases. Therefore, it was not possible to evaluate the catch per unit of effort. Seventy-five percent of total catches were reported as resulting from multiple fishing gears (MIX), mainly consisting of fyke nets combined with fixed barriers (85 percent of the MIX catches) and eel longlines combined with other gears (12 percent of MIX catches). The time span of the time-series ranged from 1951 to 2020, with consistent data for all countries from 2000 onwards, when total catches decreased from 2 373 tonnes in 2000 to 903 tonnes in 2010 and 1 048 tonnes in 2019. Average catches amounted to 1 996 tonnes in the period 2000–2010 and 1 372 tonnes from 2011 to 2019. Considering the recent five-year period, 2015–2019, yellow and silver eel commercial catches averaged 1 531 tonnes, of which 90 percent were attributable to five countries; 33 percent from Egypt, followed by France (28 percent), Italy and Türkiye (10 percent, each) and Tunisia (9 percent).

From a preliminary comparison with ICES data (ICES, 2021a), catches of yellow and silver eel commercial fisheries reported by 25 countries across the eel distribution range, including most of the Mediterranean countries (except Egypt), averaged 3 273 tonnes over the five-year period, 2015–2019. As a minimum estimation, and not considering the role of Egypt, it seems that, on average, at least 30 percent of the catches estimated for the whole eel distribution area come from the Mediterranean region.

HİGHLİGHTS

Main outcomes

- For the first time, a comprehensive data collection, revision and analysis of landings data was performed at the regional level in the Mediterranean, involving nine partner countries that account for the most important eel fisheries in the area.
- Data collection relied on all possible sources of data and information, and was aimed at gathering catch data and time series at the highest possible resolution, at site level. The revision and analysis relied on a multi-step data quality check involving scientific partners, with a final expert-judgement assessment using a reliability score (from 1 = high quality/reliable data to 3 = low quality/not validated data).
- The quality check was carried out comparing collected data with official data shared with GFCM Secretariat via the online platform for Task VI – European eel of the GFCM data collection reference framework (DCRF), also involving the national focal points (see Chapter 17).

- Data were available at the site level for most countries, for a total of 366 fishing sites. Most eel catches (over 90 percent) were from lagoon habitats, while the rest were shared between river and lake fisheries.
- Total catches at the national level show decreasing trends in all partner countries. Considering that no total effort data related to the catch data were available for the Mediterranean, conclusions emerging from the analysis of national catches should be taken with caution.
- Albania, Algeria, Greece and Spain stated that their data reflected the actual level of resource exploitation while Egypt, France, Italy, and Tunisia declared that the national exploitation level was, in all cases, underestimated and Türkiye did not provide a judgement.
- In the light of the available data, it appears that one-third of the total average catches over the last five years have been by a single country (Egypt). Excluding Egypt, total catches from the Mediterranean partner countries may represent at least 30 percent of total eel catches estimated by ICES.
- The level of eel exploitation remains high and in line with the overall level of exploitation estimated by ICES.
- The analysis of total catches and trends does not consider other Mediterranean countries (Croatia, Montenegro, Mediterranean Morocco, Slovenia, Libya) for which official fishery data exist or eel fisheries are known to exist.

Main shortcomings

- The analysis was carried out on data provided by the nine partner countries participating in the research programme. Notwithstanding the fact that this analysis includes countries where major eel fisheries are present in the Mediterranean, further effort is needed to obtain data from other Mediterranean countries involved in eel fisheries, to increase the spatial coverage.
- Five of the nine partner countries had to process the data before including them in the project databases by disaggregated catches per habitat type, at the site level, for life stages and fishing gear.
- Fishing effort data such as the number of effective eel fishers, the number of fishing gear used per day by the individual fishers and the number of effective fishing days in a fishing season, were not available in 50 percent of cases.
- Results highlight the importance of standardizing data collection methodologies. The presence of several official data collection frameworks at different levels makes the use and comparison of data over time and space challenging.
- The revision and harmonization of eel data collection methodologies are crucial, especially in light of the absence of data related to fishing effort.

Possible outcomes for management

- A framework for data collection including at the site level and recording of time-series for landings, are crucial aspects if data are to be used for the assessment of exploitation at the local level, with a view to establishing specific management measures for different fisheries.
- The overall level of exploitation in the Mediterranean and in specific habitats and sites, seems high. A reduction of fishing effort should be considered to reduce catches, coupled with other measures beneficial to silver eel escapement.
- In light of the results obtained from this preliminary analysis, it is crucial to consider the role of Mediterranean fisheries for the whole distribution area of the species.

10.1 INTRODUCTİON

This chapter presents a general review of eel exploitation in the Mediterranean region, including all coastal, transitional and inland waters within countries that fall within the southern range of distribution for European eel. It focused on collecting all types of information on commercial and recreational eel fisheries.

Eels live in all Mediterranean aquatic habitats and their exploitation in the Mediterranean region has a long-standing tradition. Artisanal fisheries mainly exploit adult eels in inland waters (estuaries, lakes and rivers), but especially in coastal lagoons, which cover a surface of over 641 000 hectares in the Mediterranean region (Cataudella, Crosetti and Massa, 2015).

Inland waters (such as rivers and lakes) are exploited too, and their fish density, as well as production patterns, are also very diverse depending on the type of environment. Coastal lagoon fisheries have a very distinctive exploitation pattern for euryhaline fish species in the Mediterranean region and yield the highest production levels as they have a wider surface area compared to inland waters (Aalto *et al.*, 2016).

Fisheries and various forms of aquaculture have traditionally been carried out in Mediterranean coastal lagoons since ancient times. They are part of the regional cultural heritage given the abundance of trophic resources in these habitats and the relative ease of access for fishing activities, which occur in a confined and relatively protected environment compared to the open sea (Cataudella, Crosetti and Massa, 2015).

Coastal lagoon fisheries mainly rely on capturing euryhaline fish species that migrate seasonally between the sea and the lagoons, bringing in juveniles to the lagoons where conditions are suitable for growth and returning adult fish to sea for spawning. In many cases, artisanal fisheries are well developed. Management is simple and, in many Mediterranean lagoons, primarily based on natural recruitment (Cataudella, Massa and Crosetti, 2005).

At present, capture fisheries in lagoons can still be considered a form of artisanal fisheries targeting more than one species (multispecies fisheries) and using a wide variety of fishing gears. Fishing gear design reflects local traditions and skills as well as a deep knowledge of species biology (for example, reproduction timing, migrations, seasonal or daily movements due to tides). Typical gears used in artisanal lagoon fisheries are fyke nets, pots, nets and longlines, as well as fixed capture systems such as barriers.

Lagoon fisheries often merge aquaculture with capture fisheries management schemes and are sometimes described as extensive aquaculture. The “vallicoltura” represents one of the oldest forms of fish culture in the Mediterranean, especially in Italy, dating back to the 11^{th} century. Historically, these two different management forms have taken mutual advantage of each other and developed together into unique forms of exploitation that coexist at present within the same environment and rely on the same trophic resources (Ciccotti, Busilacchi and Cataudella, 2000).

Eel exploitation in the Mediterranean region has a long-standing tradition (Ciccotti, 2005) and is based on all life stages; glass eel, yellow and migratory silver eel. Yellow and silver eel fisheries in the Mediterranean mostly occur in coastal lagoons, but inland eel fisheries are also found in the main rivers and lakes of most countries (Dekker, 2003). Egypt has the most southerly commercial eel fishery and the Asi river in Türkiye, is the easternmost tip of the European eel distribution area. In the Adriatic region, eel is mainly exploited in the inland waters of Albania and Italy, as well as in other countries such as Croatia, Montenegro and Slovenia.

In most Mediterranean countries, eels are fished mainly using various types of traps. The design, dimensions and materials vary according to local traditions and locations. Fishing effort in terms of the number of fyke nets or fixed systems can change within each lagoon according to the season.

According to ICES statistics, the overall production of European eels has dropped drastically since the mid-1980s (ICES, 2001). Aalto *et al.* (2016) estimated that in the Mediterranean, eel catches started to decline between 1964 and 1984 (median value = 1977), about a decade later than estimated by Dekker (2002). The decline in recruitment reported for all of Europe was confirmed for the Mediterranean area (Cataudella, Crosetti and Massa, 2015). Examination of reported landings in Europe points to a decrease in yield in most countries over the last 20 years. After high levels in the late 1970s, recruitment declined and has been very low since 2000. Recent years have shown a continued decrease while the analysis performed by the joint EIFAAC/ICES/GFCM WGEEL in 2021 recorded an annual recruitment data point for 2020 among the lowest ever (ICES, 2021a).

10.2 METHODOLOGY

10.2.1 Data collection

Within the framework of the GFCM research programme on European eel, data providers were asked to report all time-series of commercial and recreational landings, coupled with fishing effort data, through the databases established under WP3. Each of the sections below describes trends in the data series and comments on data quality.

The fishery database was prepared in Excel format, with six spreadsheets (Table 10.1, Supplemental Material on the Methodology).

- The **general info** sheet included the official codes for countries, eel management units (EMUs), habitats, life stages, fishing gears and definition of missing values.
- The two **readme** sheets explained all the fields of the commercial and the recreational fishery databases, with the corresponding units of measure for the numeric values (Table 10.2 and Table 10.3, Supplemental Material on the Methodology).
- The **two databases (commercial and recreational)** each included four sections: site information (country, region, EMU, habitat, site name, year, data source), catches, including by life stage and the yellow eel to silver eel (Y/S) ratio; fishing effort information (gear type, number of gears per fisher per day, the potential fishing capacity, the months, days and/or hours of fishing - see Chapter 9); and the reliability score for each record (1 = reliable, 2 = use with care, 3 = not validated).

The databases were compiled by separating catches by habitat, site, year, life stage and fishing gear. The data relied on all available sources including EU projects (for example, DCF [Reg. 199/2008], EU-MAP [Decision EU 2016/1251]), national/regional/local projects, other projects (including LIFE and Interreg), scientific papers, grey literature, fishery dependent data and other data.

10.2.2 Quality checks

Before starting quantitative analysis of the fishery data, a technical quality check was carried out on the data. In particular, corrections concerned duplicated rows, site names with spelling errors, inconsistencies between coordinates and site (for example, the same site with different coordinates or the same coordinates for different sites), errors in habitat attribution and empty cells.

Each database was revised and integrated with the collaboration of the data providers to:

- verify catches by life stage and fishing gear at each site;
- assign the correct fishing gears to catches;

- better characterize fishing effort at each site (e.g. number of gears, number of fishers, fishing months/days/hours declared, etc.); and,
- assign a reliability score to each record, to discriminate data that could be used in quantitative analyses from those that could only be used at a qualitative and descriptive level.

The reliability score took into account the type of data source (such as official statistics, logbooks, interviews with fishers or literature) and the reliability of the data with respect to the life stage, the fishing gear and the habitat for each site and year collected. It also relied on comparisons with the official data framework in each country. In some cases, the reliability score also depended on the data collection methodology, which was specific to each single country or habitat typology. The score was primarily assigned by the data providers and, in some cases, it was reviewed to improve definition, for example, by assigning catches to fishing gears. The final score was assessed both at the site and EMU levels. All quantitative analyses were performed taking into account reliable data at the EMU level.

10.2.3 Data analysis

Data were aggregated by year to show trends at the country level, and then analysed in detail considering life stage, single habitats and single countries.

The sites in the database were plotted to show the geographical distribution of all the fishing sites. Different maps were drawn to highlight the type of fishery (commercial, recreational), the life stage of eels caught at each site, habitat type and the fishing sites selected for the quantitative analysis.

All the maps were plotted using the software QGIS (2021) with the ESRI Ocean base map and all the graphs were plotted using "ggplot2" package (Wickham, 2016) of R software (R Core Team 2021).

Landings were standardised over the surface area of the habitat (see Chapter 2 for surface area quantification). Four timeframes were identified to detect how past and present levels of eel production changed over time: pre-1950, pre-1980, pre- and post-2009 (see Chapter 5 for the criteria). According to these time intervals, average values and ranges were estimated from sites with at least ten years of available data. Results were shown by country and habitat type.

10.3 RESULTS

10.3.1 Overall description of commercial landings

Commercial fisheries data were reported by country, year, eel life stage (yellow, silver and together) and habitat type (lagoons, estuaries, lakes and rivers). Where possible, all data were provided at the site level. Time-series for which these levels of detail were not available or not reliable, were reported by EMU or country.

Four Mediterranean countries provided both commercial and recreational fishery data, whereas seven countries only reported commercial fishery data (Figure 10.1).

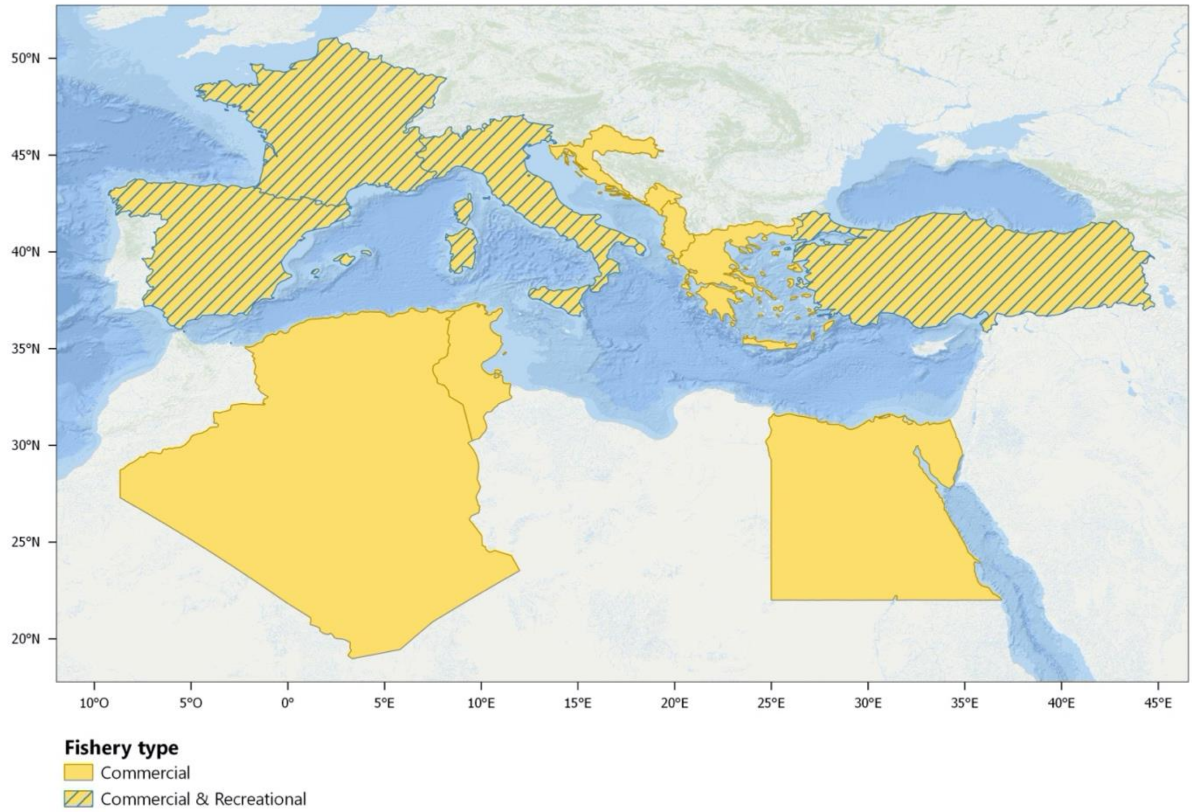

Figure 10.1. Map of Mediterranean countries identified by fishery type (only commercial or commercial and recreational)

The timespan of the series ranged from 1951 to 2020, even if for most countries, data were not fully available at the time of analysis, with a consistent overlap between countries in more recent years (Figure 10.2).

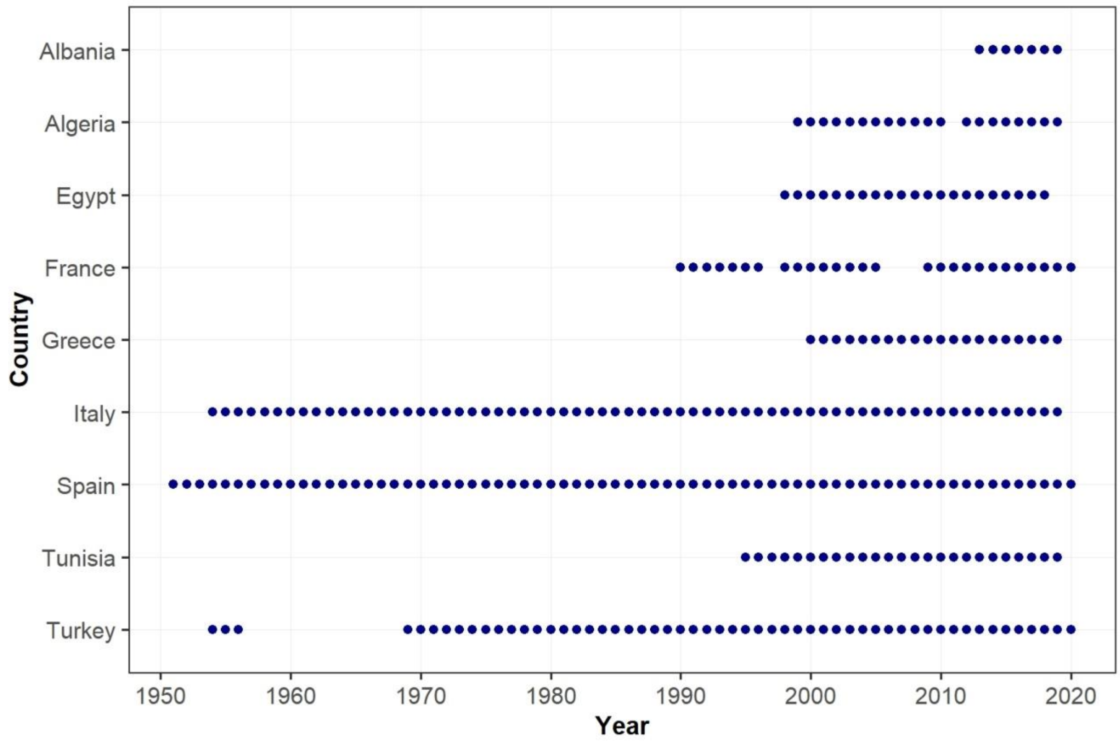

Figure 10.2. Fishing years available for each Mediterranean country. Data were aggregated at national level (all time-series available in each country)

Table 10.1 provides a synthesis of the data coverage reported by each Country relative to the WP3 fishery database (Table 10.1, Supplemental Material on the Methodology). Compared to the original data available (see also Chapter 9, Table 9.2), five out of nine countries processed the data before including them in the databases (disaggregated catches at the site level, by life stages and fishing gear). The overall data coverage was the result of expert judgement to quantify the percentage of data collected with respect to the original scope at national level. In case of medium and high levels of uncertainty, data were also classified as under- or overestimated. The percentage of not reliable fishery data was calculated as the number of records with not-reliable data at national level out of the total.

Table 10.1. Information on the data collected for commercial (COM) and recreational (REC) fisheries

Country	**Fishery type**	**Data sources**	**Overall data coverage (percent)**	**Final uncertainty in the data**	**Not reliable fishery data** (percent)
Albania	COM	Official fishery statistics			0
Algeria	COM	Official fishery statistics	100	Low	0
Egypt	COM	Official fishery statistics	90	Medium – underestimation	0
France	COM	Official fishery statistics; Log books	100 *	Medium/High – underestimation	21
	REC	Log books	100 *	Medium/High – underestimation	0
Greece	COM	Official fishery statistics	ND	Low	1.7
Italy	COM	Official fishery statistics; Log books; Literature	70	Medium/High – underestimation	21

Country	Fishery type	Data sources	Overall data coverage (percent)	Final uncertainty in the data	Not reliable fishery data (percent)
	REC	Official fishery statistics	70	Medium/High – underestimation	55.7
Spain	COM	Official fishery statistics	100	Low	0
	REC	Official fishery statistics	100	Low	0
Tunisia	COM	Official fishery statistics	ND	Medium – underestimation	65.6
Türkiye	COM	Literature; Official fishery statistics	30-40 *	Medium – under/overestimatio n	9
	REC	Official fishery statistics	30-40 *	Medium – under/overestimatio n	0

* ***France.*** *Commercial fishery: data from 2010-2019 in marine waters have 100 percent data coverage; data from 1990 to 2020 for freshwater habitats exist but need particular care. Recreational fishery: fishers are not obliged to collect data, so even if they are reported as 100 percent of the official national data available, the data are underestimated.*
* ***Türkiye.*** *The percentage of data coverage is referred to data at site level, collected from national/regional/local projects, scientific papers and grey literature.*

ND = no data available

Four of the nine countries (Albania, Algeria, Greece and Spain) declared that their data were of high quality and covered 100 percent of existing national data, reflecting the actual level of exploitation of the resource. Türkiye claimed that 40 percent of existing data was collected at most, mainly relying on information from research projects, papers and grey literature. The reliability of the data at the site level was high. However, it was not possible to evaluate if the level of exploitation that emerged at the national level was under or overestimated. The remaining countries (Egypt, France, Italy and Tunisia), despite achieving good coverage of the available data (greater than 70 percent), with reliable quality, declared that the emerging level of national exploitation was underestimated, in all cases.

Data from 366 fishing sites were included in the WP3 Fishery Database (Table 10.2), with most coming from lagoons (154 sites), followed by rivers (91 sites), lakes (51 sites), coastal marine waters (47 sites) and estuaries (23 sites). Countries with the highest number of sites were Italy (187 sites, mostly in rivers and lagoons), Tunisia (77 sites, mainly distributed between coastal marine waters and lakes), Türkiye (30 sites, mostly in lagoons) and Greece (26 sites, almost all lagoons).

The total number of sites recorded in the database is shown in Table 10.2, also considering those without a clear geographic identification or at EMU level, while all the geo-referenced sites (346 out of 366) are reported in Table 10AR1.1 of the Additional Results Part I.

Table 10.2. Total number of sites by country and habitat (CMW = coastal marine waters, LAK = lake, LGN = lagoon, RIE = estuary, RIV = river)

N° of sites					
Country	Habitat				
	CMW	LAK	LGN	RIE	RIV
Albania	0	1	8	0	0
Algeria	0	2	1	2	0

Egypt	0	0	4	0*	1*
France	0	0	12*	0*	7
Greece	0	1	24	0	1
Italy	0	13	76	20	78
Spain	1	0	7	1	0
Tunisia	46	26	5	0	0
Türkiye	0	8	18	0	4
Total	*47*	*51*	*154*	*23*	*91*

* ***Egypt.*** *Catches for the Nile river were provided aggregated both for the estuary areas and the river segment.*
* ***France.*** *The number of sites includes the gathering of several lagoons (for example, the site "Lagune de Corse" encompassing Biguglia, Urbino, Diana and Palo), lagoon complexes (for example, the site "Complex de Palavasien" encompasses several lagoons linked to each other: Arnel, Grec, Ingril, Mejean, Moures, Pérols, Pierre Blanche, Prevost and Vic), and a site where catches are aggregated from the Vendres lagoon and the adjacent estuary area. An additional lagoon site was not counted in the total because it was reported as "NA": it is a mixture of sites in the EMU Rhon, but the specific lagoon could be identified.*

Figures 10.3 and 10.4 show the geographical distribution of fishing sites, by habitat type and life stage, respectively.

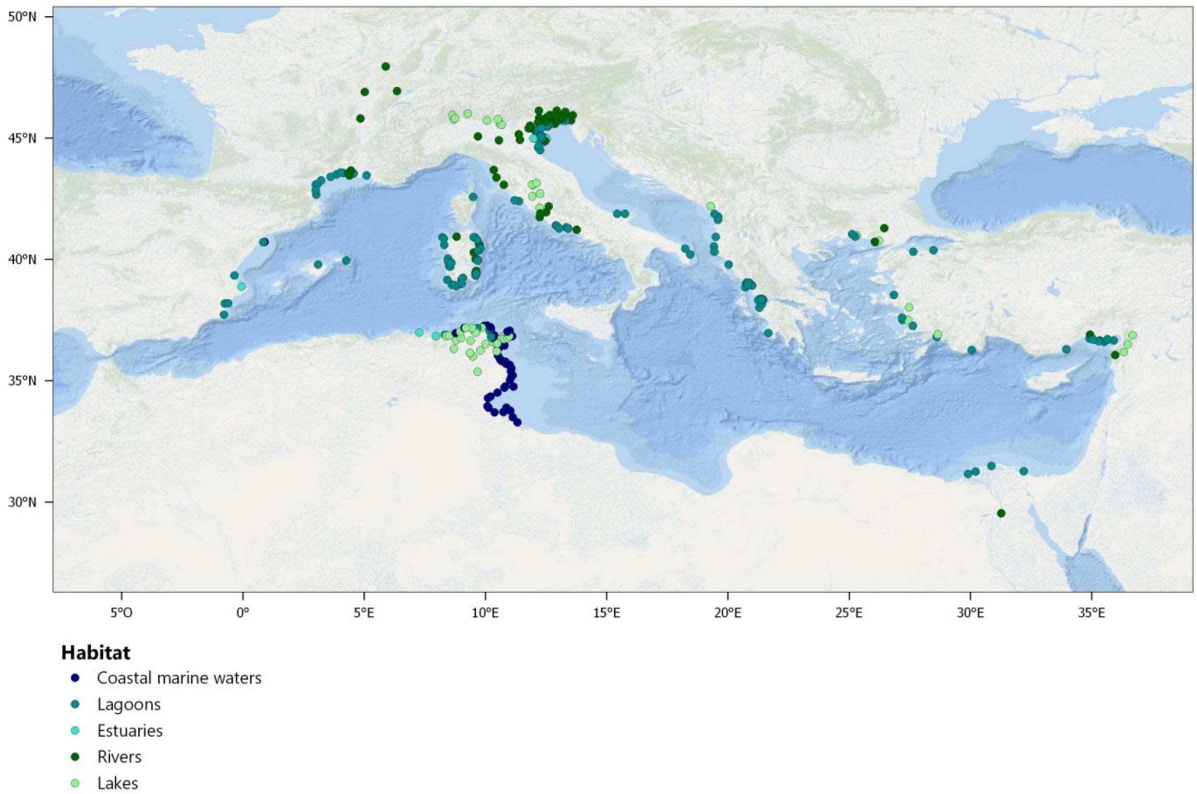

Figure 10.3. Distribution of sites by habitat type

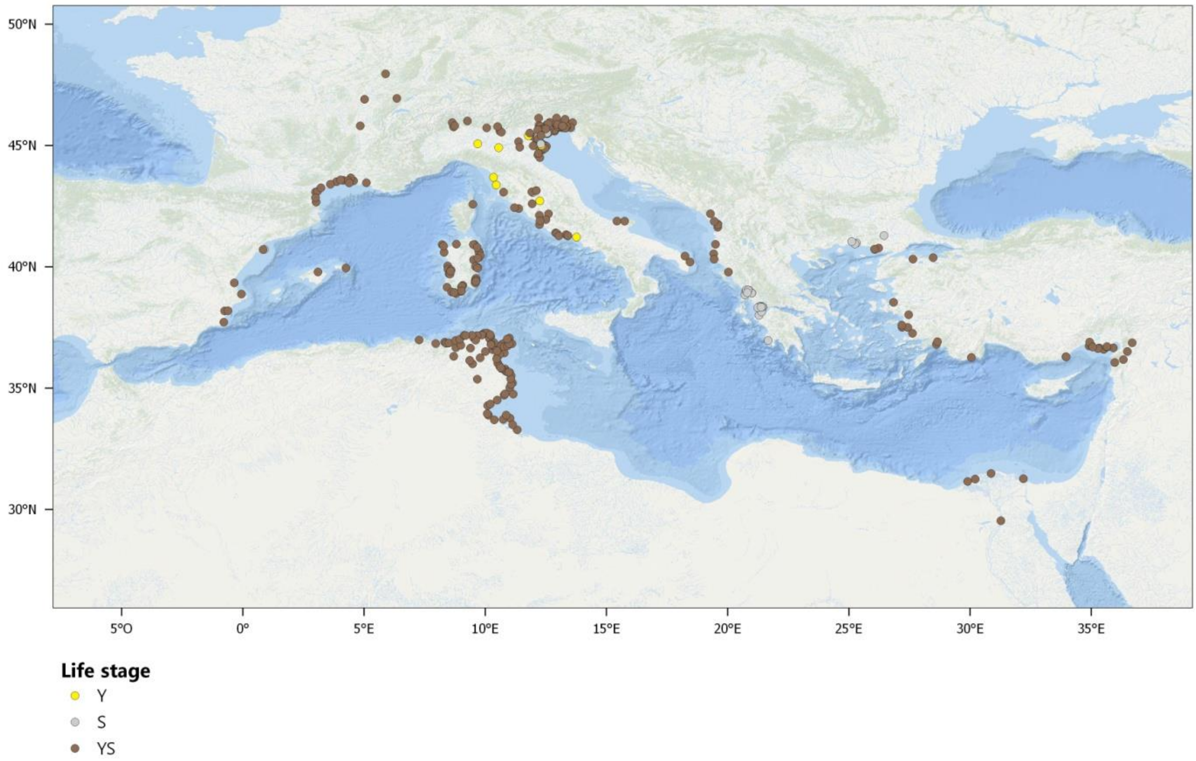

Figure 10.4. Distribution of sites by life stage (Y = yellow eel, S = silver eel, YS = mixed yellow and silver eel)

Ninety-three percent of total catches (considering all countries and all years) were from lagoons, followed by rivers and lakes (Figure 10.5a). The prevalent life stage associated to catches was yellow-silver (YS), not separated by stage (92 percent) (Figure 10.5b).

There was great variation shown in the type of fishing gears used and often it was not possible to separate catch by gear when referring to a single site, year or eel life stage. Most (75 percent) of total catches were reported as a "mix" of gears, mainly consisting of fyke nets combined with fixed barriers (85 percent of the mixed gears) and eel longlines combined with other gears (12 percent of the mixed gears). Considering catches by specific gear types, it was possible to distinguish catches related to fyke nets (seven percent of total catches), fyke nets combined with net panel cod-ends as "fences" (eight percent of total catches) and fixed barriers (two percent of total catches), while eight percent of total catches could not be associated to any fishing gear (Figure 10.5c).

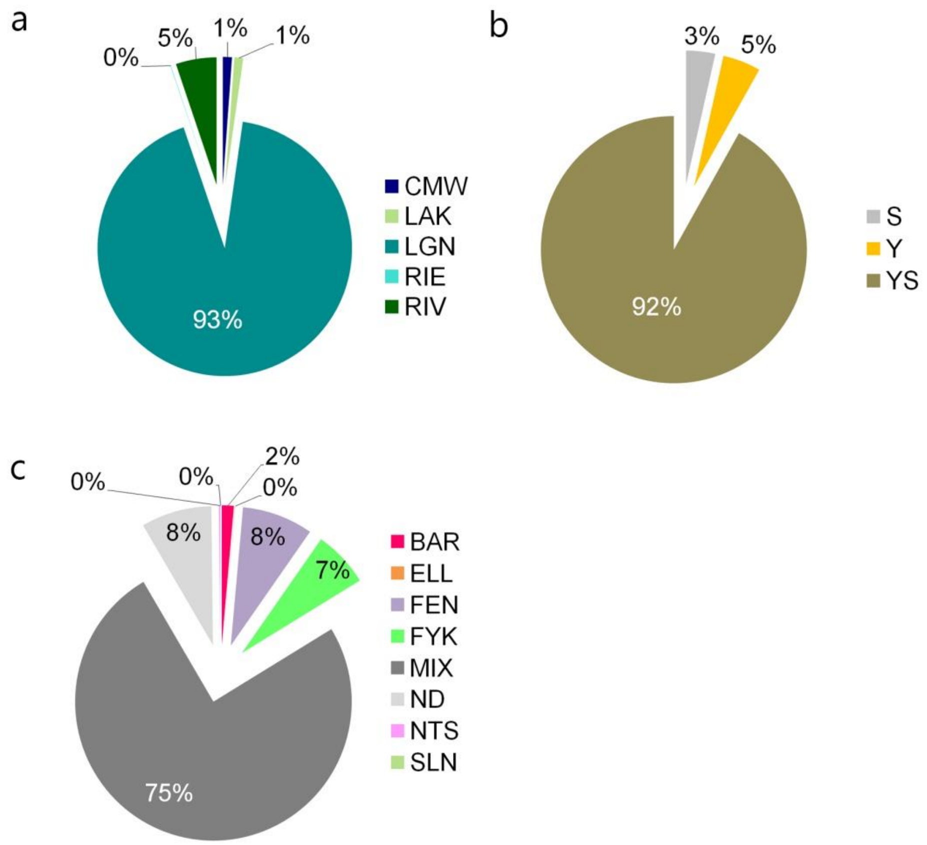

Figure 10.5. Proportion of total catches based on: **a)** habitat (CMW: coastal marine waters; LAK: lake; LGN: lagoon; RIE: estuary; RIV: river); **b)** life stage (S: silver eels; Y: yellow eels; YS: not-separated stages); **c)** fishing gear (BAR: fixed barriers; ELL: eel longlines; FEN: fences; FYK: fyke nets; MIX: mixed gears; ND: gear not known; NTS: nets; SLN: shore lift nets)

10.3.2 Site selection according to the reliability score

Following the quality check and assignment of a reliability score to each row in the database, a sub-matrix of data was selected to be used in subsequent quantitative analyses. Figure 10.6 shows the sites used in the quantitative analysis in green and Table 10.3 reports the details of sites kept for quantitative analysis compared to the total number of available sites.

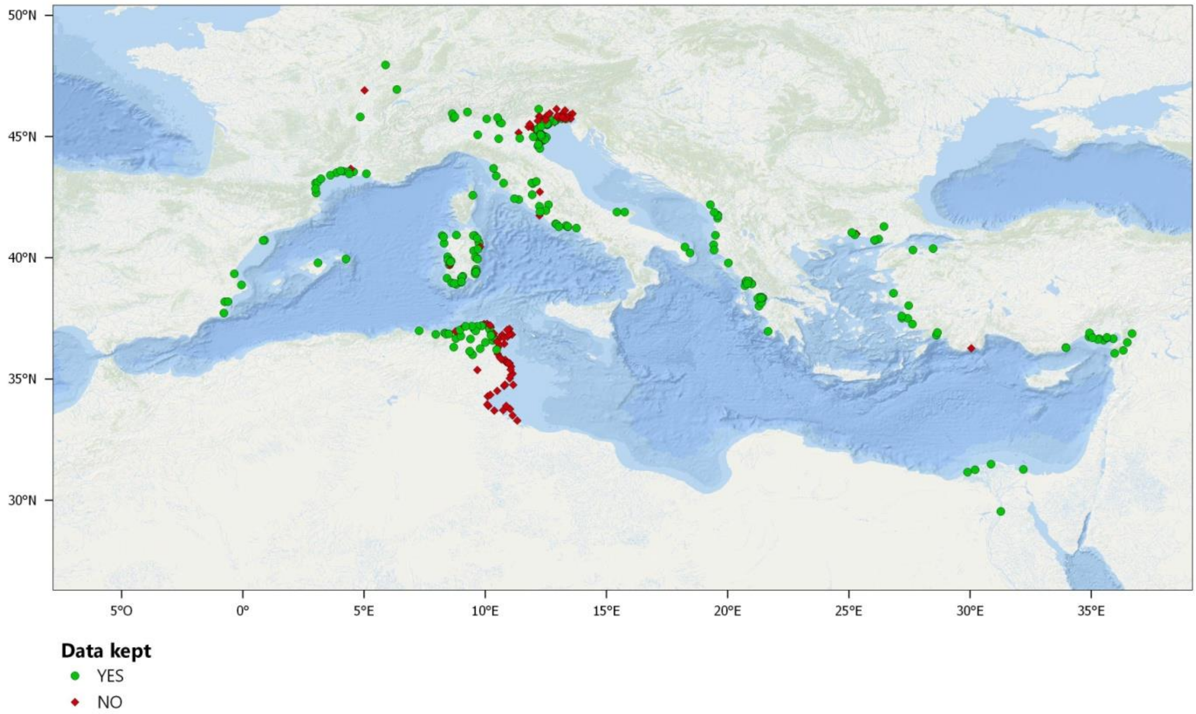

Figure 10.6. Selection of sites with reliable fishing data (YES), and therefore used in quantitative analysis

Table 10.3. Total number of sites by country and habitat (CMW = coastal marine waters, LAK = lake, LGN = lagoon, RIE = estuary, RIV = river), with the proportion of sites selected for quantitative analysis

Country	Habitat	Total number of sites	Number of sites retained	Sites retained (percent)
Albania	LAK	1	1	100
	LGN	8	8	100
Algeria	LAK	2	2	100
	LGN	1	1	100
	RIE	2	2	100
Egypt	LGN	4	4	100
	RIV+RIE *	1	1	100
France	LGN *	12	12	100
	RIV	7	6	86
Greece	LAK	1	0	0
	LGN	24	24	100
	RIV	1	1	100
Italy	LAK	13	12	92
	LGN	76	69	91
	RIE	20	15	75
	RIV	78	42	54

Country	Habitat	Total number of sites	Number of sites retained	Sites retained (percent)
Spain	CMW	1	1	100
	LGN	7	7	100
	RIE	1	1	100
Tunisia	CMW	46	9	20
	LAK	26	18	69
	LGN	5	5	100
Türkiye	LAK	7	7	100
	LGN	19	19	100
	RIV	4	4	100

* ***Egypt.*** *Catches for the Nile river were provided aggregated both for the estuary areas and the river segment.*
* ***France.*** *The number of sites includes the gathering of several lagoons (for example, the site "Lagune de Corse" encompassing Biguglia, Urbino, Diana and Palo), lagoon complexes (for example, the site "Complex de Palavasien" encompasses several lagoons linked to each other: Arnel, Grec, Ingril, Mejean, Moures, Pérols, Pierre Blanche, Prevost and Vic), and a site where catches are aggregated from the Vendres lagoon and the adjacent estuary area. An additional lagoon site was not counted in the total because it was reported as "NA": it is a mixture of sites in the EMU Rhon, but the specific lagoon could be identified.*

10.3.3 Total catches

Catches by year and country

Figure 10.7 presents the time-series to date, including 2020, for total commercial landings, as reported by nine countries. Fishing time-series start in the 1950s and vary greatly from country to country. It can be observed that from 1998, Egyptian catches were many orders of magnitude higher than all other countries (see Table 10.4 for the quantitative data associated to the graph).

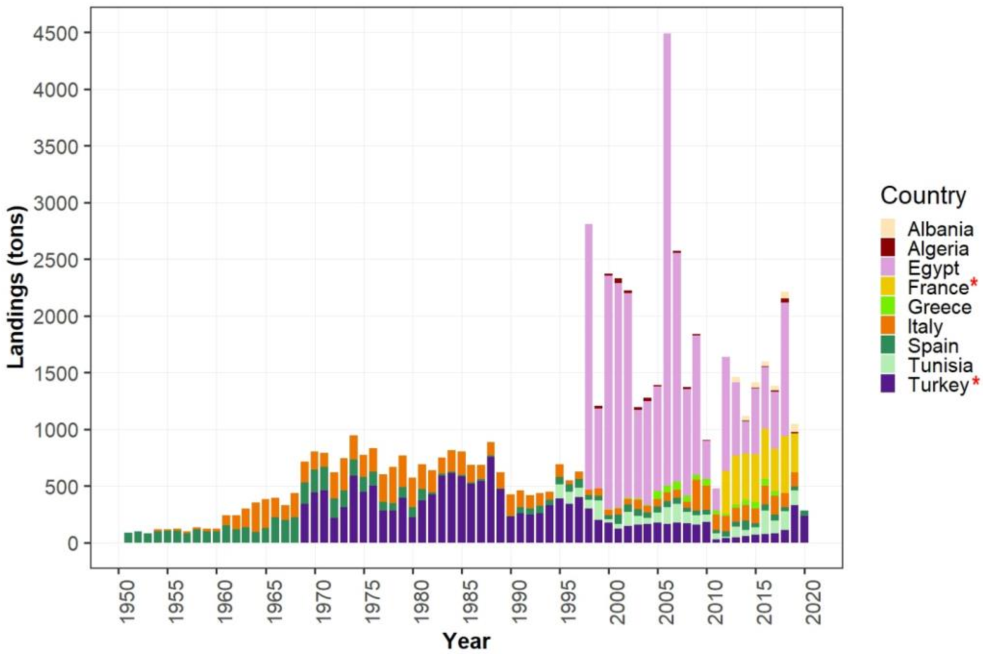

Figure 10.7. Total catches in tonnes per year and country (all eel life stages)

* ***France.*** *Data from 2012 to 2019 are from marine fishery; data from 2000 to 2005 are from freshwater fishery. Recorded official data is very underestimated.*
* ***Türkiye.*** *Data source GFCM official fishery at national level.*

Table 10.4. Total catches (in tonnes) reported by year and country (AL = Albania, DZ = Algeria, EG = Egypt, ES = Spain, FR = France, GR = Greece, IT = Italy, TN = Tunisia, TR = Türkiye) for all life stages.

Year	AL	DZ	EG	ES	FR*	GR	IT	TN	TR*
1951				90.00					
1952				102.20					
1953				80.20					
1954				97.70			17.62		2.59
1955				102.90			15.37		7.51
1956				106.12			17.95		14.80
1957				80.00			19.35		
1958				115.00			20.09		
1959				100.00			20.53		
1960				98.00			23.12		
1961				153.84			89.25		
1962				114.94			128.15		
1963				136.85			166.48		
1964				91.50			260.02		
1965				130.44			254.87		
1966				222.18			173.23		
1967				199.85			132.94		
1968				220.93			215.51		
1969				188.40			182.47		342.00
1970				201.26			163.71		441.00
1971				210.21			123.88		460.00
1972				172.01			231.04		220.00
1973				146.05			283.02		315.00
1974				143.09			212.57		588.00
1975				132.87			192.48		448.00
1976				129.20			204.55		499.00
1977				80.05			241.86		282.00
1978				67.03			316.32		283.00
1979				96.82			276.33		396.00
1980				89.80			260.08		224.00
1981				97.71			218.61		374.00
1982				19.87			191.30		424.00
1983				18.39			146.35		588.00
1984				10.97			187.27		616.00
1985				14.48			207.07		583.00
1986				12.11			154.50		517.00
1987				18.94			123.65		543.00
1988				12.69			115.81		756.00
1989				3.94			146.76		472.00
1990				8.30			186.63		230.00
1991				48.78			147.03		262.00
1992				53.01			121.08		245.00
1993				65.67			107.77		261.00
1994				49.62			72.60		329.00
1995				67.94			109.79	123.60	390.00
1996				60.47			39.65	108.40	342.00
1997				74.03			66.26	85.00	400.00
1998			2341.00	39.01			49.40	78.30	300.00
1999		20.39	709.00	43.22			60.72	172.00	200.00
2000		17.22	2064.00	38.70	3.48	0.93	45.23	27.62	176.00
2001		44.50	1979.00	78.71	2.49	6.48	53.97	43.99	122.00
2002		25.39	1802.00	65.29	7.59	4.22	49.38	122.46	147.00
2003		25.20	781.00	63.68	3.29	8.08	78.52	75.22	158.00

Year	AL	DZ	EG	ES	FR*	GR	IT	TN	TR*
2004		29.00	916.00	49.07	0.00	7.25	56.77	53.96	165.00
2005		7.59	924.00	55.80	0.00	73.06	61.31	89.24	176.00
2006		2.65	3983.00	51.40		61.28	78.52	151.38	162.00
2007		14.60	2019.00	53.37		70.58	70.68	162.31	179.00
2008		13.95	944.00	32.19		49.53	55.46	102.90	171.00
2009		14.20	1228.00	43.25		42.23	271.98	81.38	158.00
2010		6.80	337.00	43.33		58.62	210.43	64.43	182.00
2011			197.00	29.29		34.26	134.72	54.88	28.30
2012		0.80	1005.00	48.18	378.00	19.39	133.99	15.05	38.00
2013	46.98	3.00	641.00	40.16	431.50	29.71	126.28	94.77	48.20
2014	43.01	6.00	282.00	86.15	409.42	46.16	134.54	53.26	56.00
2015	49.99	3.00	578.00	34.84	422.68	56.50	134.04	63.74	71.00
2016	40.97	2.00	546.00	49.31	441.16	59.86	168.93	210.47	75.00
2017	47.02	10.60	503.00	50.22	368.68	46.10	164.33	115.11	81.00
2018	59.95	32.96	1180.00	38.31	501.13	1.88	123.51	163.82	111.00
2019	70.00	13.00		35.72	342.66	1.72	126.63	128.26	330.00
2020				50.17					232.75

* ***France.*** *Data from 2012 to 2019 are from marine fishery; data from 2000 to 2005 are from freshwater fishery. Recorded official data is very underestimated.*
* ***Türkiye.*** *Data source GFCM official fishery at national level.*

Before the 1980s, the average of total catches (mean 1951–1980) was around 400 tonnes per year, based on catches from Spain, Italy and Türkiye, but this dropped to around 160 tonnes per year in 2010 from the same countries. From 2000 onwards, during years for which data were available for all nine countries, catches decreased from an average of 1 996 tonnes for 2000–2010 to 1 372 tonnes for the period from 2011 to the present day. In Egypt, the average catch for the period 1998 to 2010 was 1 541 tonnes and this has decreased to approximately 617 tonnes in the years since then.

In 2019, total catches of yellow and silver eels (Y, S and YS) totalled 1 048 tonnes (excluding Egypt, as data were not available). Yellow and silver eel commercial fisheries averaged 1 531 tonnes over the five years, 2015–2019, of which 90 percent were attributable to five countries: Egypt (33 percent), followed by France (28 percent), Italy and Türkiye (10 percent, each) and Tunisia (9 percent).

Catches by life stage and fishing gear

About the 77 percent of total catches could not be separated by life stage (YS), but a proportion was reported separately as either silver or yellow eel (Figure 10.8).

The proportion of total catches reported as deriving from a “mix” of gears was 31 percent, mainly consisting of eel longlines combined with other gears (84 percent of the mixed gear catch). The other common gears used were fences (24 percent) and fyke nets (16 percent), while 24 percent of total catches were not associated with any fishing gear.

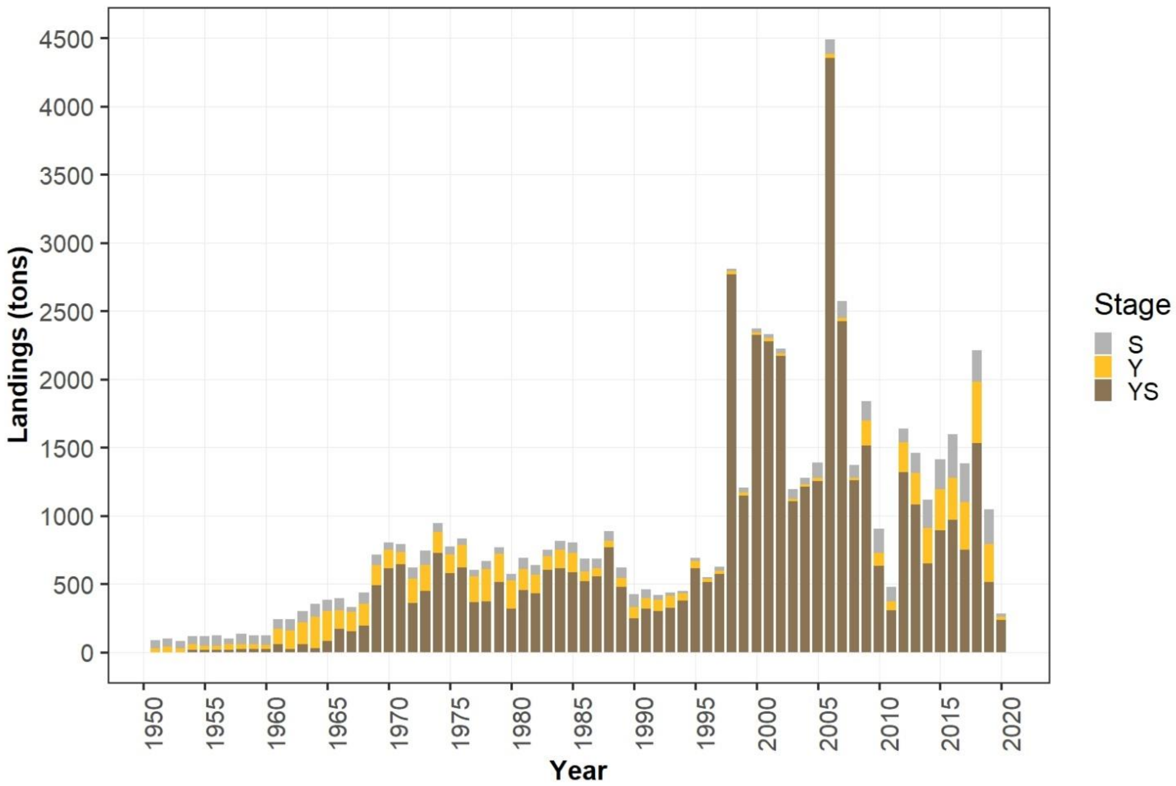

Figure 10.8. Total catches by year and life stage (Y = yellow eel, S = silver eel, YS = mixed yellow and silver eel)

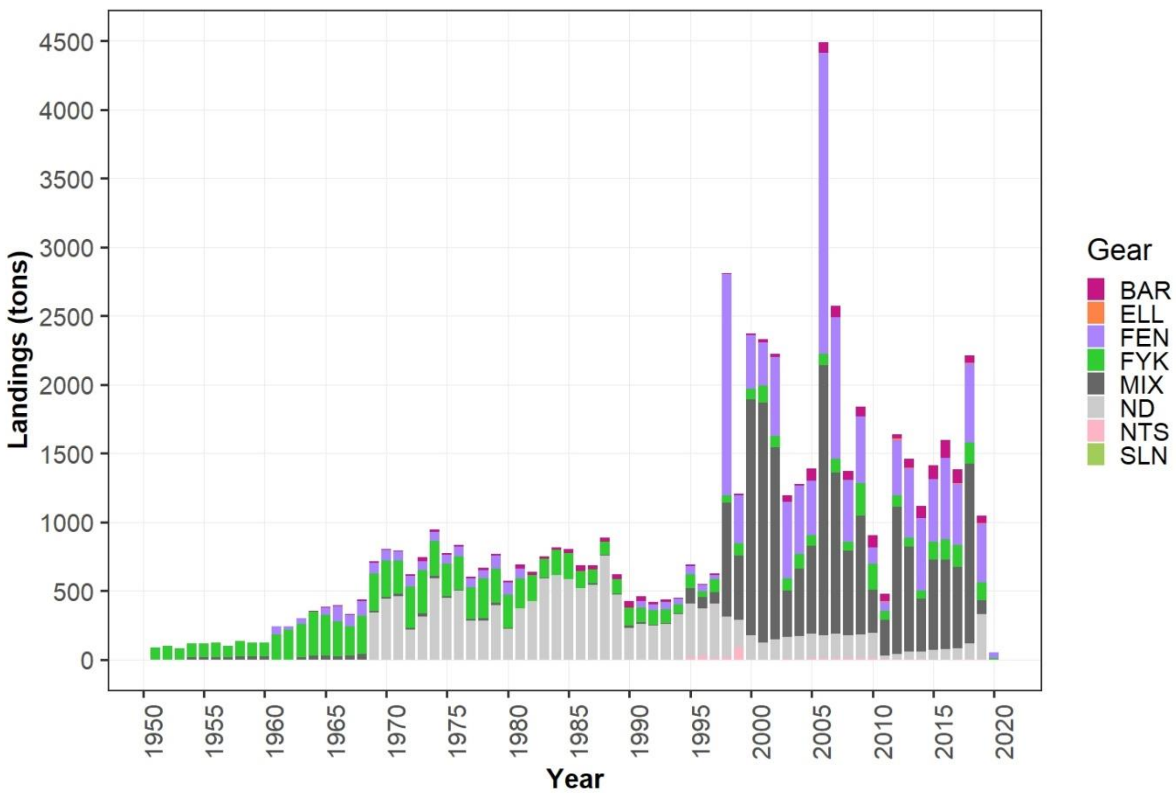

Figure 10.9. Total catches by year and fishing gear (BAR: fixed barriers; ELL: eel longlines; FEN: fences; FYK: fyke nets; MIX: mixed gears; ND: gear not known; NTS: nets; SLN: shore lift nets)

10.3.4 Analysis by Habitat

Adding up the total catches based on single habitat types, lagoons were the habitat where most catches occurred in seven out of nine countries. In Algeria and Türkiye, lakes were the predominant habitat for eel catches, while in Egypt a significant proportion of the catches also came from the Nile river, including the Nile delta (Figure 10.10).

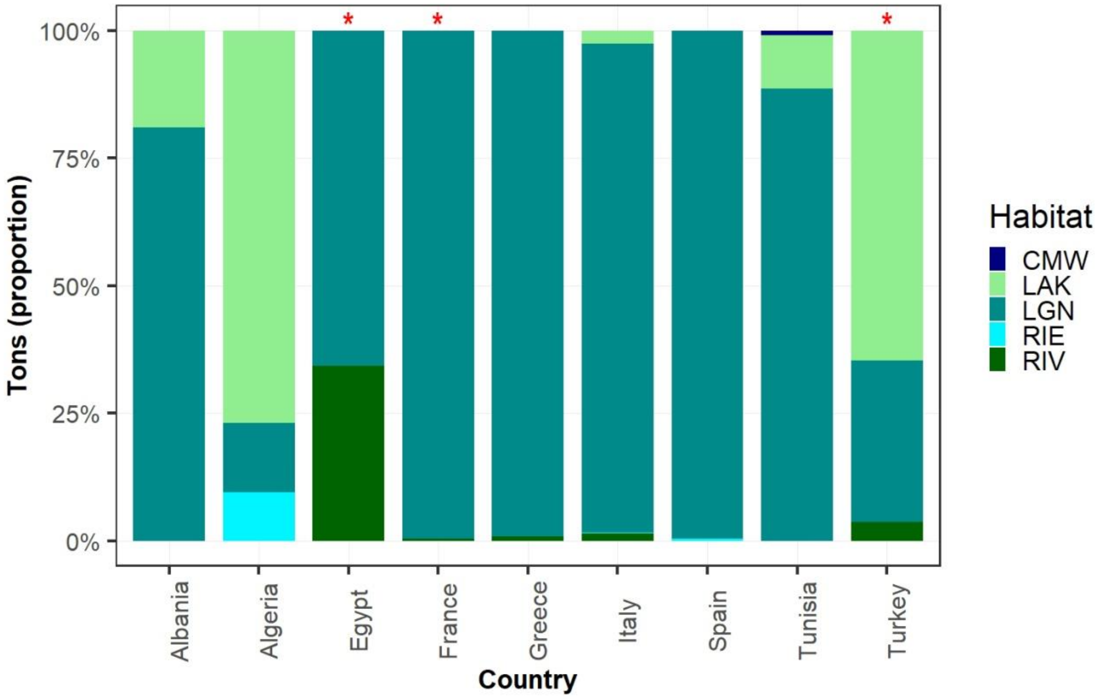

Figure 10.10. Proportion of total catch by habitat (CMW = coastal marine waters, LAK = lake, LGN = lagoon, RIE = estuary, RIV = river) in each country.

* ***Egypt.*** *Catches for the Nile river were provided aggregated both for the estuary area and the river segment.*
* ***France.*** *Lagoons include a site where catches are aggregated from the Vendres lagoon and the next estuary area.*
* ***Türkiye.*** *Data source literature and DCRF (only 2020).*

All countries have lagoon fisheries and provided historical time-series starting from the 1950s. The highest catches were reported for Egypt, Italy, Spain, Tunisia and France (Figure 10.11; Table 10AR2.1, Additional Results Part II). Almost all catches in rivers were from Egypt (Figure 10.11; Table 10AR2.2, Additional Results Part II). Fishing in lakes was practiced in five countries with the highest catches from Türkiye, followed by Tunisia, Italy and Algeria (Figure 10.11; Table 10AR2.3, Additional Results Part II). Only three countries reported fishing in estuaries. Data were from recent years with scarce and with low annual catch values (Figure 10.11; Table 10AR2.4, Additional Results Part II). Fishing in coastal marine waters was limited to Spain and Tunisia where the highest value of annual catches was reported by Tunisia, although these were concentrated in only two years (Figure 10.11; Table 10AR2.5, Additional Results Part II).

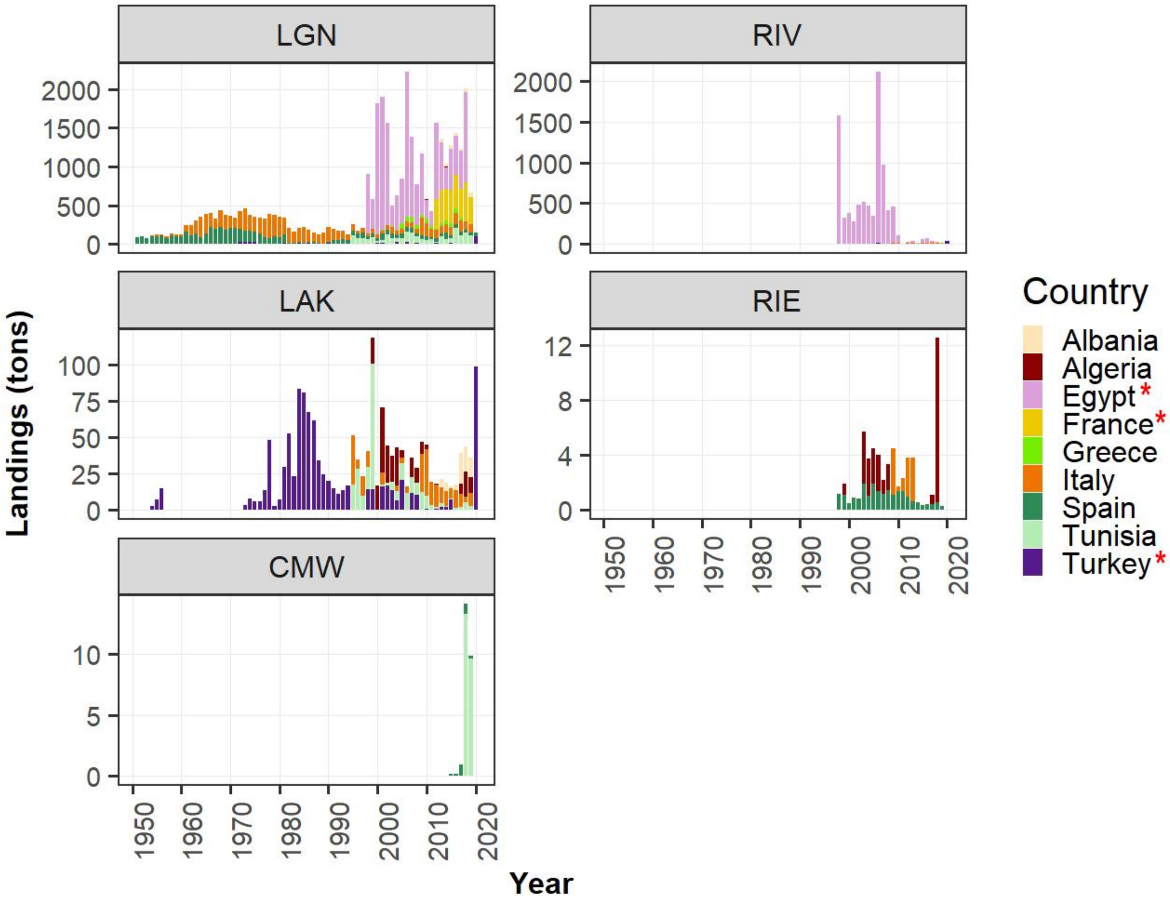

Figure 10.11. Total catches in the five habitats (CMW = coastal marine waters, LAK = lake, LGN = lagoon, RIE = estuary, RIV = river), by year and country. Note the different scales on the y-axes (tonnes) for each habitat

* ***Egypt.*** *Catches for the Nile river were provided aggregated both for the estuary area and the river segment.*
* ***France.*** *Lagoons include a site where catches are aggregated from the Vendres lagoon and the next estuary area.*
* ***Türkiye.*** *Data source literature and DCRF (only 2020).*

10.3.5 Analysis by country

Albania

Albanian data included nine sites; eight lagoons and one lake. For all sites, continuous data series from 2013 to 2019 were provided. Yellow eels were caught only in the Shkodra lake, with a mean value of 9.73 tonnes/year. Silver eel and mixed stages (YS) were mainly caught in lagoons (84 percent of the catch; 41.4 tonnes/year) (Figure 10.12a). Fishing gears were well identified and separated for each life stage (Figure 10.12b). Table 10.5 reports the quantitative catches in tonnes by year and by habitat.

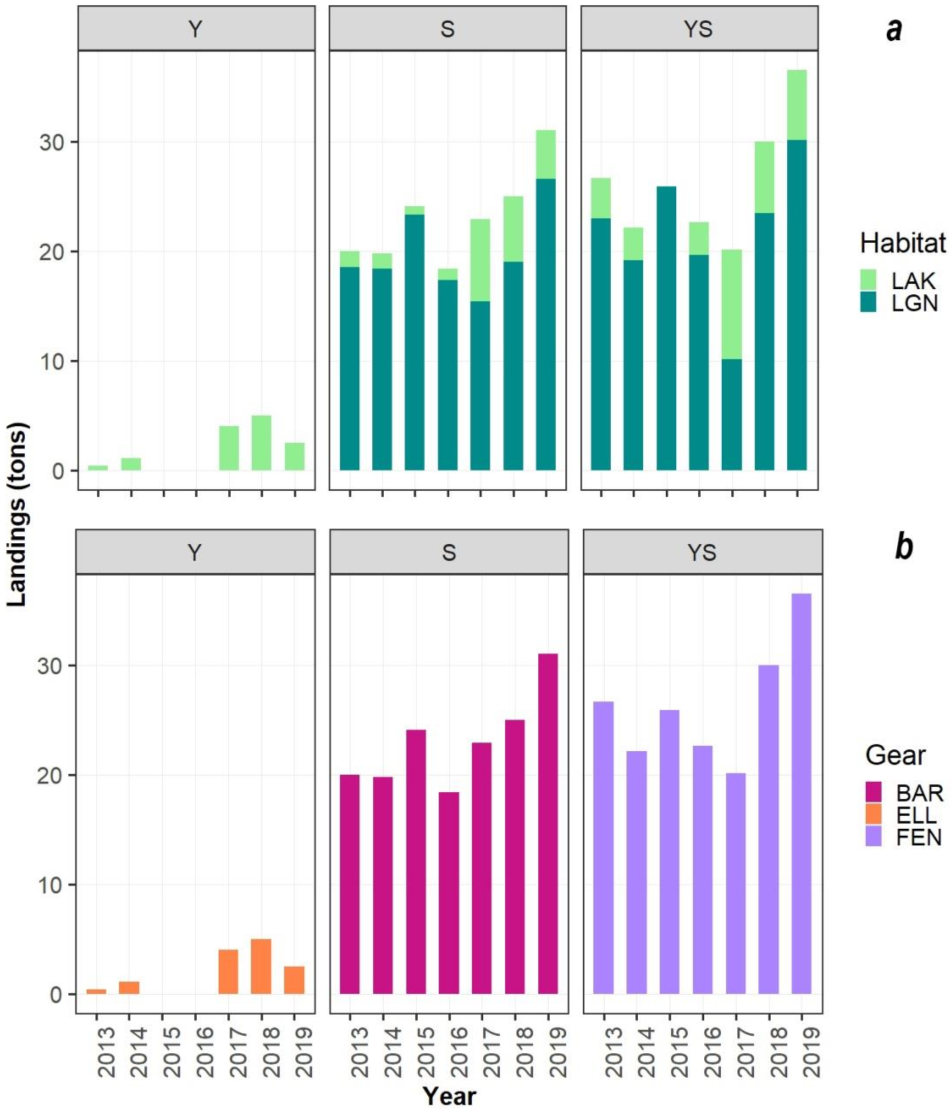

Figure 10.12. Total catches per year, separated by life stage (Y = yellow eel, S = silver eel, YS = mixed yellow and silver eel) and coloured by **a)** habitat type (LAK: lake; LGN: lagoon) and **b)** fishing gear (BAR: fixed barriers; ELL: eel longlines; FYK: fyke nets). Data source: official fishery statistics

Table 10.5. Albania: total catches (tonnes) reported by year and habitat (LAK = lake, LGN = lagoon)

Year	LAK	LGN
2013	5.50	41.48
2014	5.50	37.51

Year	LAK	LGN
2015	0.80	49.19
2016	4.00	36.97
2017	21.50	25.52
2018	17.50	42.45
2019	13.30	56.70
2020		

Algeria

The Algerian data included five sites: two lakes, two estuaries and one lagoon. For three sites, data series were provided from 1998 to 2019. In all habitats, the gear used was the fyke net. Catches were not separated by life stage and the largest proportion was in lakes (77 percent of the catches, 15 tonnes/year) (Figure 10.13). Catches are reported in tonnes by year and by habitat in Table 10.6.

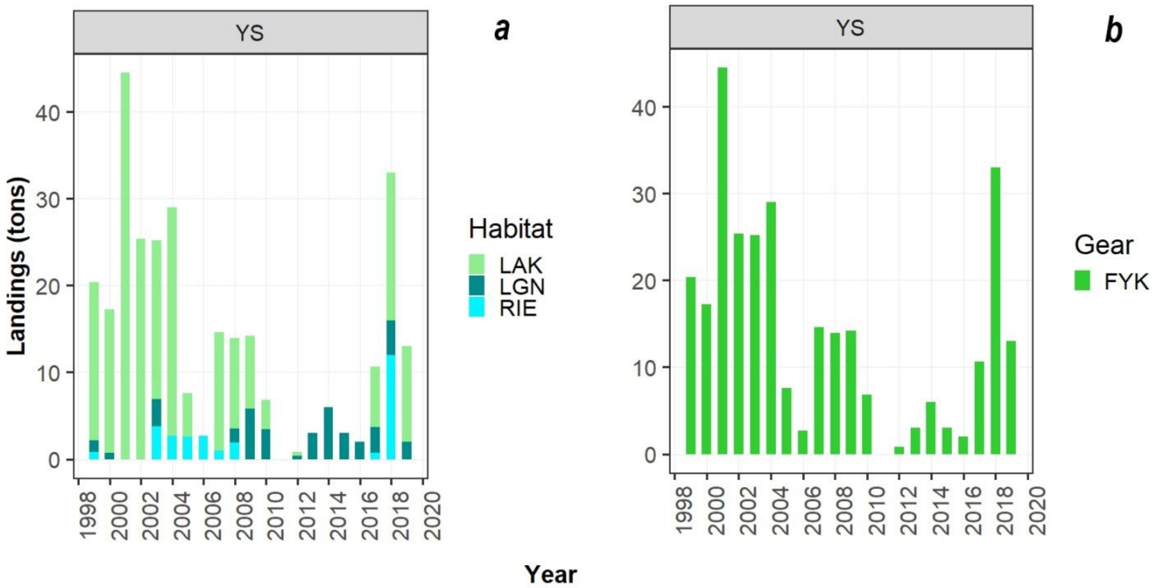

Figure 10.13. Total catches by year, coloured by **a)** habitat type (LAK: lake; LGN: lagoon; RIE: estuary) and **b)** fishing gear (FYK: fyke nets). Data source: official fishery statistics

Table 10.6. Algeria: total catches (tonnes) reported by year and habitat (LAK: lake; LGN: lagoon; RIE: estuary)

Year	LAK	LGN	RIE
1999	18.18	1.38	0.82
2000	16.52	0.70	
2001	44.50		
2002	25.39		
2003	18.33	3.10	3.77
2004	26.30		2.70
2005	5.00		2.59
2006			2.65
2007	13.60		1.00
2008	10.41	1.59	1.95
2009	8.40	5.80	
2010	3.40	3.40	
2012	0.40	0.40	
2013		3.00	

Year	LAK	LGN	RIE
2014		6.00	
2015		3.00	
2016		2.00	
2017	6.90	3.00	0.70
2018	17.00	4.00	11.96
2019	11.00	2.00	
2020			

Egypt

Egyptian data included five sites: four lagoons and one river. The catches on the Nile river referred to both the river and the Nile delta (Damietta and Rosetta branches). For all sites (except Mariout lagoon) 21-year data series, from 1998 to 2018, were provided. The catches were not separated by life stage. The Nile river catches made up 34 percent of total catches, with an average of 408 tonnes/year with only fences used. The four lagoons represented 66 percent of total catches (780.6 tonnes/year), where a mixture of eel longlines and other fishing gears were used (Figure 10.14). Catches in tonnes by year and habitat are reported in Table 10.7.

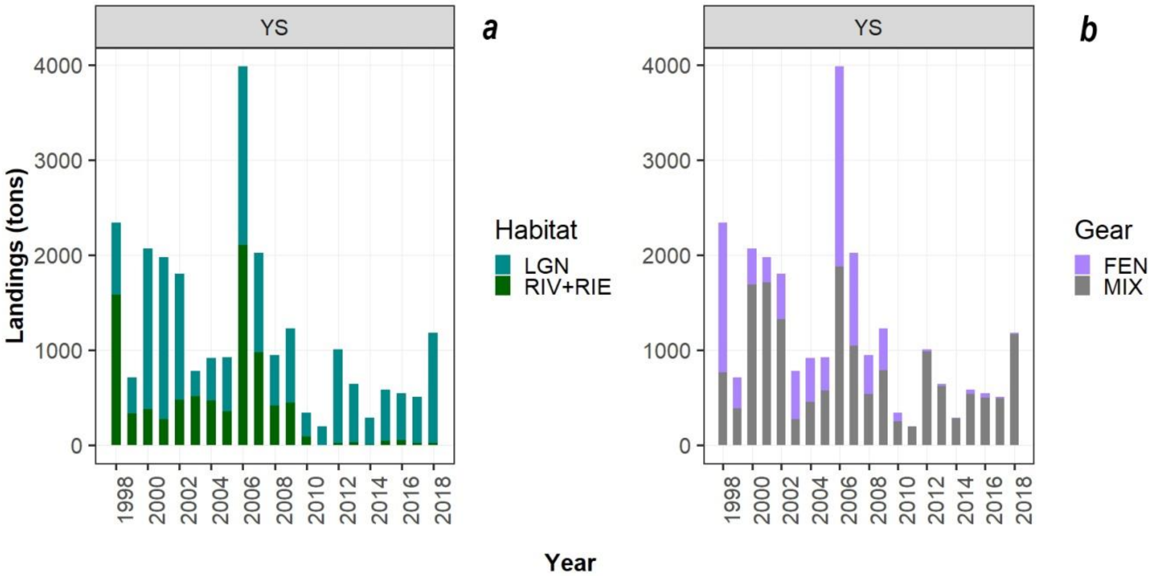

Figure 10.14. Egypt: total catches (tonnes) by year, coloured by **a)** habitat type (LGN: lagoon; RIV+RIE: river Nile + Delta area) and **b)** fishing gear (FYK: fyke nets; MIX: mixed gears). Data source: official fishery statistics

Table 10.7. Egypt: total catches (tonnes) reported by year and habitat (LGN = lagoon, RIV+RIE = combined river and estuary)

Year	LGN	RIV+RIE
1998	760.00	1581.00
1999	382.00	327.00
2000	1687.00	377.00
2001	1710.00	269.00
2002	1327.00	475.00
2003	267.00	514.00
2004	450.00	466.00

Year	LGN	RIV+RIE
2005	574.00	350.00
2006	1878.00	2105.00
2007	1043.00	976.00
2008	533.00	411.00
2009	786.00	442.00
2010	246.00	91.00
2011	197.00	0.00
2012	986.00	19.00
2013	617.00	24.00
2014	274.00	8.00
2015	532.00	46.00
2016	494.00	52.00
2017	487.00	16.00
2018	1162.00	18.00
2019		
2020		

France

French data included 18 sites: 12 complexes of lagoons, with 31 sites (from 2012 to 2019), and six river segments, all coming from the Rhône river basin (from 2000 to 2005). Some data from lagoons were considered aggregated into complexes as it was impossible to attribute catches to specific sites (for example, the Corsica lagoons), or because fishers operated in different lagoons connected to each other (for example, in the Petite Camargue complex). The catches from Vendres lagoon also referred to the adjacent estuary area. The average catch for lagoons was 412 tonnes/year, whereas for rivers it was 2.8 tonnes/year. However, catches for freshwater habitats (rivers) may have been significantly underestimated as, according to a scientific partner, the correct value should be around 10 tonnes/year.

To populate the WP3 Fishery database, it was necessary to aggregate gears and life stages, as the original data was either incomplete, often missing or mis-reported. For the quantitative analysis, it was possible to separate only a part of yellow eel catches in relation to gears, whereas silver eel catches were merged into the mixed stage (YS) (Figure 10.15a). The fishing gear category "mix" was used when the type of gear used was unknown, including capéchade, fyke nets or assemblages of fyke nets. Fences were the most common gears, representing 85 percent of catches and only in lagoons, followed by mixed gear (both in rivers and in lagoons). Eel longlines represented only 0.3 percent of the catches (only in lagoons) (Figure 10.15b).

Catches in tonnes by year and habitat are reported in Table 10.8.

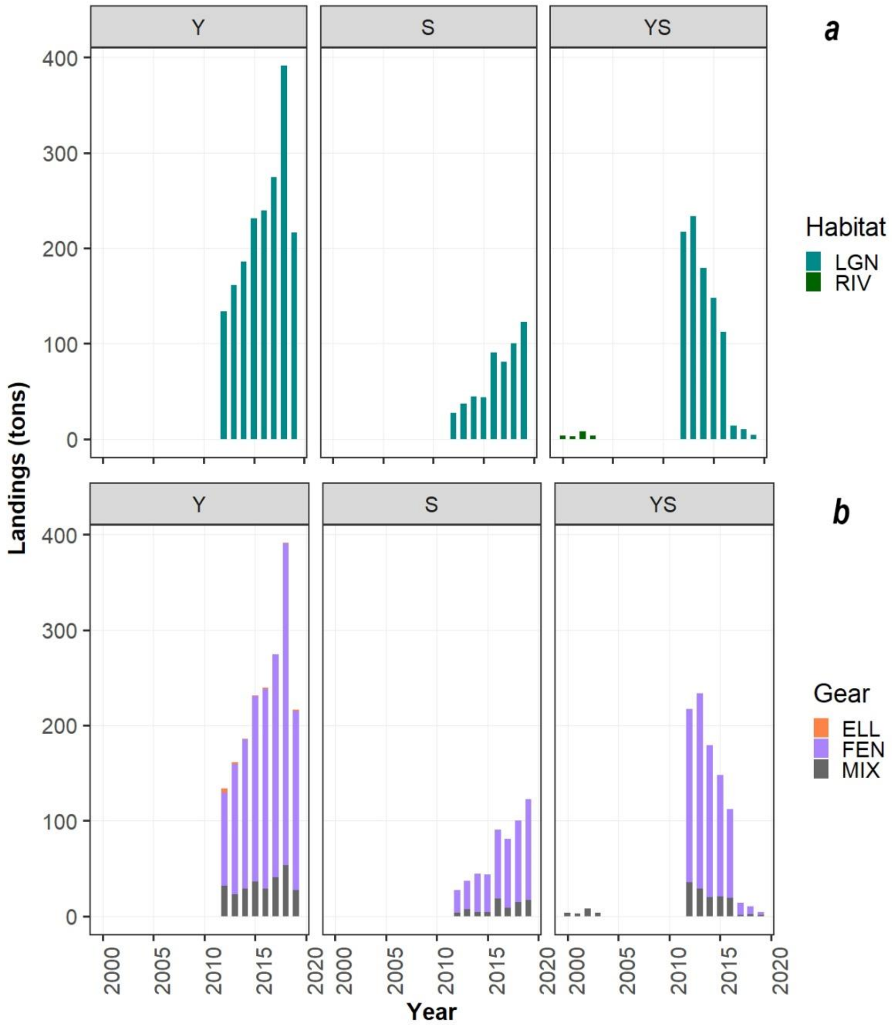

Figure 10.15. France: total catches (tonnes) by year, separated per life stage and coloured by **a)** habitat type (LGN: lagoon; RIV: river) and **b)** fishing gear (ELL: eel longlines; FEN: fences; MIX: mixed gears). Data source: official fishery statistics, log books

Table 10.8. France: total catches (tonnes) reported by year and habitat (LGN = lagoon, RIV = river)

Year	LGN	RIV*
2000		3.50
2001		2.49
2002		7.59
2003		3.29
2004		0.00
2005		0.00
2012	378.00	
2013	431.50	
2014	409.42	
2015	422.68	
2016	441.16	
2017	368.68	
2018	501.13	
2019	342.66	
2020		

* ***RIV.*** *Recorded official data may have been significantly underestimated.*

Greece

Greek data included 26 sites: 24 in lagoons, one river site and one lake site. For five sites, data series longer than ten years were provided. All the eels caught were silver eels. The lagoon fishery with fixed barriers represented 99 percent of the data, with an average value of 33.6 tonnes/year (Figure 10.16a). Fyke nets were used on the rivers (1.2 tonnes/year) (Figure 10.16b). Catches in tonnes by year and habitat are reported in Table 10.9.

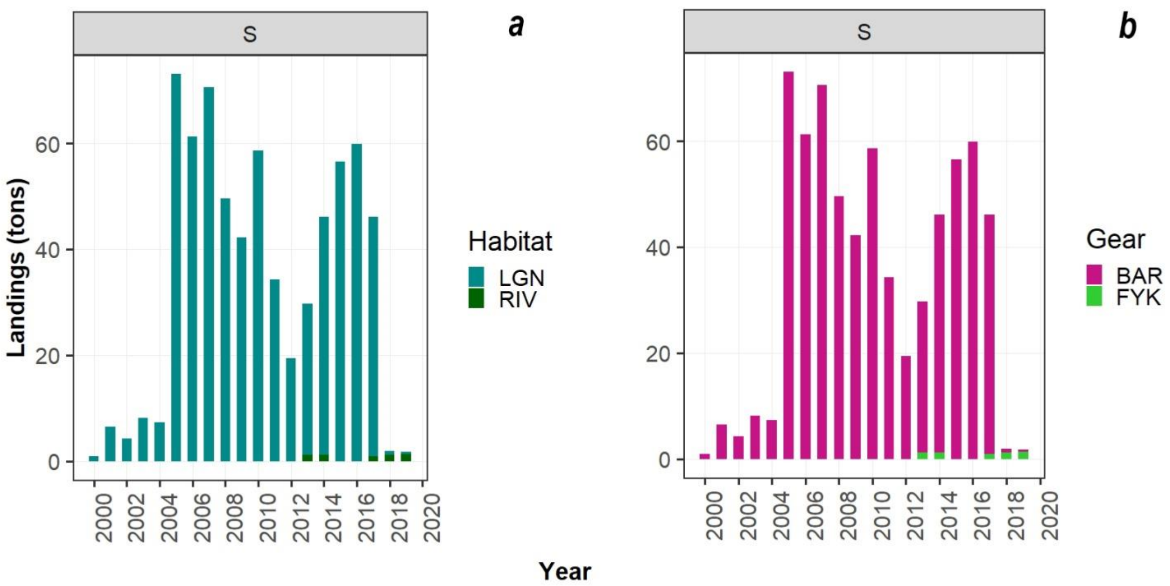

Figure 10.16. Greece: total catches by year, coloured by **a)** habitat type (LGN: lagoon; RIV: river) and **b)** fishing gear (BAR: fixed barriers; FYK: fyke nets). Data source: official fishery statistics

Table 10.9. Greece: total catches (tonnes) reported by year and habitat (LGN = lagoon, RIV = river)

Year	LGN	RIV
2000	0.93	
2001	6.48	
2002	4.22	
2003	8.08	
2004	7.25	
2005	73.06	
2006	61.28	
2007	70.58	
2008	49.53	
2009	42.23	
2010	58.62	
2011	34.26	
2012	19.39	
2013	28.51	1.20
2014	44.96	1.21
2015	56.50	
2016	59.86	
2017	45.21	0.89
2018	0.64	1.24
2019	0.39	1.32
2020		

Italy

The Italian data included 187 sites: 78 sites in rivers, 76 lagoon sites, 20 estuary sites and 13 sites in lakes. For most of the sites, catch data referred to time spans of less than ten years, but there were seven sites with longer time-series (from 11 to 59 years). Catches were separated by life stage. The habitat with highest catch rates was lagoons for all life stages (95.7 percent of total catches, average 130 tonnes/year), while 12.6 percent of the mixed stage eels (YS) were caught in lakes (Figure 10.17a).

There was a wide variety of fishing gears in use for both for life stages and in different habitats. The most frequently used gears were fyke nets (78 percent of catches) and fixed barriers (12 percent). Seven percent of total catches referred to mixed gears including fixed barriers with fyke nets, fences or nets, fences with eel long lines, and fyke nets with fences or eel longlines. Yellow eels were mainly caught with fyke nets, silver eels with fyke nets and fixed barriers, whereas the mixed stages were caught mainly with mixed gears (Figure 10.17b).

Fyke nets were the most commonly used gear in all habitats: 83 percent of catches in lakes, 82 percent in rivers, 78 percent in lagoons and 57 percent in estuaries. In lagoons, fixed barriers (12.4 percent) and mixed gears (7.2 percent) were also used. In rivers, 13.6 percent of the catches were by fences. Eel fisheries in estuaries also used fences (26 percent) and mixed gears (17 percent).

Catches in tonnes by year and habitat are reported in Table 10.10.

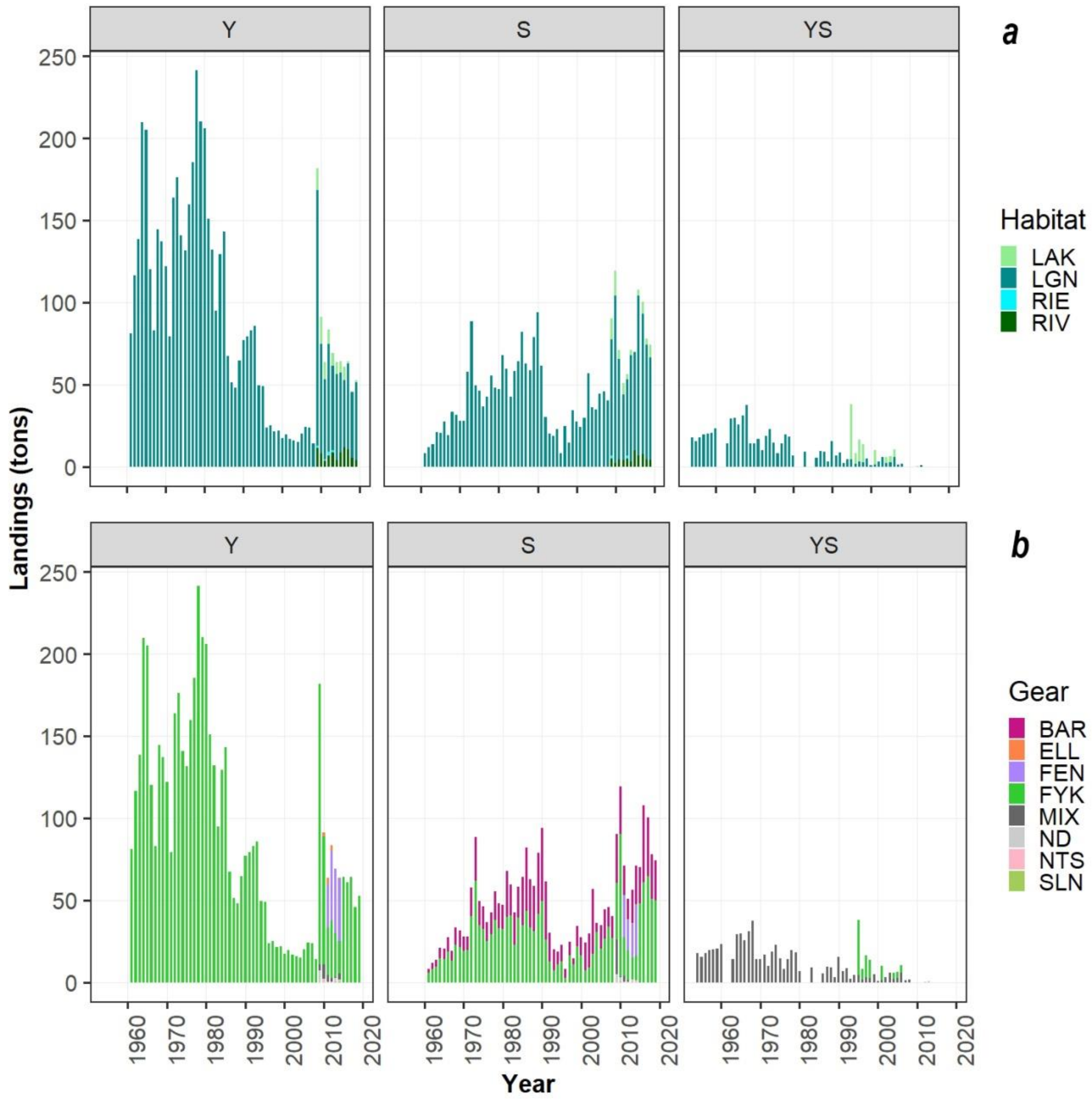

Figure 10.17. Italy: total catches (tonnes) per year, separated by life stage and coloured by **a)** habitat type (LAK: lake; LGN: lagoon; RIE: estuary; RIV: river) and **b)** fishing gear (BAR: fixed barriers; ELL: eel longlines; FEN: fences; FYK: fyke nets; MIX: mixed gears; ND: gear not known; NTS: nets; SLN: shore lift nets). Data source: official fishery statistics, fishery report.

Table 10.10. Italy: total catches (tonnes) reported by year and habitat (LAK = lake, LGN = lagoon, RIE = estuary, RIV = river)

Year	LAK	LGN	RIE	RIV
1954		17.62		
1955		15.37		
1956		17.95		
1957		19.35		
1958		20.09		
1959		20.53		
1960		23.12		
1961		89.25		
1962		128.15		
1963		166.48		
1964		260.02		

Year	LAK	LGN	RIE	RIV
1965		254.87		
1966		173.23		
1967		132.94		
1968		215.51		
1969		182.47		
1970		163.71		
1971		123.88		
1972		231.04		
1973		283.02		
1974		212.57		
1975		192.48		
1976		204.55		
1977		241.86		
1978		316.32		
1979		276.33		
1980		260.08		
1981		218.61		
1982		191.30		
1983		146.35		
1984		187.27		
1985		207.07		
1986		154.50		
1987		123.65		
1988		115.81		
1989		146.76		
1990		186.63		
1991		147.03		
1992		121.08		
1993		107.77		
1994		72.60		
1995	33.67	76.13		
1996	6.55	33.11		
1997	13.06	53.20		
1998	11.02	38.38		
1999		60.72		
2000		45.23		
2001	8.72	45.25		
2002		49.38		
2003		78.52		
2004	3.44	53.33		
2005	3.88	57.43		
2006	4.57	73.95		
2007		70.68		
2008		55.46		
2009	26.19	226.17	3.42	16.21
2010	31.84	168.17	0.31	10.10
2011	16.11	109.68	0.97	7.96
2012	15.28	105.56	2.79	10.35
2013	11.29	97.71	3.16	14.11
2014	10.31	117.36		6.88
2015	7.06	108.67		18.31
2016	12.21	137.97		18.76
2017	8.65	137.73		17.95
2018	4.26	109.78		9.47
2019	8.97	109.53		8.12
2020				

Spain

Spanish data included nine sites: seven lagoons, one estuary and one coastal site. Reports for most of the sites, included catch data from a long time-span (ten years to 65 years) and catches were separated by life stage. Lagoons represented 99.6 percent of catches, with an average of 80.5 tonnes/year (Figure 10.18a). Fyke nets (58 percent of total catches) and fences (42 percent) were used in all habitats and for all life stages, although fences were the most frequently used gear for mixed stages (YS, 68 percent) (Figure 10.18b). In coastal marine waters and estuaries only fences were used, whereas in lagoons both fences and fyke nets were used.

Table 10.11 reports the quantitative catches in tonnes, by year and habitat.

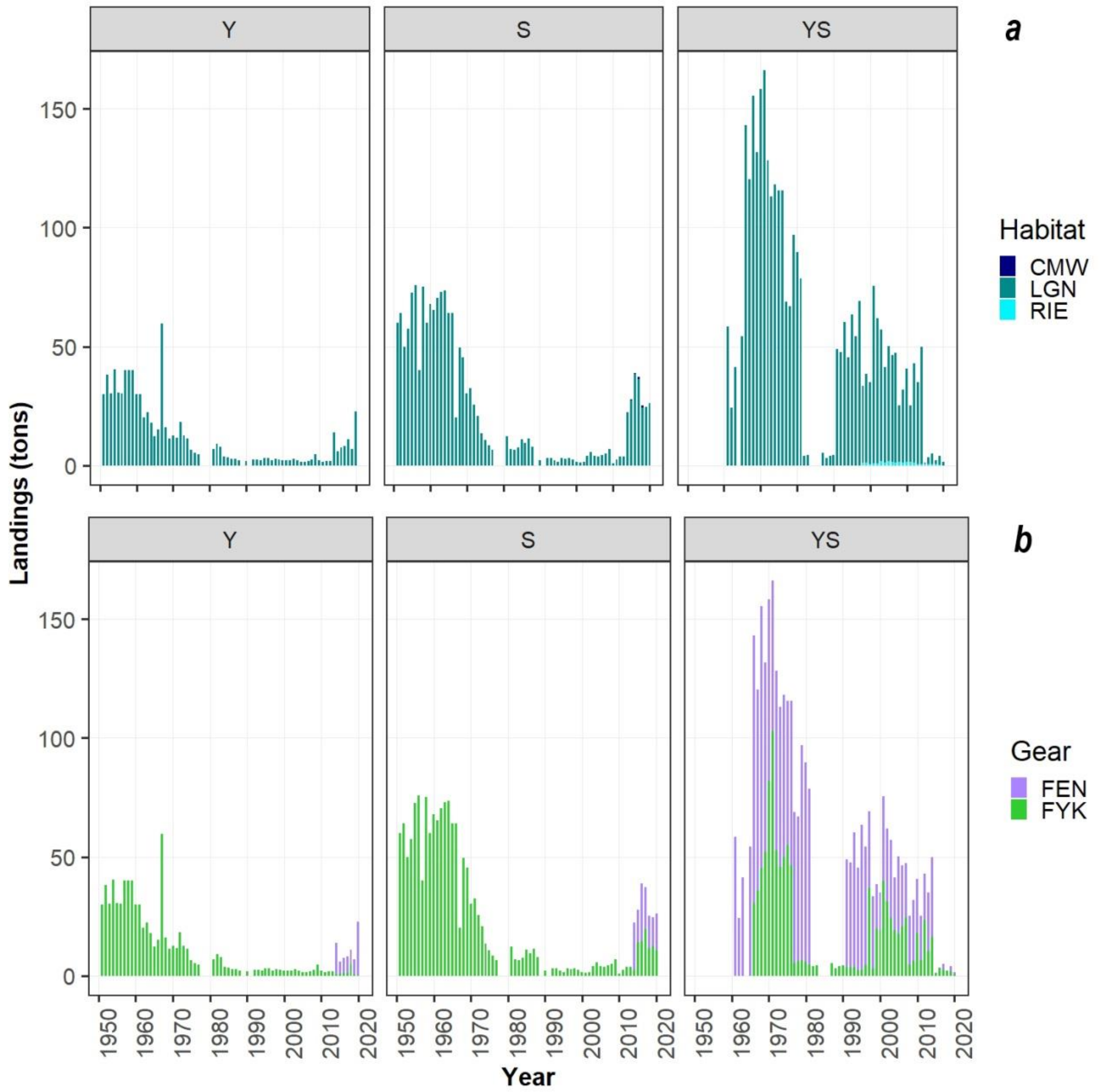

Figure 10.18. Spain: total catches (tonnes) by year and by life stage (Y = yellow eel, S = silver eel, YS = mixed yellow and silver eel) and coloured by **a)** habitat type (CMW: coastal marine waters; LGN: lagoon; RIE: estuary) and **b)** fishing gear (FEN: fences; FYK: fyke nets). Data source: official fishery statistics

Table 10.11. Spain: total catches (tonnes) reported by year and habitat (CMW = coastal marine waters, LGN = lagoon, RIE = estuary)

Year	CMW	LGN	RIE
1951		90.00	
1952		102.20	
1953		80.20	
1954		97.70	
1955		102.90	
1956		106.12	
1957		80.00	
1958		115.00	
1959		100.00	
1960		98.00	
1961		153.84	
1962		114.94	
1963		136.85	
1964		91.50	
1965		130.44	
1966		222.18	
1967		199.85	
1968		220.93	
1969		188.40	
1970		201.26	
1971		210.21	
1972		172.01	
1973		146.05	
1974		143.09	
1975		132.87	
1976		129.20	
1977		80.05	
1978		67.03	
1979		96.82	
1980		89.80	
1981		97.71	
1982		19.87	
1983		18.39	
1984		10.97	
1985		14.48	
1986		12.11	
1987		18.94	
1988		12.69	
1989		3.94	
1990		8.30	
1991		48.78	
1992		53.01	
1993		65.67	
1994		49.62	
1995		67.94	
1996		60.47	
1997		74.03	
1998		37.81	1.20
1999		42.15	1.07
2000		38.20	0.50
2001		77.84	0.87
2002		64.48	0.82
2003		61.77	1.91
2004		48.03	1.04
2005		53.88	1.92
2006		50.03	1.37

Year	CMW	LGN	RIE
2007		52.21	1.17
2008		30.78	1.41
2009		42.17	1.08
2010		41.96	1.38
2011		27.92	1.37
2012		47.19	1.00
2013		39.54	0.62
2014		85.59	0.57
2015	0.21	34.26	0.37
2016	0.18	48.67	0.46
2017	0.93	48.86	0.43
2018	0.89	36.83	0.59
2019	0.21	35.23	0.28
2020	0.01	50.16	

Tunisia

Tunisia reported data from 77 sites: 46 marine sites, 26 lakes and five lagoons. Most of the catch data was from short time spans (less than ten years), but eight sites had long time-series (from 11 to 20 years). Catches were not separated by life stage. The highest catches were from lagoons (88.5 percent of total catches, average 86.5 tonnes/year), followed by lakes (10.5 percent, 11.7 tonnes/year), even if some of them were artificial dams. Coastal marine waters represented less than one percent of total catches (Figure 10.19a). The most frequently used gear type reported was a mixture of gears (66.8 percent of total catches, Figure 10.19b), which included fixed barriers with fyke nets, fences, nets or eel longlines, fyke nets with eel longlines and nets with eel longlines. Mixed gears were mostly used in coastal marine waters and lagoons while fences were also used in lagoons and nets were used only in lakes.

Catches in tonnes by year and habitat are reported in Table 10.12.

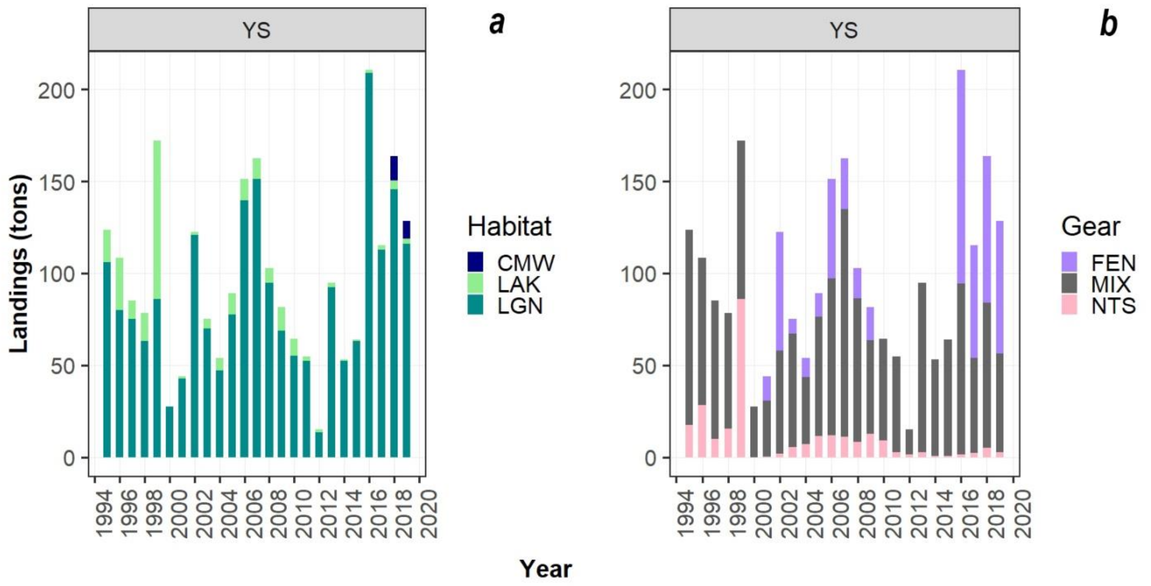

Figure 10.19. Tunisia: total catches (tonnes) by year, coloured by **a)** habitat type (CMW: coastal marine waters; LAK: lake; LGN: lagoon) and **b)** fishing gear (FEN: fences; MIX: mixed gears; NTS: nets). Data source: official fishery statistics

Table 10.12. Tunisia: total catches (tonnes) reported by year and habitat (CMW: coastal marine waters; LAK: lake; LGN: lagoon)

Year	CMW	LAK	LGN
1995		17.60	106.00
1996		28.40	80.00
1997		10.00	75.00
1998		15.30	63.00
1999		86.00	86.00
2000			27.62
2001		1.20	42.79
2002		1.80	120.66
2003		5.30	69.92
2004		6.90	47.06
2005		11.50	77.74
2006		11.70	139.68
2007		11.20	151.11
2008		8.10	94.80
2009		12.50	68.88
2010		9.20	55.23
2011		2.70	52.18
2012		1.44	13.61
2013		2.46	92.31
2014		0.82	52.44
2015		0.68	63.06
2016		1.43	209.04
2017		2.36	112.75
2018	13.24	5.12	145.46
2019	9.61	2.81	115.83
2020			

Türkiye

Official fishery data were provided at national level, without indications of habitat or fishing effort. For the specific analysis on habitats and fishing gears, literature data were used instead of the official data, even if data from scientific papers did not cover everything reported at national level (Figure 10.20).

Turkish data included 30 sites: 18 in lagoons, eight lakes and four rivers. For most sites, catch data covered a short time span (less than ten years), but long time-series were provided for seven sites (from 11 to 33 years). Different fishing gears were used in different habitats, but the catches were not separated by life stage (all reported as YS). The highest catches were in lakes (64.7 percent of total catches, average 21.5 tonnes/year), followed by lagoons (31.6 percent, 14 tonnes/year) (Figure 10.21a). The most frequently used gears were fyke nets, used in all habitats (66 percent of total catches), and fixed barriers (33.4 percent), used mainly in lakes (Figure 10.21b). A small percentage of lagoon catches referred to a mixture of gears, including fixed barriers and fyke nets; fyke nets and eel longlines.

Catches in tonnes separated by habitat and data source are reported in Table 10.13.

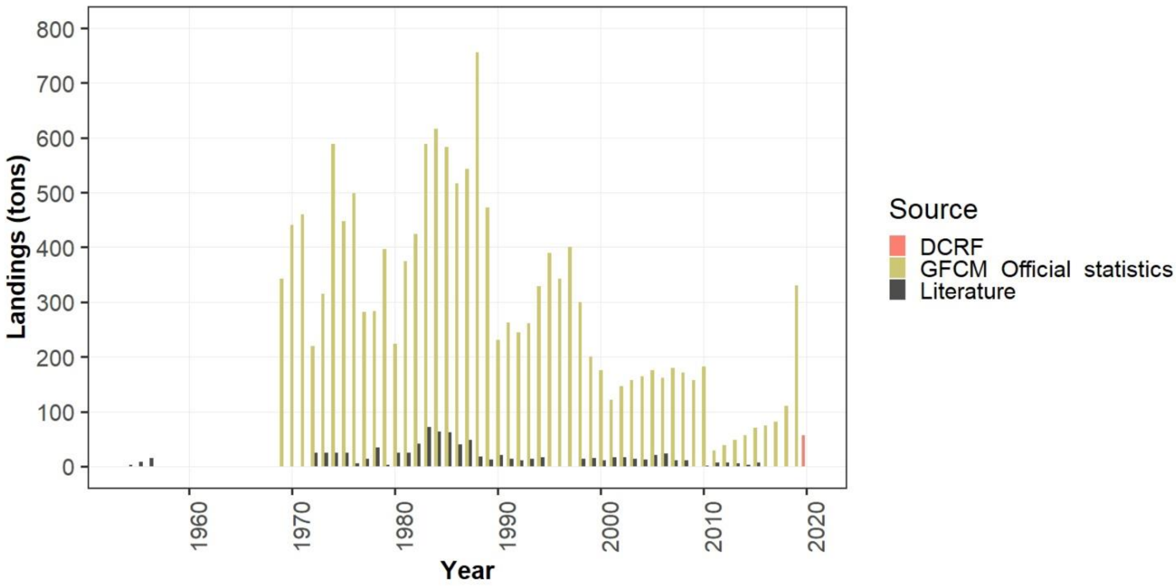

Figure 10.20. Türkiye: total catches (tonnes) by year reported with respect to the data source: DCRF, GFCM official fishery statistics and literature

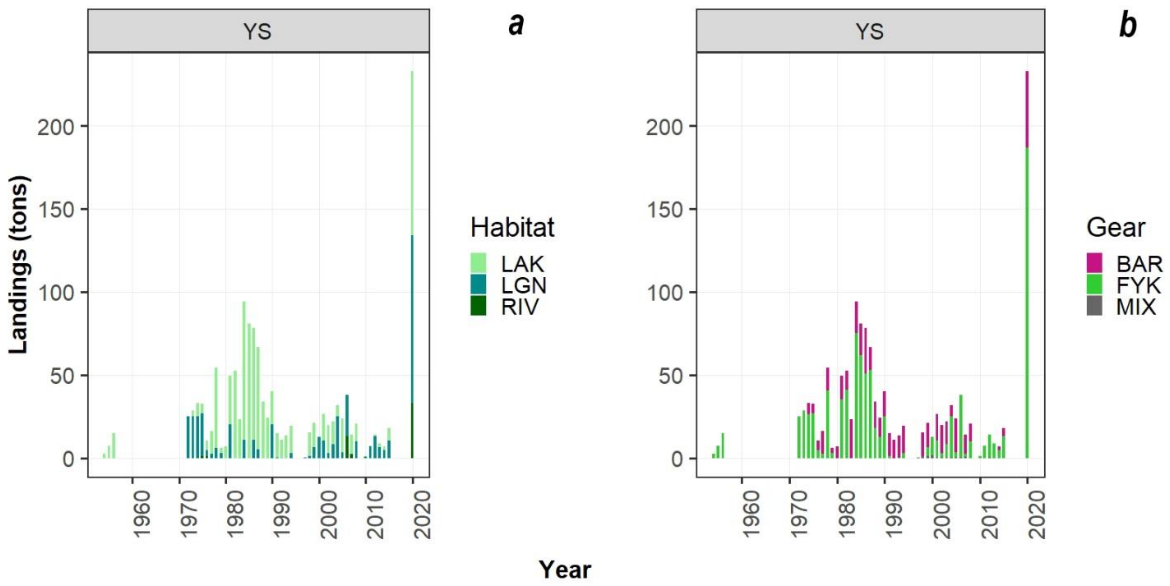

Figure 10.21. Türkiye: total catches (tonnes) by year, coloured by **a)** habitat type (LAK: lake; LGN: lagoon; RIV: river) and **b)** fishing gear (BAR: fixed barriers; FYK: fyke nets; MIX: mixed gears). Data source: literature and GFCM official fishery statistics

Table 10.13. Türkiye: total catches (tonnes) reported by source, year and habitat (LAK: lake; LGN: lagoon; RIV: river)

	Literature			Official fishery statistics			
Year	**LAK**	**LGN**	**RIV**	**All habitats**	**LAK**	**LGN**	**RIV**
1954	2.59						
1955	7.51						
1956	14.80						
1969				342.00			
1970				441.00			

1971				460.00			
1972		25.00		220.00			
1973	3.50	25.00		315.00			
1974	8.10	25.00		588.00			
1975	5.79	25.95	0.99	448.00			
1976	6.01	3.46	1.10	499.00			
1977	13.87	2.40		282.00			
1978	48.32	6.00		283.00			
1979	3.05	3.00		396.00			
1980	6.93	25.00		224.00			
1981	29.52	45.00		374.00			
1982	52.61	25.00		424.00			
1983	135.11	25.00		588.00			
1984	83.00	36.00		616.00			
1985	80.86	25.00		583.00			
1986	67.55	35.70		517.00			
1987	61.57	30.00		543.00			
1988	33.82			756.00			
1989	24.35			472.00			
1990	20.24	20.00		230.00			
1991	14.84	0.05		262.00			
1992	10.80			245.00			
1993	13.47	0.01		261.00			
1994	16.52	2.90		329.00			
1995				390.00			
1996				342.00			
1997		0.33		400.00			
1998	14.38	0.98		300.00			
1999	14.47	6.63		200.00			
2000	0.03	12.63		176.00			
2001	16.10	10.49		122.00			
2002	16.94	2.75		147.00			
2003	13.89	8.21		158.00			
2004	6.30	25.62		165.00			
2005	20.56	3.29		176.00			
2006		24.48	13.25	162.00			
2007	11.44	0.75	1.90	179.00			
2008	10.70	10.00		171.00			
2009	0.03			158.00			
2010	0.61	0.57		182.00			
2011	0.52	7.05		28.30			
2012	1.04	12.95		38.00			
2013	2.01	6.53		48.20			
2014	2.01	4.89		56.00			
2015	7.37	10.46		71.00			
2016				75.00			
2017				81.00			
2018				111.00			
2019				330.00			
2020					98.50*	101.25*	33.00*

* DCRF data at site level

10.3.6 Eel productivity

This section presents the eel catch time-series expressed as production per hectare. Results are shown by each country and habitat type. Because the time-series for eel landings covered varying time intervals, the period, 2009–2019 was selected as it provided the most significant number of overlapping time series for countries and guaranteed the most complete representation of sites according to habitat types, length of time-series and spatial coverage.

Based on these criteria, 64 time-series from nine countries were retained for an in-depth description of the eel yields by sites and habitat type (Table 10AR3.1, Additional Results Part III).

Eeel production trends

Figures 10.22a, 10.22b and 10.22c and Table 10.14 show the trends in eel production. The analysis did not consider fishing effort over the years, so the productivity data should be regarded as the minimum level of eel production.

Table 10.14 reports eel production averaged over four timeframes: *pre-1950*, *pre-1980*, *pre* and *post 2009*, that is, before and after the implementation of the EU eel regulation, and as an average value of the entire length of each time series.

In lagoons, production values were highly variable between and within countries (Figure 10.22a). In Albania, the mean productivity fluctuated between the years, especially in the lagoons of Patoku, Vain and Viluni, with values ranging from two kg/ha to 17 kg/ha. Manzala lagoon (Egypt) had a sharp decline from a mean value of around 25 kg/ha in 2001 to an average of 1.3 kg/ha in the following years. Burullus lagoon (Egypt) showed increasing productivity from 2006 to the present day, with mean productivity of around 20 kg/ha.

Most French lagoons had mean productivities between 4.2 kg/ha and 20 kg/ha. The Gruissan Complex, Bages-Sigean and Or had the highest productivity levels. All the time-series showed a decrease in recent years. Vistonida lagoon (Greece) showed a stable mean productivity over the years, around one kg/ha. In Italy, the two lagoons with a long time-series of historical data, Comacchio and Orbetello, had high peaks of productivity in the period before the 1980s and 1990s, and a decreasing trend in productivity over the years. The highest mean value for Comacchio was recorded in 1968 (32 kg/ha), while in 1978, the peak in Orbetello reached an average value greater than 100 kg/ha. The lagoon of Gravile (Italy) also showed high and fluctuating production values, with a maximum in 2015 of 88 kg/ha. Almost all other lagoons showed decreasing productivity levels and lower values.

In Spain, between 1950 and 1970, Albufera de Valencia had its highest productivity (from 23 kg/ha to 46 kg/ha). From 1980 onwards, all Spanish lagoons had mean productivity values between three kg/ha (Albufera) and 0.15 kg/ha (Laguna del Hondo). The productivity of Tunisian lagoons was characterised by high fluctuations, especially in Ghar El Melh where the highest value was 24 kg/ha in 2013 and in Tunis north lake, peak productivity was 46.5 kg/ha in 2016 while the productivity of other Tunisian sites ranged between 0.01 kg/ha and two kg/ha. Meanwhile, the two Turkish lagoons had very scattered and often unreliable data.

Figure 10.22b shows the yearly productivity of lakes in each country. Shkodra Lake (Albania) had the lowest mean productivity (no higher than 0.6 kg/ha). In Algeria, Tonga had a decreasing productivity trend from a maximum value of 13.8 kg/ha in 2001 to 1.5 kg/ha in 2018. The productivity of lake Oubeira remained more or less constant over the years, around an average value of five kg/ha. In Italy, the series followed a decreasing trend: Lake Bolsena had the highest values in 1995 (29 kg/ha), decreasing to an average of 1.5 kg/ha in the last ten years for all the lakes. Tunisia was represented only by one lake, Sidi El Barrak, with a mean productivity value of 0.60 kg/ha. Bafa Lake (Türkiye) had a productivity peak in the 1980s while Köyceğiz has had a stable value, around 2.2 kg/ha.

Figure 10.22c shows the annual productivity of rivers in each country. For the Nile river, it was not possible to separate the catches between the delta and the river, so it was considered separately as “RIE+RIV” category (estuary and river). Here productivity ranged between 26.42 kg/ha in 1998 and 0.30 kg/ha in 2018, with a peak eel yield of 35.17 kg/ha in 2006. Among the Italian rivers, the Flumendosa river had the highest production value per hectare, at around 15 kg/ha, which has decreased in recent years while other rivers showed stable productivity. Two peaks above 20 kg/ha were observed in the last decade, belonging to eel fisheries in Flumendosa and Coghinas. The Po delta showed fluctuating mean productivity values between 13.2 kg/ha in 2013 and 0.5 kg/ha in 2019. In Spain, the Ebro delta had the highest productivity between the 1960s and the 1970s, with a clearly decreasing trend in recent years (average 7.6 kg/ha) while the productivity of the Marajal de Pego Oliva river has remained stable over the years, between 1 kg/ha and 3.5 kg/ha.

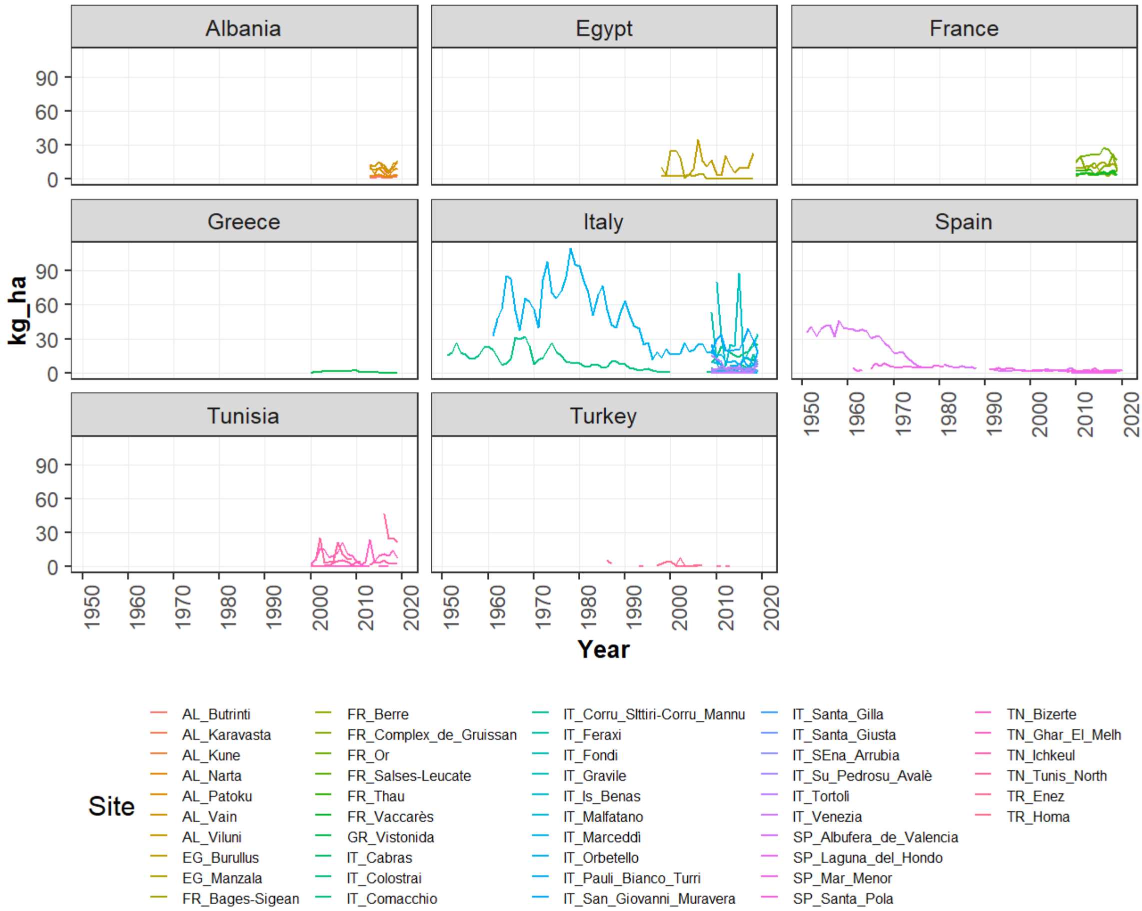

Figure 10.22a. Trends in eel productivity (kg/ha/year) in lagoons by country at site level

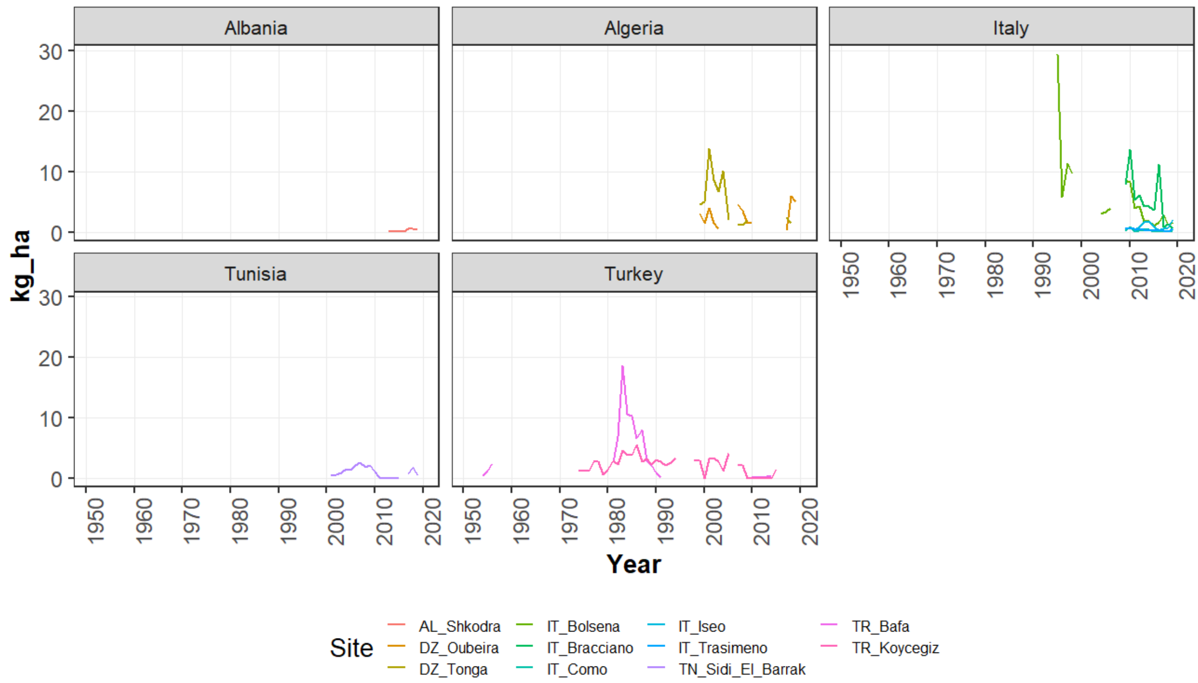

Figure 10.22b. Trends in eel productivity (kg/ha/year) in lakes by country at site level

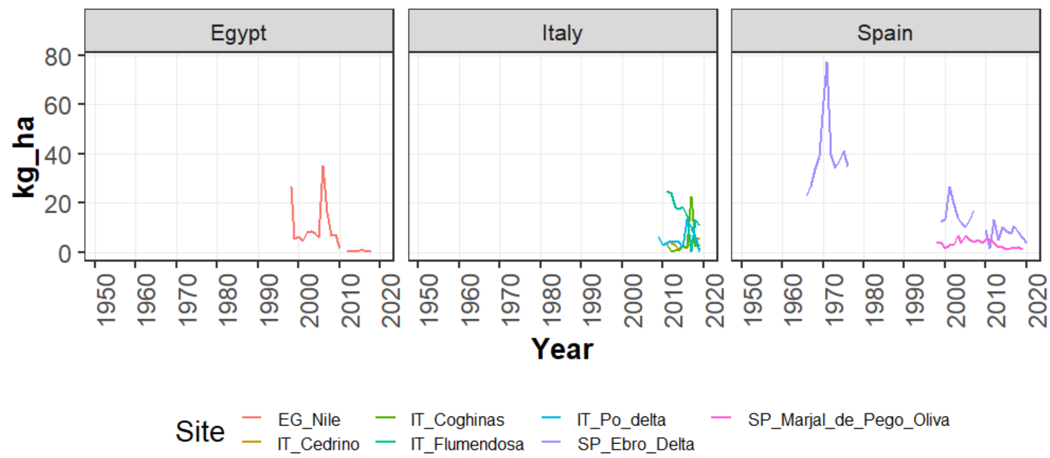

Figure 10.22c. Trends in eel productivity (kg/ha/year) in rivers and estuaries by country at site level

Variability in eel production across habitats

Of the 64 time-series selected, the values of the post-2009 timeframe were used to compare sites and discriminate eel productivity ranges against each main habitat typology.

Figure 10.23 and Table 10.14 show the variability, range (minimum and maximum values) and average values of eel yields at all sites in the last ten years. Eel production levels per site did not show clear distribution patterns according to latitude, country or habitat type.

The most productive lagoons for European eel were in France (Or), Italy (Gravile, San Giovanni and Colostrai lagoons) and Tunisia (Tunis lake), ranging from 10 kg/ha/year to 30 kg/ha/year with average values around 20 kg/ha/year. Comparable levels of production were found in the river estuary of

Flumendosa. Average values of around 10 kg/ha/year were seen in lagoons in Albania (Vain, Kune and Villuni), France (Gruissan and Bages-Sigean), Egypt (Burullus), Tunisia (Ghar El Melh) and Italy (Orbetello) and Spanish estuaries (Ebro).

Italian lakes and estuaries (Bolsena and Coghinas lakes, Flumendosa river) showed comparable levels to some lagoons in France and Italy with median values of 5 kg/ha/year. Almost 50 percent of the sites across countries were under the average value of 5 kg/ha/year in lakes, estuaries and many other lagoons with reduced productivity.

Table 10.14. Range and average values for eel production (kg per hectare per year) in Mediterranean eel fishery sites across four time periods; pre-1950, pre-1980, pre-2009 and post 2009.

				Eel production (kg ha^{-1} averaged values of time framework)														
				Pre '50			Pre '80			Pre 2009			Post 2009			All series		
Country	**Habitat**	**Site**	**Code**	**min**	**max**	**mean**	**min**	**max**	**mean**	**min**	**max**	**mean**	**min**	**max**	**mean**	**min**	**max**	**mean**
Albania	LGN	Butrinti	AL_Butr	ND	ND	ND	ND	ND	ND	0.00	0.00	ND	0.96	2.44	1.62	0.96	2.44	1.62
Albania	LGN	Karavasta	AL_Kara	ND	ND	ND	ND	ND	ND	0.00	0.00	ND	2.00	4.15	3.03	2.00	4.15	3.03
Albania	LGN	Kune	AL_Kune	ND	ND	ND	ND	ND	ND	0.00	0.00	ND	4.72	15.20	10.85	4.72	15.20	10.85
Albania	LGN	Narta	AL_Nart	ND	ND	ND	ND	ND	ND	0.00	0.00	ND	2.14	4.27	3.11	2.14	4.27	3.11
Albania	LGN	Patoku	AL_Pato	ND	ND	ND	ND	ND	ND	0.00	0.00	ND	2.31	10.88	7.31	2.31	10.88	7.31
Albania	LAK	Shkodra	AL_Shko	ND	ND	ND	ND	ND	ND	0.00	0.00	ND	0.02	0.58	0.26	0.02	0.58	0.26
Albania	LGN	Vain	AL_Vain	ND	ND	ND	ND	ND	ND	0.00	0.00	ND	6.12	13.65	9.98	6.12	13.65	9.98
Albania	LGN	Viluni	AL_Vilu	ND	ND	ND	ND	ND	ND	0.00	0.00	ND	7.67	16.67	12.20	7.67	16.67	12.20
Algeria	LAK	Oubeira	DZ_Oube	ND	ND	ND	ND	ND	ND	0.49	4.59	2.47	0.18	5.91	2.57	0.18	5.91	2.51
Algeria	LAK	Tonga	DZ_Tong	ND	ND	ND	ND	ND	ND	1.12	13.85	5.50	1.54	2.46	2.00	1.12	13.85	4.92
Egypt	LGN	Burullus	EG_Buru	ND	ND	ND	ND	ND	ND	2.29	34.68	8.94	3.61	23.27	11.03	2.29	34.68	9.84
Egypt	LGN	Manzala	EG_Manz	ND	ND	ND	ND	ND	ND	0.19	25.39	8.30	0.15	1.07	0.48	0.15	25.39	4.95
Egypt	RIE+RIV	Nile	EG_Nile	ND	ND	ND	ND	ND	ND	4.49	35.17	11.55	0.13	1.52	0.57	0.13	35.17	7.16
France	LGN	Bages-Sigean	FR_Bage	ND	ND	ND	ND	ND	ND	0.00	0.00	ND	9.72	15.18	11.66	9.72	15.18	11.66
France	LGN	Berre	FR_Berr	ND	ND	ND	ND	ND	ND	0.00	0.00	ND	2.69	6.30	4.46	2.69	6.30	4.46
France	LGN	Gruissan	FR_Grui	ND	ND	ND	ND	ND	ND	0.00	0.00	ND	7.25	22.4	12.9	7.25	22.4	12.9
France	LGN	Or	FR_Or	ND	ND	ND	ND	ND	ND	0.00	0.00	ND	14.35	27.82	21.17	14.35	27.82	21.17
France	LGN	Salses-Leucate	FR_Sals	ND	ND	ND	ND	ND	ND	0.00	0.00	ND	2.73	6.38	4.58	2.73	6.38	4.58
France	LGN	Thau	FR_Thau	ND	ND	ND	ND	ND	ND	0.00	0.00	ND	3.47	8.64	6.40	3.47	8.64	6.40
France	LGN	Vaccarès	FR_Vacc	ND	ND	ND	ND	ND	ND	0.00	0.00	ND	3.57	6.96	4.78	3.57	6.96	4.78
Greece	LGN	Vistonida	GR_Vist	ND	ND	ND	ND	ND	ND	0.22	2.47	1.57	0.09	1.91	0.47	0.09	2.47	1.02
Italy	LAK	Bolsena	IT_Bols	ND	ND	ND	ND	ND	ND	3.00	29.39	9.19	1.08	8.24	2.83	1.08	29.39	5.84
Italy	LAK	Bracciano	IT_Brac	ND	ND	ND	ND	ND	ND	7.84	7.84	7.84	0.48	13.66	5.12	0.48	13.66	5.36
Italy	LGN	Cabras	IT_Cabr	ND	ND	ND	ND	ND	ND	4.64	4.64	4.64	1.10	13.44	5.94	1.10	13.44	5.83
Italy	RIE	Cedrino	IT_Cedr	ND	ND	ND	ND	ND	ND	8.04	8.04	8.04	1.01	5.79	3.48	1.01	8.04	3.98
Italy	RIE	Coghinas	IT_Cogh	ND	ND	ND	ND	ND	ND	0.00	0.00	ND	0.30	22.93	4.18	0.30	22.93	4.18
Italy	LGN	Colostrai	IT_Colo	ND	ND	ND	ND	ND	ND	8.95	8.95	8.95	14.09	27.11	19.21	8.95	27.11	18.28
Italy	LGN	Comacchio	IT_Coma	3.70	32.60	14.10	7.10	32.10	17.07	0.28	10.40	4.36	0.45	1.15	0.73	0.28	32.60	12.99
Italy	LAK	Como	IT_Como	ND	ND	ND	ND	ND	ND	0.28	0.28	0.28	0.01	0.87	0.21	0.01	0.87	0.22
Italy	LGN	Corru S'Ittiri - Corru Mannu	IT_Corr	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.15	7.57	3.78	0.15	7.57	3.78
Italy	LGN	Feraxi	IT_Fera	ND	ND	ND	ND	ND	ND	4.04	4.04	4.04	0.71	16.16	4.86	0.71	16.16	4.78
Italy	RIV	Flumendosa	IT_Flum	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.19	24.96	15.78	0.19	24.96	15.78

				Eel production (kg ha^{-1} averaged values of time framework)														
				Pre ‘50			Pre ‘80			Pre 2009			Post 2009			All series		
Country	**Habitat**	**Site**	**Code**	**min**	**max**	**mean**	**min**	**max**	**mean**	**min**	**max**	**mean**	**min**	**max**	**mean**	**min**	**max**	**mean**
Italy	LGN	Fondi	IT_Fond	ND	ND	ND	ND	ND	ND	53.67	53.67	53.67	0.43	8.27	3.53	0.43	53.67	8.09
Italy	LGN	Gravile	IT_Grav	ND	ND	ND	ND	ND	ND	ND	ND	ND	6.00	88.00	34.17	6.00	88.00	34.17
Italy	LGN	Is Benas	IT_IsBe	ND	ND	ND	ND	ND	ND	0.59	0.59	0.59	0.02	1.71	0.66	0.02	1.71	0.66
Italy	LAK	Iseo	IT_Iseo	ND	ND	ND	ND	ND	ND	0.41	0.41	0.41	0.20	2.01	0.98	0.20	2.01	0.92
Italy	LGN	Malfatano	IT_Malf	ND	ND	ND	ND	ND	ND	10.36	10.36	10.36	0.36	8.27	2.88	0.36	10.36	3.56
Italy	LGN	Marceddì	IT_Marc	ND	ND	ND	ND	ND	ND	0.97	0.97	0.97	0.10	2.31	0.82	0.10	2.31	0.84
Italy	LGN	Orbetello	IT_Orbe	ND	ND	ND	33.05	109.84	69.72	11.73	80.97	36.38	6.99	16.72	11.14	6.99	109.84	43.40
Italy	LGN	Pauli Bianco Turri	IT_Paul	ND	ND	ND	ND	ND	ND	24.83	24.83	24.83	2.78	19.72	7.91	2.78	24.83	9.44
Italy	RIE	Po	IT_Po	ND	ND	ND	ND	ND	ND	6.21	6.21	6.21	0.46	13.32	5.16	0.46	13.32	5.25
Italy	LGN	S.G. Muravera	IT_SGio	ND	ND	ND	ND	ND	ND	18.68	18.68	18.68	18.27	39.10	25.81	18.27	39.10	25.16
Italy	LGN	Santa Gilla	IT_SGil	ND	ND	ND	ND	ND	ND	1.66	1.66	1.66	0.33	2.80	1.31	0.33	2.80	1.34
Italy	LGN	Santa Giusta	IT_SGiu	ND	ND	ND	ND	ND	ND	2.39	2.39	2.39	0.06	2.79	0.73	0.06	2.79	0.88
Italy	LGN	S'Ena Arrubia	IT_SEna	ND	ND	ND	ND	ND	ND	0.67	0.67	0.67	0.85	7.09	3.80	0.67	7.09	3.52
Italy	LGN	Su Pedrosu Avalè	IT_SuPe	ND	ND	ND	ND	ND	ND	15.50	15.50	15.50	0.90	12.50	5.87	0.90	15.50	6.75
Italy	LGN	Tortolì	IT_Tort	ND	ND	ND	ND	ND	ND	3.78	3.78	3.78	1.29	9.52	4.26	1.29	9.52	4.22
Italy	LAK	Trasimeno	IT_Tras	ND	ND	ND	ND	ND	ND	0.58	0.58	0.58	0.13	0.61	0.37	0.13	0.61	0.39
Italy	LGN	Venezia	IT_Vene	ND	ND	ND	ND	ND	ND	0.01	0.01	0.01	0.03	0.10	0.06	0.01	0.10	0.06
Spain	LGN	Albufera de Valencia	SP_Albu	ND	ND	ND	6.91	46.20	30.65	1.32	7.68	3.33	1.07	2.71	1.87	1.07	46.20	13.77
Spain	RIE	Ebro Delta	SP_Ebro	ND	ND	ND	23.04	77.29	39.46	0.71	26.54	13.92	1.43	13.23	7.96	0.71	77.29	21.63
Spain	LGN	Laguna del Hondo	SP_Hond	ND	ND	ND	ND	ND	ND	0.16	0.16	0.16	0.02	0.52	0.16	0.02	0.52	0.16
Spain	LGN	Mar Menor	SP_MarM	ND	ND	ND	1.79	8.33	5.18	1.18	6.22	2.83	1.38	4.96	2.00	1.18	8.33	3.52
Spain	RIE	Marjal de Pego Oliva	SP_MPeg	ND	ND	ND	ND	ND	ND	1.79	6.89	4.29	1.00	4.93	2.53	1.00	6.89	3.49
Spain	LGN	Santa Pola	SP_SPol	ND	ND	ND	ND	ND	ND	0.96	2.17	1.57	0.06	3.05	1.35	0.06	3.05	1.39
Tunisia	LGN	Bizerte	TN_Bize	ND	ND	ND	ND	ND	ND	0.04	0.14	0.09	ND	0.07	0.02	ND	0.14	0.06
Tunisia	LGN	Ghar El Melh	TN_Ghar	ND	ND	ND	ND	ND	ND	2.87	21.57	11.39	1.93	23.91	9.25	1.93	23.91	10.32
Tunisia	LGN	Ichkeul	TN_Ichk	ND	ND	ND	ND	ND	ND	0.07	6.04	2.47	2.13	6.09	3.53	0.07	6.09	2.97
Tunisia	LAK	Sidi El Barrak	TN_Sidi	ND	ND	ND	ND	ND	ND	0.37	2.56	1.49	0.01	1.83	0.48	0.01	2.56	0.98
Tunisia	LGN	Tunis North	TN_Tuni	ND	ND	ND	ND	ND	ND	3.20	25.80	10.01	21.45	46.48	29.55	3.20	46.48	16.03
Türkiye	LAK	Bafa	TR_Bafa	ND	ND	ND	0.43	5.78	2.48	0.03	18.67	5.82	0.08	0.33	0.20	0.03	18.67	3.85
Türkiye	LGN	Enez	TR_Enez	ND	ND	ND	ND	ND	ND	0.33	8.33	2.53	0.06	2.43	1.02	0.06	8.33	2.21
Türkiye	LGN	Homa	TR_Homa	ND	ND	ND	ND	ND	ND	ND	10.96	1.98	0.03	0.31	0.12	ND	10.96	1.63

				Eel production (kg ha^{-1} averaged values of time framework)														
				Pre '50			Pre '80			Pre 2009			Post 2009			All series		
Country	**Habitat**	**Site**	**Code**	**min**	**max**	**mean**	**min**	**max**	**mean**	**min**	**max**	**mean**	**min**	**max**	**mean**	**min**	**max**	**mean**
Türkiye	LAK	Köyceğiz	TR_Koyc	ND	ND	ND	0.61	2.75	1.60	0.01	5.52	2.80	ND	1.47	0.25	ND	5.52	2.18

ND = no data available

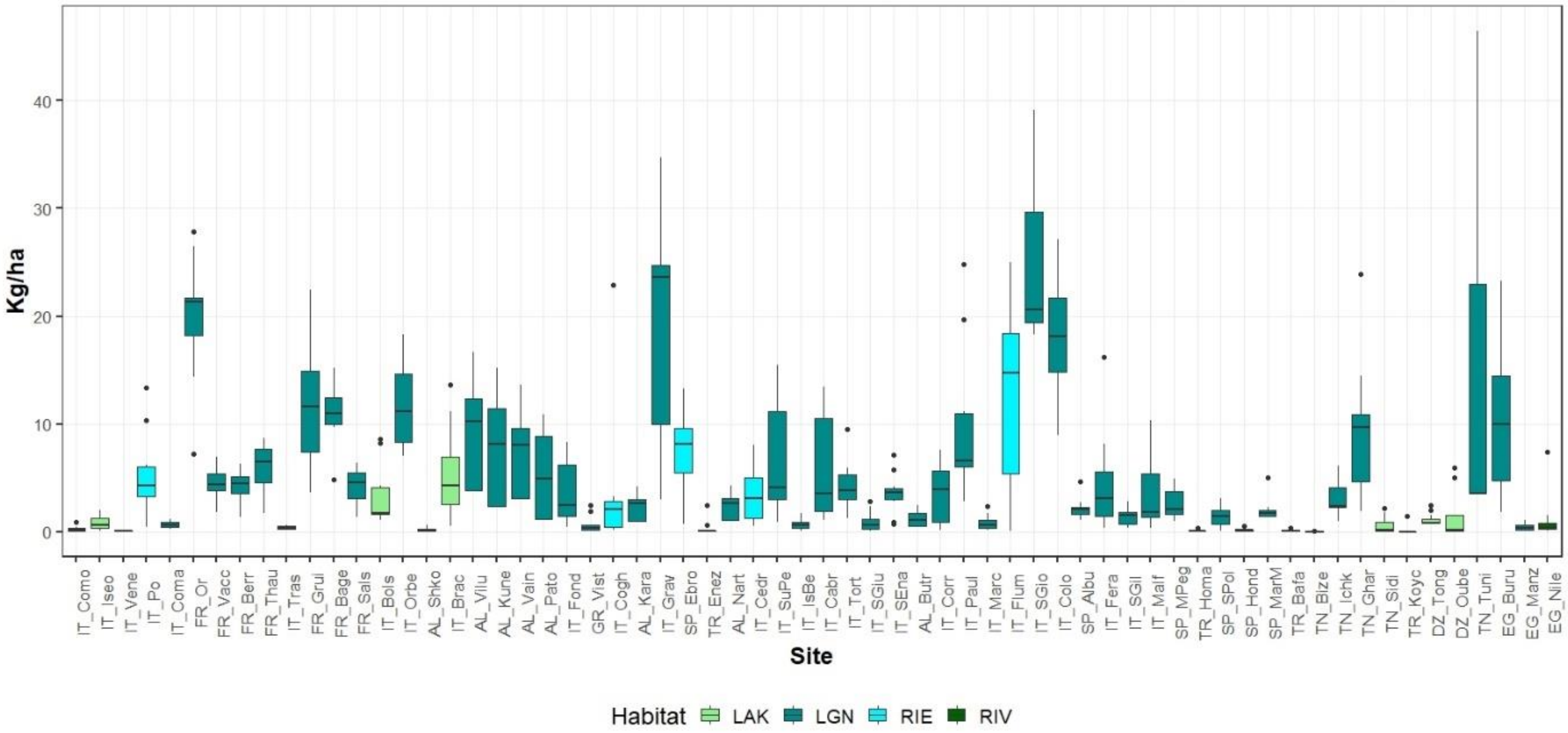

Figure 10.23. Variability in eel production (kg/ha/year) at site level by habitat type (LAK = lake, LGN = lagoon, RIE = estuary, RIV = river) for the time period, 1999-2010. Box-plots show mean, SE, and min–max eel yields (kg/ha/yr). Sites ordered by latitude**.**

10.3.7 Recreational landings

Figure 10.24 presents the time-series up to and including 2020 for total recreational landings, as reported by four countries. The time-series start in 1990, but data are concentrated from 2010 onwards. The highest recreational catches were from Italy and Türkiye (Figure 10.24, Table 10.15). Riverine sites were the habitats that were most frequently exploited by recreational fishers in all countries, except for Spain, where fishing took place in lagoons only. In Italy, recreational fishing in rivers represented 55 percent of total recreational catches, followed by lakes (30 percent) and estuaries (14 percent).

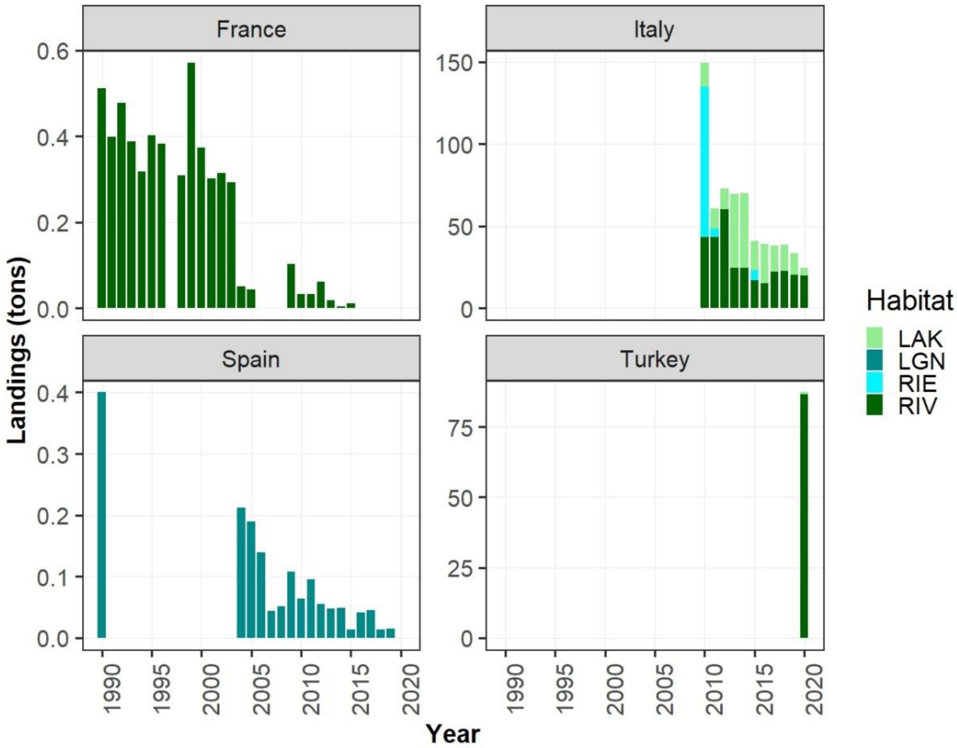

Figure 10.24. Recreational landings: total catches (tonnes) by country and coloured by habitat (LAK = lake, LGN = lagoon, RIE = estuary, RIV = river). Note the different scales on the y-axes for each country

The most frequently used fishing gear was the fishing rod (65 percent of reported catches), followed by shore lift nets (16 percent) and eel longlines (12 percent) (Figure 10.25).

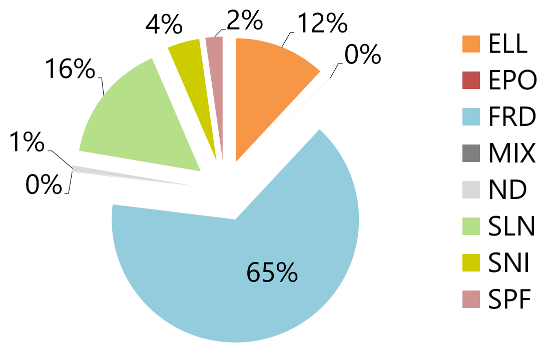

Figure 10.25. Recreational landings: proportion (percent) of fishing gears based on total catches (ELL: eel longlines; EPO: eel pot; FRD: fishing rod; MIX: mixed gears; ND: gear not known; SLN: shore lift nets; SNI: snigging / umbrella; SPF: spearfishing)

Table 10.15. Recreational landings: total catches (tonnes) reported by year and country, 1990–2020.

Year	France	Italy	Spain	Türkiye
1990	0.51		0.40	
1991	0.40			
1992	0.48			
1993	0.39			
1994	0.32			
1995	0.40			
1996	0.38			
1998	0.31			
1999	0.57			
2000	0.37			
2001	0.30			
2002	0.32			
2003	0.29			
2004	0.05		0.21	
2005	0.04		0.19	
2006			0.14	
2007			0.04	
2008			0.05	
2009	0.10		0.11	
2010	0.03	149.50	0.06	
2011	0.03	60.64	0.10	
2012	0.06	72.78	0.06	
2013	0.02	69.83	0.05	
2014	0.00	69.91	0.05	
2015	0.01	40.75	0.01	
2016		39.22	0.04	
2017		38.32	0.05	
2018		38.38	0.01	
2019		33.66	0.01	
2020		24.53		87.25

About the 60 percent of the total catches were yellow eels, followed by silver eels (20 percent) (Figure 10.26).

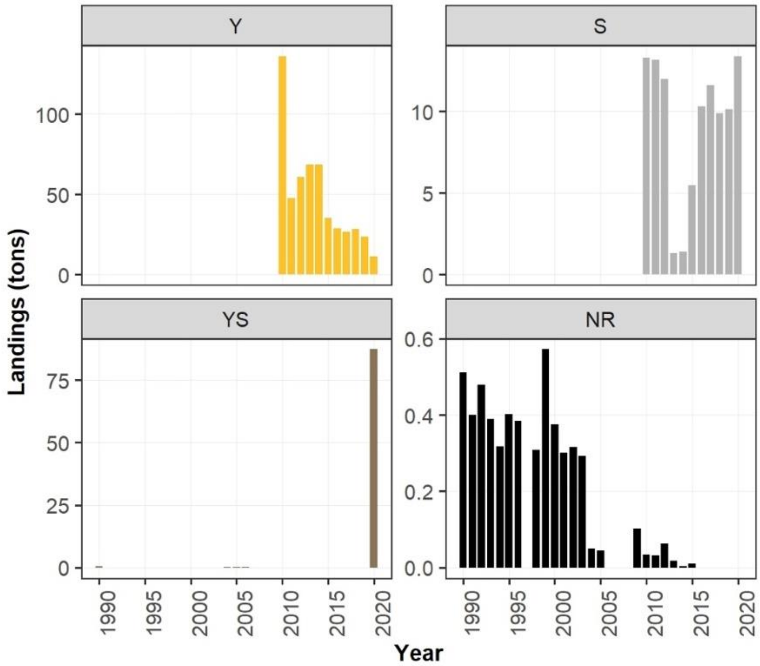

Figure 10.26. Recreational landings: total catches (tonnes) for different life stages (Y = yellow eel, S = silver eel, YS = mixed yellow and silver eel) by year and country. NR: information about life stage not reported. Note the different scales on the y-axes for each life stage

An interesting issue arises from the comparison between commercial and recreational fisheries, in countries where recreational eel catches were recorded, for example, in Italy and Türkiye. There were significant recreational catches, of the same order of magnitude as commercial landings (Figure 10.27), because they were obtained by shore lift nets and eel long lines, respectively, two gears that are included within the recreational gears.

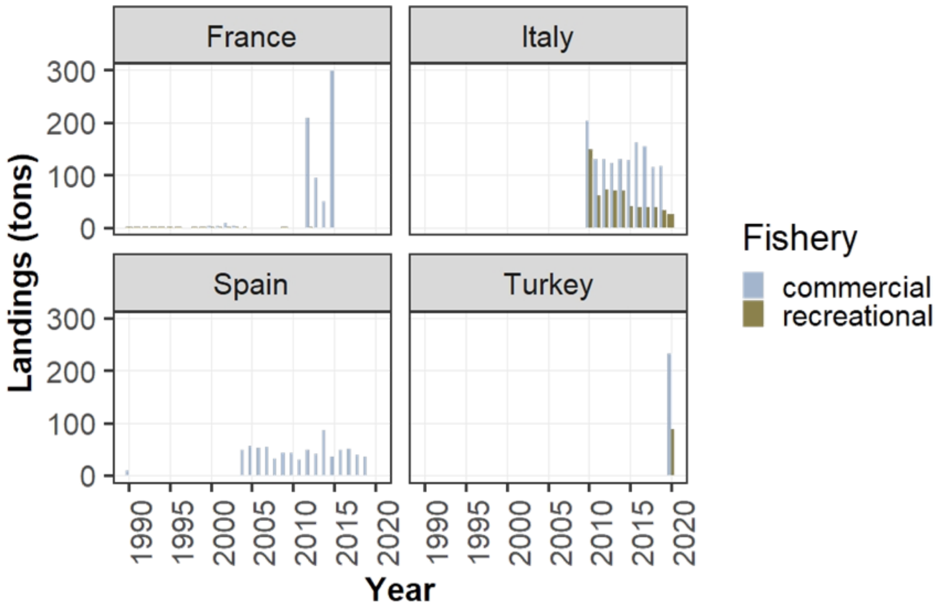

Figure 10.27. Comparison between commercial and recreational fishing landings (tonnes) by country

10.4 DISCUSSION

10.4.1 Data collection and spatial coverage

Stemming from a comprehensive data collection and revision performed under WP3, this chapter is the first detailed analysis of eel landings in the Mediterranean. It was performed with the involvement of nine partner countries, which account for the most important eel fisheries in the area. The global picture of catches and trends does not consider other Mediterranean countries (Croatia, Montenegro, Morocco-Med, Slovenia and Libya), for which official fishery data exist or eel fisheries are known to exist at present or in the past.

Data collection relied on all possible data sources, including national fishery statistics, fishing reports, grey and scientific literature and logbooks, and aimed at gathering catch data and time series at the site level and as far back in time as possible.

From the methodological point of view, an important achievement was the assessment of data quality by a multi-step quality check. This was performed by involving scientific partners and was based on an "expert judgment" approach, that resulted in a reliability score associated to all data included in the fishery database.

All data were used to analyse landings at the fishing site level and by habitat. On the other hand, only data with high reliability scores were selected to report landings by country.

10.4.2 Eel fishery description

Detailed information related to eel fisheries for 366 sites, including lagoons (154 sites), rivers (91 sites), lakes (51 sites), coastal marine waters (47 sites) and estuaries (23 sites) is provided. Of these, 65 sites, including 47 lagoons, 11 lakes, and seven between rivers and estuaries, had landings time-series with a length of at least ten years. The work resulted in a significant expansion of the catches and landings database in support of detailed quantitative and qualitative analyses.

A first comprehensive analysis of eel catches in Mediterranean coastal lagoons was carried out by Aalto *et al.* (2016). The authors relied on fishery-based data from bibliographic sources and a preliminary search carried within the GFCM Pilot Action in 2015, that had resulted in fisheries data relating to 45 lagoons.

The timespan of the commercial data-series ranged from 1951 to 2020 (provisional data), with a consistent overlap between countries in recent years (since 2000), coincident with the establishment of several fishery data collection frameworks.

Four Mediterranean countries (France. Italy, Spain and Türkiye) provided data for both commercial and recreational eel fisheries, whereas in seven countries, data were only related to commercial fisheries, either because recreational eel fisheries are banned (Greece) or because data were not available. When available, data series for recreational catches started in 1990, but most data concerned the period from 2010 onwards.

In general, in northern and central European countries, commercial eel landings are from coastal water fisheries (47 percent), followed by catches in freshwater habitats (33 percent, river and lakes). Landings from transitional waters (lagoons and estuaries) amount to 8 percent while the remainder is not attributable to any habitat type (ICES, 2019; ICES, 2020).

In contrast, most of the commercial catches for eel in Mediterranean region are from lagoon habitats. In 2019, lagoon fisheries represented 766 tonnes of the total reported Mediterranean catch of 1,048 tonnes and the average proportion of lagoon catch compared to total catch, over time, was greater than 90 percent. This result is in accordance with the overall distribution of wetted areas of eel habitat in the Mediterranean, where lagoons comprised 72 percent of the total wetted area, while the ecological features of lagoons also account for higher eel productivity levels compared to other habitats (Section 11.3.6 Eel productivity; Aalto *et al.*, 2016). On the other hand, recreational eel fishing occurs mostly in freshwater habitats.

Specific features of eel fisheries were highlighted for the Mediterranean region. Notwithstanding the diversity in materials and design, the analysis revealed eight prevailing gear-types in commercial fisheries and two in recreational fishing. Most catches were from fyke nets and fences specific for eels (75 percent) and from fixed barriers (10 percent) which are not specific for eel. Specifically, concerning the catch at fishing barriers targeting silver eel, there is a need to address management at regional level, for example, through a reduction in catches and effort coupled with other measures beneficial to silver eel escapement.

10.4.3 Eel landings and trends

ICES (2019, 2020, 2021a) stated that the information needed to provide a reliable estimate of the total catches of eel, fishing effort, and fishing capacity is still lacking. Notwithstanding the noticeable improvement in data availability and quality, a similar conclusion can be drawn for the Mediterranean region. Fishing effort metrics were missing information in 50 percent of cases. Therefore, it was not possible to evaluate the catch per unit of effort or provide estimates for stock trends (see also Chapter 9 Fishing effort).

Notwithstanding this, reported catches show a general declining trend for the Mediterranean. Prior to the 1980s, the average of total yields (mean 1951–1980) amounted to 400 tonnes per year (data available only for three countries: Spain, Italy and Türkiye), dropping to about 160 tonnes per year in 2010 for the same countries.

From 2000 onwards, data were available for all nine countries and average values amounted to 1 996 tonnes in the period 2000–2010 and 1,372 tonnes in the period 2011–2019. Cumulative landings decreased from 2 373 tonnes in 2000 to 903 tonnes in 2010 and were 1 048 tonnes in 2019.

Yellow and silver eel commercial fisheries averaged 1 531 tonnes over the recent five-year period, 2015–2019, when 90 percent of catches were attributable to five countries: Egypt (33 percent), followed by France (28 percent), Italy and Türkiye (10 percent, each) and Tunisia (9 percent). Albania, Algeria, Greece and Spain stated that the data reflects the actual level of resource exploitation, while Egypt, France, Italy, and Tunisia declared that the national exploitation level was underestimated and Türkiye did not provide an opinion.

ICES (2021b) reviewed total commercial landings from the overall distribution range of the European eel. Several countries were considered, including the Baltic countries, northern Europe, Spain, France and Morocco-Atlantic, Slovenia and Croatia based on official landings, as well as those participating in the GFCM eel research programme, except for Egypt, for which fishery data were temporarily set aside, pending a final quality check. Eel total commercial landings decreased from around 18 000 tonnes to 20 000 tonnes in the 1950s to around 2 000 tonnes to 3 000 tonnes since 2009 (ICES, 2021a). Landings from yellow and silver eel commercial fisheries (Y, S and YS) totalled 2 219 tonnes in 2019 and 2 263 tonnes in 2020 (provisional). Yellow and silver eel commercial fisheries averaged 3 273 tonnes over the five year period, 2015–2019.

The results of the eel research programme are in line with the overall landings levels estimated by ICES. It can be observed that as a minimum, at least 30 percent of total catches from the whole distribution area of European eel over the last five years may result from the Mediterranean region, without considering Egyptian catches. Catches from Mediterranean countries all concurrently showed decreasing levels and a high level of eel exploitation, especially in specific habitats and sites.

Data on recreational fisheries were limited to a few countries, but nevertheless resulted in significant catches. As regulations for recreational fishing vary between countries and may not be specific to eel (for example, in Italy - see Chapter 12 Management), unreported catches and catches overlapping with poaching could be present. Attention also has to be paid to the different fishing techniques, in view of a revision of the fishing gear codes. Some are listed both as commercial and recreational gears, such as eel longlines, and others including shore lift nets are able to capture quantities of eel far in excess of those caught by anglers using true recreational fishing gear such as fishing rods.

A reduction in fishing effort to reduce catches, in both commercial and recreational fisheries, should be considered, coupled with other measures to enhance escapement of silver eel.

However, any conclusions emerging from the analysis of national catches should be taken with caution, considering the lack of a standardised system for collection of eel fishery data, the lack of standardised reporting of fishing effort related to landings and noticeable variations in the length of time-series available by country, due to past inconsistencies in reporting or due to lack of information. It should also be considered that changes in management frameworks due to specific regulations for eel fisheries being applied in some countries may have also affected reporting of landings.

10.4.4. Eel production

Yields per hectare did not show a clear pattern according to habitat type because the main habitat categories of river, lake, estuary and lagoon, are too broad and contain water bodies that are too heterogeneous from the point of view of their ecological features.

The biological productivity of aquatic ecosystems depends on their geomorphological features including physical, chemical and ecological gradients for lagoons (Pérez-Ruzafa *et al.*, 2005, Pérez-Ruzafa, Mompeán and Marcos, 2007; Pérez-Ruzafa and Marcos, 2012) while temperature, flow, water velocity, vegetation cover and depth are important for inland waters (Acou *et al.*, 2011). Several authors have reported that eel fishing yields are dependent upon geographical location, morphometry, salinity, exchange of waters and trophic status in lagoons (Pérez-Ruzafa *et al.*, 2010; Aalto *et al.*, 2016). Temperature, distance inland, prey availability and other factors such as fish density have been found to be important in rivers (Acou *et al.*, 2008; Acou *et al.*, 2011).

In this work, it was not possible to find any relationship between eel yields and factors related to ecosystem productivity and this hampered the possibility of evaluating eel trends over time.

A second-level categorization of habitat types using morphometric, geological and physicochemical criteria descriptors should be envisaged to account for the high variability in eel production across sites. This could allow a categorization of eel habitats at a more detailed level, better discriminating between aquatic systems with different ecological and productive features.

10.5. RECOMMENDATIONS

10.5.1 Landings data and overall stock assessment and management – need to revise fishery data collection

Within the time frame of the GFCM eel research programme, there were considerable improvements in both data consistency and area coverage, thanks to the coordinated work of partners (both scientific partners and national focal points) in providing data and checking data quality. The results have increased awareness among all participants about the importance of data collection, quality checking and the use of landing and fishing effort data, while also reducing gaps in data availability and reliability between central-northern countries and southern countries in the European eel range area.

Recently, ICES (2021a; 2021b) stressed the importance of reconsidering data on landings as an additional indicator to estimate fishing mortality for assessment models and provide estimates for trends for the eel stock.

During the revision of the eel time-series, several problems were detected:

- Five out of nine countries had to process data before including them in the databases, that is, disaggregating catches by habitat type, for life stages and fishing gear, at the site level.
- Data were initially available at the EMU/region/country level for most countries rather than at site level.
- The prevalent life stage associated with catches was yellow-silver (YS) with 92 percent of data not reported separately.
- Most of the commercial catch series had missing data or information on effort, or had unreliable data on the effort at the site level, or did not allow the detection of changes in fishing effort in the time-series over time.

These conditions, dictated by the original data collection methodology in force in each country, made it difficult to analyse data reliability and use and compare data over time and space.

The results highlighted the importance of standardising data collection methodologies to develop a consistent approach to landings analysis across all types of natural eel habitats. The revision and harmonisation of eel data collection methodologies are crucial, especially regarding the lack of data on fishing effort and for time-series where cumulative figures are given for yellow and silver eel catches, that cannot be used in biometric analysis for assessment models (ICES, 2021b).

Many of these problems are also common to data series from the overall eel distribution area, including in non-Mediterranean, European countries. This is despite the fact that the framework for eel fishery-related data collection is supposed to be uniform under the EU-Map framework, but it allows the inclusion of past data-series, dating from the period preceding the implementation of the EU-DCF framework.

The implementation of a framework for eel data collection at site level, along with the retrieval, recording and quality check of landings time-series, is also crucial in view of the need to establish specific, local-level fisheries management measures.

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Supplementary Material on the Methodology – ReadMe spreadsheet for the WP3 database relative to eel fisheries, with the list of variables and relative information for compilation

Table 10SM.1. ReadMe spreadsheet for commercial fisheries

SITE INFORMATION	CODE	EXPLANATION	UNITS	TYPE OF UNITS	NOTES
Country	**Country_fullname**	Full name of your Country		Character	
Country code	**Country_code**	Two letter code of your Country		Character	
Region	**Region**			Character	
EMU	**EMU_nameshort**	See ***EMU*** codes in the *General INFO* spreadsheet		Character	
Habitat	**Habitat_code**	See ***HABITAT*** codes in the *General INFO* spreadsheet		Character	
Site	**Site_name**	The name you give to your site - add successive rows for different sites		Character	
Year	**Year**	Four digits (YYYY) - add successive rows for different years		Number	
Info source	**Info_source**	Origin of the data collected: EU project (e.g. DCF [Reg. 199/2008], EU-MAP [Decision EU 2016/1251], etc.), national/regional/local project, other project (e.g. LIFE, Interreg, etc.), scientific papers, grey literature, data dependent on fishery, other data (specify)		Character	

CATCHES	CODE	EXPLANATION	UNITS	TYPE OF UNITS	NOTES
Life stage	**Life_stage**	See ***LIFE STAGE*** codes in the *General INFO* spreadsheet		Character	
Captures	**Catches_COM**	Kilograms of eels caught per fishing gear	kg	Number	
Ratio Y/S	**YS_ratio**	If the catches can't be separated between yellow (Y) and silver (S) eels, specify the percent ratio Y/S		Number	

FISHING EFFORT	CODE	EXPLANATION	UNITS	TYPE OF UNITS	NOTES
Fishing gear	**Gear_type**	See ***FISHING GEAR*** codes in the *General INFO* spreadsheet		Character	
Mean number of gears per day per fisher	**Gear_day_ fisher**	Mean number of gears per day per fisher		Number	
Maximum number of authorized fishers (potential capacity)	**Potential_ capacity**	Number of fishers with fishing rights or licenses, or number of licenses, or number of authorizations released		Number	
Potential capacity parameter	**Fisher_ parameter**	Specify the parameter collected in the potential capacity: number of fishers with fishing rights or licenses, or number of licenses, or number of authorizations released		Character	
Months in the fishing period	**Fishing_months**	Number of months in the fishing authorized period		Number	
Number of effective fishing days	**Fishing_days**	Number of effective fishing days, e.g. consider weather conditions or other causes that can limit the fishing activities		Number	*Include this information when available, even when the fisher goes just to inspect, and specify it in the "notes" field. Then, describe in detail the type of fishing gear/method used with all the information available in the word qualitative questionnaire*
Mean number of fishing hours per day	**Fishing_hours_ day**	Mean number of fishing hours per day (when available)		Number	
Comments, notes and other data	**Notes**	Report here if your data are different from those specified in the database, if there is a particular situation in your Country not described here, or any other information you think could be useful to be added to the database		Character	

Indication on data reliability	**Data reliability**	Judgment on the reliability of the data for each record: 1- if you are confident with your data; 2- if the reliability is medium; 3- if they are not validated data	Character

Table 10SM.2. ReadMe spreadsheet for recreational fisheries

SITE INFORMATION	CODE	EXPLANATION	UNITS	TYPE OF UNITS	NOTES
Country	**Country_fullname**	Full name of your Country		Character	
Country code	**Country_code**	Two letter code of your Country		Character	
Region	**Region**			Character	
EMU	**EMU_nameshort**	See ***EMU*** codes in the *General INFO* spreadsheet		Character	
Habitat	**Habitat_code**	See ***HABITAT*** codes in the *General INFO* spreadsheet		Character	
Site	**Site_name**	The name you give to your site - add successive rows for different sites		Character	
Year	**Year**	Four digits (YYYY) - add successive rows for different years		Number	
Info source	**Info_source**	Origin of the data collected: EU project (e.g. DCF [Reg. 199/2008], EU-MAP [Decision EU 2016/1251], etc.), national/regional/local project, other project (e.g. LIFE, Interreg, etc.), scientific papers, grey literature, data dependent on fishery, other data (specify)		Character	

CATCHES	CODE	EXPLANATION	UNITS	TYPE OF UNITS	NOTES
Life stage	**Life_stage**	See ***LIFE STAGE*** codes in the *General INFO* spreadsheet		Character	
Captures	**Catches_REC**	Kilograms of eels caught per fishing gear	kg	Number	
Ratio Y/S	**YS_ratio**	If the catches can't be separated between yellow (Y) and silver (S) eels, specify the percent ratio Y/S		Number	

FISHING EFFORT	CODE	EXPLANATION	UNITS	TYPE OF UNITS	NOTES
Fishing gear	**Gear_type**	See ***FISHING GEAR*** codes in the *General INFO* spreadsheet		Character	
Mean number of gears per day per angler	**Gear_day_angler**	Mean number of gears per day per angler		Number	
Number of anglers / licence	**Anglers_nr**	Number of fishers with fishing rights or licenses		Number	

FISHING EFFORT	CODE	EXPLANATION	UNITS	TYPE OF UNITS	NOTES
Months in the fishing period	**Fishing_months**	Number of months in the fishing authorized period		Number	
Number of fishing day per authorized period	**Fishing_days**	Total number of fishing days per each authorized period		Number	
Mean number of hours per day per angler	**Fishing_hours_ day**	Mean number of fishing hours per day per angler (when available)		Number	
Comments, notes and other data	**Notes**	Report here if your data are different from those specified in the database, if there is a particular situation in your Country not described here, or any other information you think could be useful to be added to the database		Character	
Indication on data reliability	**Data reliability**	Judgment on the reliability of the data for each record: 1- if you are confident with your data; 2- if the reliability is medium; 3- if they are not validated data		Character	

Additional Results Part I – List of georeferenced fishing sites, target eel stages and fishing gears used by fisheries

Table 10AR.1. List of the fishing sites censured at the habitat level per each country, with information about eel life stage and fishing gear used.

Country	Habitat	Site	Lat	Long	Life stage	Fishing gear
Albania	LAK	Shkodër	42.188	19.289	YS, S, Y	FYK, BAR, EEL
Albania	LGN	Viluni	41.873	19.447	S, YS	BAR, FYK
Albania	LGN	Vain	41.734	19.593	S, YS	BAR, FYK
Albania	LGN	Kune	41.760	19.596	S, YS	BAR, FYK
Albania	LGN	Patoku	41.629	19.591	S, YS	BAR, FYK
Albania	LGN	Karavasta	40.928	19.499	S, YS	BAR, FYK
Albania	LGN	Narta	40.533	19.467	S, YS	BAR, FYK
Albania	LGN	Orikum	40.317	19.442	S, YS	BAR, FYK
Albania	LGN	Butrinti	39.784	20.031	S, YS	BAR, FYK
Algeria	LGN	Mellah	36.894	8.325	YS	FYK
Algeria	LAK	Tonga	36.860	8.497	YS	FYK
Algeria	LAK	Oubeira	36.847	8.386	YS	FYK
Algeria	RIE	Mafragh	36.837	7.958	YS	FYK
Algeria	RIE	El-Kebir west	36.985	7.272	YS	FYK
Egypt	RIV+RIE	River Nile	29.533	31.271	YS	FYK
Egypt	LGN	Lake Burullus	31.483	30.867	YS	MIX
Egypt	LGN	Lake Manzala	31.267	32.200	YS	MIX
Egypt	LGN	Lake Edko	31.251	30.211	YS	MIX
Egypt	LGN	Lake Mariout	31.153	29.899	YS	MIX
France	RIE+LGN	Vendres	43.256	3.222	S, Y, YS	FEN, MIX
France	LGN	Vaccarès	43.544	4.567	S, Y, YS	FEN, MIX
France	RIV	Saône aval/Saône amont/Doubs	46.903	5.021	YS	NTS
France	RIV	Saône aval	45.809	4.843	YS	MIX
France	RIV	Saône amont	47.951	5.888	YS	MIX
France	LGN	Salses-Leucate	42.849	2.996	S, Y, YS	FEN, MIX
France	RIV	Rhône amont	43.666	4.453	YS	MIX

Country	Habitat	Site	Lat	Long	Life stage	Fishing gear
France	RIV	Rhône aval	43.545	4.349	YS	MIX
France	RIV	Rhône deltaïque	43.457	4.390	S, Y, YS	MIX
France	LGN	Lagunes de Corse	42.576	9.487	S, Y, YS	FEN, MIX
France	RIV	Doubs	46.941	6.352	YS	MIX
France	LGN	Complexe de Petite Camargue	43.565	4.146	S, Y, YS	FEN, MIX, EPO
France	LGN	Bages-Sigean	43.081	3.000	S, Y, YS	FEN
France	LGN	Berre	43.464	5.095	S, Y, YS	FEN, MIX, EPO
France	LGN	Canet	42.668	3.023	S, Y, YS	FEN, MIX
France	LGN	Complexe de Gruissan	43.154	3.078	S, Y, YS	FEN, MIX
France	LGN	Complexe palavasien	43.628	3.797	S, Y, YS	FEN, MIX
France	LGN	Or	43.582	4.030	S, Y, YS	FEN, MIX
France	LGN	Thau	43.404	3.612	S, Y, YS	FEN, MIX, EPO, EEL
Greece	LGN	Lefkada	38.844	20.716	S	BAR
Greece	LGN	Diavlos	38.369	21.405	S	BAR
Greece	RIV	Evros	41.287	26.447	S	FYK
Greece	LAK	Ismarida	40.984	25.318	S	FYK
Greece	LGN	Gialova	36.962	21.670	S	BAR
Greece	LGN	Klisova	38.338	21.455	S	BAR
Greece	LGN	Koftra Palaiompouka	38.920	21.001	S	BAR
Greece	LGN	Komma	38.327	21.360	S	BAR
Greece	LGN	Kotychi	38.004	21.294	S	BAR
Greece	LGN	Logarou	39.034	20.890	S	BAR
Greece	LGN	Mazoma	39.012	20.754	S	BAR
Greece	LGN	Mesolongiou-Aitolikou	38.369	21.328	S	BAR
Greece	LGN	Palaiopotamos	38.917	20.994	S	BAR
Greece	LGN	Pappas	38.193	21.395	S	BAR
Greece	LGN	Ptelea	40.945	25.247	S	BAR
Greece	LGN	Pogonitsa	38.964	20.816	S	BAR

Country	Habitat	Site	Lat	Long	Life stage	Fishing gear
Greece	LGN	Prokopanistos	38.318	21.306	S	BAR
Greece	LGN	Prokopou	38.145	21.397	S	BAR
Greece	LGN	Schoinias	38.362	21.298	S	BAR
Greece	LGN	Tholi	38.316	21.243	S	BAR
Greece	LGN	Tourlida	38.349	21.430	S	BAR
Greece	LGN	Tsopeli	39.046	20.770	S	BAR
Greece	LGN	Tsoukalio	39.038	20.848	S	BAR
Greece	LGN	Vasiladi	38.337	21.384	S	BAR
Greece	LGN	Vathy	38.934	20.811	S	BAR
Greece	LGN	Vistonida	41.040	25.123	S	BAR
Italy	LGN	Acquatina	40.442	18.239	Y, S	ND
Italy	RIV	Adige	45.156	11.376	YS	ND
Italy	LGN	Alimini	40.198	18.446	Y, S	FYK, FEN
Italy	RIV	Arenariu, Su Graneri	40.588	9.758	Y, S	FYK, FEN
Italy	LGN	Su Pedrosu Avalè	40.353	9.694	Y, S	FYK, FEN, MIX, NTS, BAR
Italy	RIV	Bacchiglione e Brenta, Codevigo	45.236	12.100	Y, S	ND
Italy	RIV	Bacchiglione, Brenta e canale Brentella, Montegrotto	45.438	11.829	Y, S	FYK
Italy	RIV	Bacchiglione, Selvazzano	45.398	11.782	Y	FYK
Italy	RIV	Bacchiglione e canale Piovego	45.395	11.912	YS	ND
Italy	LGN	Barbamarco	44.990	12.476	Y, S	FYK, FEN
Italy	RIV	Barbamarco e Po Tramontana	44.981	12.499	Y, S	ND
Italy	LGN	Boi Cerbus	39.157	8.422	Y, S	FYK, FEN, BAR
Italy	LAK	Bolsena	42.598	11.934	Y, S, YS	FYK, FEN, EEL, MIX
Italy	LAK	Bracciano	42.122	12.233	Y, S	FYK, EEL, MIX
Italy	RIV	Brenta	45.512	11.836	Y, S	ND
Italy	LGN	Ca' Zuliani	44.969	12.451	S	BAR
Italy	LGN	Burano	42.400	11.382	Y, S	FYK
Italy	LGN	Cabras	39.948	8.494	Y, S	FYK, FEN, EEL

Count ry	Habitat	Site	Lat	Lon g	Life stage	Fishing gear
Italy	LGN	Cagliari	39.2 37	9.07 4	Y, S	FYK
Italy	LGN	Caleri	45.0 79	12.3 26	Y, S	ND
Italy	RIV	Canale Cormor, Castions di Strada	45.9 19	13.1 62	S	ND
Italy	LGN	Calich	40.5 96	8.30 2	Y, S	FYK, FEN
Italy	LGN	Canale Pordelio, Cavallino-Treporti	45.4 84	12.5 49	Y	FYK
Italy	RIV	Canarin, Po di Pila	44.9 43	12.4 87	Y, S	FEN
Italy	LGN	Canarin	44.9 30	12.4 83	Y, S	FYK, FEN
Italy	LGN	Caorle	45.6 55	12.9 02	Y, S, YS	FYK, ND
Italy	LGN	Capoterra	39.1 70	9.02 0	Y, S	FYK, FEN
Italy	LGN	Caprolace	41.3 52	12.9 70	Y, S, YS	FYK, MIX
Italy	LGN	Casaraccio	40.9 15	8.22 1	Y, S	FYK, FEN, MIX
Italy	RIV	Cedrino	40.3 87	9.69 5	Y, S	FYK, FEN
Italy	LAK	Chiusi	43.0 56	11.9 66	S	FYK
Italy	RIV	Coghinas	40.9 33	8.80 9	Y, S, YS	FYK, FEN, EEL
Italy	LGN	Colostrai	39.3 51	9.59 0	Y, S	FYK, FEN, BAR
Italy	LAK	Comabbio	45.7 64	8.69 1	Y, S	FYK
Italy	LGN	Comacchio	44.6 10	12.1 72	Y, S, YS	FYK, FEN, MIX, BAR
Italy	LAK	Corbara	42.7 16	12.2 50	Y	FYK
Italy	LAK	Como	46.0 11	9.26 5	Y, S, YS	FYK, MIX, EEL, NTS, BAR
Italy	LGN	Corru S'Ittiri - Corru Mannu	39.7 60	8.52 9	Y, S	FYK, FEN, NTS, BAR,
Italy	RIE	Delta del Po, Scardovari, Porto Tolle	44.9 10	12.4 48	Y, S, YS	ND
Italy	RIE	Delta del Po, Adria	45.0 20	12.0 88	Y, S	ND
Italy	RIE	Delta del Po, Porto Tolle	44.9 55	12.3 29	Y, S	ND
Italy	RIE	Delta del Po, Porto Viro, Taglio di Po	45.0 12	12.2 15	Y, S	ND
Italy	RIV	Fascia costiera Pisa	43.6 87	10.3 41	Y	FYK
Italy	RIV	Fascia costiera Rosignano	43.3 73	10.4 53	Y	FYK
Italy	LGN	Feraxi	39.3 33	9.59 2	Y, S	FYK, FEN, BAR
Italy	RIV	Flumendosa	39.4 29	9.62 7	Y, S	FYK, FEN
Italy	RIV	Flumendosa e Quirra	39.4 29	9.62 7	YS	ND

Country	Habitat	Site	Lat	Long	Life stage	Fishing gear
Italy	RIV	Flumendosa, Villaputzu	39.433	9.586	Y, S	FYK
Italy	RIV	Flumini Durci	39.524	9.616	Y, S	FYK, FEN
Italy	LGN	Fogliano	41.400	12.905	Y, S, YS	FYK, MIX
Italy	LGN	Fondi	41.324	13.334	Y, S	FYK, FEN, SLN
Italy	RIV	Garigliano, Ofanto, Minturno	41.223	13.762	Y	FYK
Italy	LAK	Garda	45.550	10.667	Y, S	FYK, FEN, EEL, MIX, NTS
Italy	LGN	Goro	44.812	12.325	Y, S	FYK, FEN
Italy	LGN	Grado	45.728	13.336	Y, S	FYK, FEN
Italy	LGN	Gravile	40.916	9.559	S	FYK, FEN, MIX, NTS, BAR
Italy	LAK	Idro	45.779	10.508	YS	ND
Italy	LGN	Is Benas	40.038	8.449	Y, S	FYK, FEN, EEL
Italy	RIE	Isonzo, Grado	45.735	13.526	YS	ND
Italy	RIV	Isonzo, Gorizia	45.940	13.602	YS	ND
Italy	RIV	Isonzato, Fiumicello	45.885	13.503	YS	ND
Italy	LAK	Iseo	45.725	10.059	Y, S, YS	FYK, FEN, NTS
Italy	RIV	Lia e Monticano, Oderzo	45.801	12.489	Y, S	FYK
Italy	LGN	Lesina	41.882	15.433	Y, S	FYK, FEN
Italy	RIV	Livenza	45.820	12.584	Y, S	ND
Italy	RIV	Livenza, Caorle	45.631	12.842	Y, S	ND
Italy	RIE	Livenza foce, Caorle	45.589	12.864	Y, S, YS	ND
Italy	RIV	Livenza, Portobuffolè	45.855	12.534	Y, S	ND
Italy	RIV	Livenza, Ceggia	45.717	12.671	Y, S	ND
Italy	RIV	Livenza, Motta di Livenza	45.779	12.622	Y, S	ND
Italy	LGN	Longu, Posada	40.624	9.738	Y, S	FYK, FEN, NTS
Italy	RIV	Lotzorai	39.972	9.664	Y, S	FYK
Italy	LGN	Lungo	41.274	13.404	Y, S	FYK
Italy	LGN	San Puoto	41.285	13.408	Y, S	FYK, EEL
Italy	LAK	Maggiore	45.942	8.638	Y, S	NTS, ELL
Italy	LGN	Malfatano	38.901	8.804	Y, S	NTS

Country	Habitat	Site	Lat	Long	Life stage	Fishing gear
Italy	LGN	Marano	45.732	13.158	Y, S, YS	FYK, FEN, ELL
Italy	LGN	Marceddì	39.708	8.520	Y, S	FYK, FEN, MIX, NTS
Italy	RIV	Mesola	44.923	12.226	Y, S	FYK
Italy	LGN	Mistras	39.904	8.460	Y, S	FYK, FEN, MIX, BAR
Italy	LGN	Monaci	41.377	12.940	Y, S	FYK, MIX
Italy	LAK	Montepulciano	43.090	11.919	Y, S	ND
Italy	RIV	Natissa, Aquileia	45.765	13.357	Y, S	SLN
Italy	RIV	Noncello, Pordenone	45.953	12.662	YS	ND
Italy	RIV	Noncello, Prata di Pordenone	45.900	12.603	YS	ND
Italy	LGN	Nora	38.988	9.006	Y, S	FYK
Italy	LGN	Olbia	40.915	9.508	Y, S	FYK, FEN, MIX
Italy	LGN	Orbetello	42.435	11.204	Y, S	FYK, BAR
Italy	LGN	Sabaudia	41.275	13.037	Y, S, YS	FYK, FEN, BAR
Italy	LGN	Pauli Bianco Turri	39.726	8.512	Y, S	FYK, FEN, NTS
Italy	RIV	Piave, Villorba	45.795	12.278	Y, S	ND
Italy	RIV	Piave, S. Pietro di Feletto	45.827	12.212	Y	ND
Italy	RIV	Piave	46.128	12.203	Y, S, YS	FYK
Italy	LGN	Pilo	40.856	8.281	Y, S	FYK, FEN, MIX
Italy	RIE	Po delta	44.953	12.433	Y, S	ND
Italy	RIV	Po di Goro	44.856	12.298	Y, S	FYK
Italy	RIE	Po di Goro, Sacca di Goro	44.816	12.354	Y, S	FYK, MIX
Italy	RIE	Po di Pila	44.963	12.471	Y, S	FYK, FEN
Italy	RIE	Po di Maistra	44.993	12.364	Y, S	ND
Italy	RIE	Po di Volano, Sacca di Goro	44.810	12.271	Y	FYK, FEN
Italy	RIE	Po di Venezia, Corbola	45.006	12.070	Y, S	FEN
Italy	RIE	Po, Berra	44.985	11.980	Y, S	FYK
Italy	RIV	Po, Bondeno	44.929	11.422	Y, S	FYK
Italy	RIV	Po, Borretto	44.909	10.554	Y, S	FYK
Italy	RIE	Po, Busa Dritta	44.966	12.522	Y, S	ND

Country	Habitat	Site	Lat	Long	Life stage	Fishing gear
Italy	RIV	Po, Trebbia, Piacenza	45.068	9.689	Y	FYK
Italy	LGN	Porto Pino	38.962	8.612	Y, S	FYK, FEN, MIX, BAR
Italy	RIV	Pramaera	40.013	9.594	Y, S	FYK, FEN, NTS
Italy	RIV	Provincia Livorno e Grosseto	43.075	10.753	Y, S	FYK
Italy	RIV	Rio Siniscola	40.586	9.749	Y, S	FYK
Italy	RIV	Rio Leonaxiu	38.942	8.722	Y	NTS
Italy	RIV	S. Lucia, Su Stanieddu e Bidda	39.156	9.017	Y	ND
Italy	LGN	Sa Curcurica	40.455	9.788	Y, S	FYK
Italy	LGN	Sa Praia	39.440	9.619	Y, S	FYK, FEN, BAR
Italy	LGN	San Giovanni, Muravera	39.402	9.610	Y, S	FYK, FEN, BAR
Italy	LGN	San Teodoro	40.801	9.666	Y, S	FYK, FEN, MIX, BAR
Italy	LGN	Santa Gilla	39.199	9.037	Y, S	FYK, FEN, MIX, ELL, NTS
Italy	LGN	Santa Giusta	39.867	8.591	Y, S	FYK, FEN, EEL, BAR
Italy	LGN	Scardovari	44.862	12.419	Y, S, YS	FYK, FEN
Italy	RIE	Scardovari, Po di Goro	44.844	12.344	Y, S	ND
Italy	RIE	Scardovari, Porto Tolle	44.882	12.465	Y, S	FEN
Italy	RIE	Scardovari, Po di Gnocca, Porto Tolle	44.894	12.326	Y, S	ND
Italy	LGN	S'Ena Arrubia	39.823	8.566	Y, S	FYK, FEN, BAR
Italy	RIE	Sile	45.512	12.426	Y, S	ND
Italy	RIV	Sile, Casale sul Sile	45.596	12.328	Y, S	FYK
Italy	RIV	Sile, Treviso	45.645	12.302	Y, S	FYK
Italy	RIV	Sile, Quinto di Treviso	45.642	12.168	Y, S	FYK
Italy	RIV	Sile e affluenti, S. Biagio di Callalta	45.687	12.393	Y, S	FYK
Italy	RIV	Sile	45.627	12.320	YS	FYK
Italy	RIV	Sile, Musestre, Altino	45.558	12.371	Y, S	ND
Italy	RIV	Stella, Palazzolo dello Stella	45.799	13.078	YS	ND
Italy	RIV	Stella, Precenicco	45.786	13.080	Y, S	ND
Italy	LGN	Su Stangioni Pula	39.007	9.020	Y, S	FEN

Country	Habitat	Site	Lat	Long	Life stage	Fishing gear
Italy	LGN	Su Stangioni, Teulada	38.939	8.719	Y, S	FYK, FEN, MIX, BAR
Italy	RIV	Tagliamento	46.132	12.939	Y, S	ND
Italy	RIV	Tagliamento, Latisana	45.778	12.989	Y, S	ND
Italy	RIV	Tagliamento, Morsano al Tagliamento	45.859	12.976	YS	ND
Italy	RIV	Terzo di Aquileia	45.799	13.351	Y, S	SLN
Italy	RIV	Tevere Arrone	41.898	12.258	Y, S	FYK
Italy	RIV	Torre, Remanzacco, Udine	46.077	13.291	Y, S	SLN
Italy	RIV	Tevere	42.184	12.609	Y, S	FYK
Italy	LGN	San Giovanni Tortolì	39.702	8.546	YS	ND
Italy	LGN	Tortolì	39.947	9.676	Y, S	FYK, FEN, BAR
Italy	LAK	Trasimeno	43.141	12.106	Y, S	FYK, MIX, BAR
Italy	LGN	Valle del Lovo	45.768	13.186	Y, S	ND
Italy	LGN	Valle Casonetto	45.093	12.297	S	ND
Italy	LGN	Valle Cavallino	45.492	12.564	Y, S	FYK, BAR
Italy	LGN	Valle Dogà	45.528	12.615	Y, S	BAR
Italy	LGN	Valle Drago, Jesolo	45.503	12.557	S	BAR
Italy	LGN	Valle Fattibello, Comacchio	44.674	12.190	Y, S	FYK, FEN, MIX, BAR
Italy	LGN	Valle Figheri	45.330	12.165	S	BAR
Italy	LGN	Valle Grassabò	45.515	12.545	S	BAR
Italy	LGN	Valle Millecampi	45.272	12.178	Y, S	FYK
Italy	LGN	Valle Moraro	45.001	12.315	Y	FYK
Italy	LGN	Valle Morosina	45.108	12.274	S	BAR
Italy	LGN	Valle Segà	45.088	12.283	S	BAR
Italy	LGN	Valle Noghera	45.714	13.298	Y, S	ND
Italy	LGN	Pialassa Baiona	44.503	12.250	Y, S	FYK
Italy	LGN	Varano	41.879	15.749	Y, S	FYK, FEN, ELL, MIX
Italy	LAK	Varese	45.812	8.742	Y, S	FYK, FEN, NTS, MIX
Italy	LGN	Veniera	45.061	12.295	S	ND

Country	Habitat	Site	Lat	Long	Life stage	Fishing gear
Italy	RIV	Zellina, Carlino	45.803	13.193	Y, S	ND
Italy	RIV	Zenson di Piave	45.679	12.498	Y, S	ND
Italy	LGN	Venezia	45.413	12.300	Y, S, YS	FYK, FEN, MIX
Spain	LGN	Albufera de Valencia	39.337	-0.354	S, Y	FYK
Spain	LGN	Albufera Mallorca	39.788	3.098	YS	FYK
Spain	LGN	Albufera des Grau	39.948	4.253	YS	FYK
Spain	CMW	Ebro	40.719	0.891	S	FYK
Spain	LGN	Ebro Delta	40.712	0.835	S, YS	FYK
Spain	LGN	Laguna del Hondo	38.182	-0.752	YS	FYK
Spain	LGN	Mar Menor	37.717	-0.786	Y, S, YS	FEN
Spain	RIE	Marjal de Pego-Oliva	38.876	-0.059	YS	FYK
Spain	LGN	Santa Pola	38.189	-0.616	YS	FYK
Tunisia	CMW	Aghir	33.759	11.025	YS	MIX
Tunisia	CMW	Ajim	33.707	10.737	YS	MIX
Tunisia	LAK	Abid	36.819	10.703	YS	NTS
Tunisia	LAK	Bakbaka	36.583	10.307	YS	NTS
Tunisia	LAK	Bezirk	36.721	10.633	YS	NTS
Tunisia	CMW	Bekalta	35.644	11.007	YS	MIX
Tunisia	LAK	Barbara	36.248	9.790	YS	NTS
Tunisia	LAK	Bir M'cherga	36.507	10.005	YS	NTS
Tunisia	CMW	Bizerte	37.262	9.949	YS	MIX
Tunisia	LGN	Bizerte	37.197	9.856	YS	MIX
Tunisia	CMW	Bni Khiar	36.450	10.785	YS	MIX
Tunisia	LAK	Bni Atta	37.213	10.084	YS	NTS
Tunisia	LAK	Bouhethma	36.667	8.786	YS	NTS
Tunisia	LAK	Chiba	36.708	10.771	YS	NTS

Country	Habitat	Site	Lat	Long	Life stage	Fishing gear
Tunisia	CMW	Chebba	35.216	11.126	YS	MIX
Tunisia	CMW	Cap Zebib	37.272	10.070	YS	MIX
Tunisia	LAK	Chok El Felfel	37.185	9.856	YS	NTS
Tunisia	CMW	Essalloum	36.281	10.499	YS	MIX
Tunisia	CMW	El Awabid	34.747	10.799	YS	MIX
Tunisia	CMW	Elgrin	33.280	11.319	YS	MIX
Tunisia	CMW	Ellouza	35.023	11.010	YS	MIX
Tunisia	CMW	Ezzahra	36.751	10.322	YS	MIX
Tunisia	CMW	El Awabid	34.747	10.799	YS	MIX
Tunisia	CMW	Ghannouch	33.946	10.082	YS	MIX
Tunisia	CMW	Gabes	33.886	10.128	YS	MIX
Tunisia	LGN	Ghar El Melh	37.150	10.175	YS	MIX
Tunisia	LAK	Ghezala	37.053	9.541	YS	NTS
Tunisia	CMW	Hammamet	36.390	10.590	YS	MIX
Tunisia	CMW	Haouaria	37.062	10.998	YS	MIX
Tunisia	CMW	Hergla	36.035	10.513	YS	MIX
Tunisia	LAK	Hjar	36.848	11.030	YS	MIX
Tunisia	CMW	Houmet Essouk	33.888	10.864	YS	NTS
Tunisia	CMW	Hergla	36.035	10.513	YS	MIX
Tunisia	LGN	Ichkeul lake	37.167	9.666	YS	MIX
Tunisia	CMW	Jendouba	36.961	8.775	YS	MIX
Tunisia	LAK	Joumine	36.977	9.606	YS	NTS
Tunisia	LGN	Kalaat Al Andalous	37.046	10.173	YS	MIX
Tunisia	CMW	Kantaoui	35.902	10.594	YS	MIX
Tunisia	LAK	Kasseb	36.767	8.993	YS	NTS
Tunisia	CMW	Kekennah	34.754	11.154	YS	MIX
Tunisia	CMW	Kelibia	36.832	11.101	YS	MIX
Tunisia	CMW	Khniss	35.715	10.831	YS	MIX
Tunisia	CMW	Ksibet El Madiouni	35.693	10.852	YS	MIX

Count ry	Habitat	Site	Lat	Lon g	Life stage	Fishing gear
Tunisi a	CMW	La Goulette	36.8 14	10.3 16	YS	MIX
Tunisi a	LAK	Lebna	36.7 41	10.9 14	YS	NTS
Tunisi a	LAK	Lakhmes	35.9 97	9.47 7	YS	NTS
Tunisi a	LAK	Masri	36.5 31	10.4 86	YS	NTS
Tunisi a	CMW	Melloulech	35.1 52	11.0 64	YS	MIX
Tunisi a	CMW	Monastir	35.7 86	10.8 22	YS	MIX
Tunisi a	LAK	Mlaabi	36.8 30	10.9 83	YS	NTS
Tunisi a	CMW	Mahres	34.5 09	10.4 93	YS	MIX
Tunisi a	CMW	Mahdia	35.5 11	11.0 68	YS	MIX
Tunisi a	LAK	Mellegue	36.3 11	8.70 0	YS	NTS
Tunisi a	CMW	Rafraf	37.2 04	10.2 06	YS	MIX
Tunisi a	CMW	Rades	36.7 78	10.2 95	YS	MIX
Tunisi a	LAK	Rmel	36.2 10	10.4 69	YS	NTS
Tunisi a	CMW	Salakta	35.3 86	11.0 47	YS	MIX
Tunisi a	CMW	Sayada	35.6 74	10.9 04	YS	MIX
Tunisi a	CMW	Sfax	34.7 10	10.7 79	YS	MIX
Tunisi a	CMW	Sidi Bou Said	36.8 71	10.3 59	YS	MIX
Tunisi a	CMW	Sidi Mechreg	37.1 73	9.12 8	YS	MIX
Tunisi a	LAK	Sidi Saad	35.3 68	9.67 2	YS	NTS
Tunisi a	CMW	Sidi Daoud	37.0 24	10.9 05	YS	MIX
Tunisi a	CMW	Skhira	34.2 81	10.1 01	YS	MIX
Tunisi a	CMW	Sidi Mansour	34.7 62	10.8 17	YS	MIX
Tunisi a	LAK	Sejnane	37.1 75	9.44 9	YS	NTS
Tunisi a	LAK	Seliana	36.1 40	9.35 9	YS	NTS
Tunisi a	CMW	Sidi Abdelhamid	35.8 07	10.6 69	YS	MIX
Tunisi a	LAK	Sidi El Barrak	37.0 17	8.95 3	YS	NTS
Tunisi a	LAK	Sidi Salem	36.6 47	9.39 0	YS	NTS
Tunisi a	LAK	Smati	36.1 43	9.36 1	YS	NTS
Tunisi a	CMW	Sousse	35.8 44	10.6 33	YS	MIX

Country	Habitat	Site	Lat	Long	Life stage	Fishing gear
Tunisia	CMW	Teboulba	35.657	10.974	YS	MIX
Tunisia	LGN	Tunis North	36.819	10.238	YS	FEN
Tunisia	LGN	Tunis South	36.794	10.235	YS	FEN
Tunisia	CMW	Zabboussa	34.346	10.210	YS	MIX
Tunisia	CMW	Zarat	33.692	10.372	YS	MIX
Tunisia	CMW	Zarzis	33.493	11.128	YS	MIX
Tunisia	LAK	Ziatine	37.169	9.189	YS	NTS
Turkey	RIV	Acıkulak	36.657	35.330	YS	FYK
Turkey	LGN	Ağyatan Hurmaboğazı	36.596	35.513	YS	BAR
Turkey	LGN	Akgöl	36.293	33.956	YS	FYK
Turkey	LGN	Akgöl-Paradeniz	36.290	33.963	YS	FYK
Turkey	LGN	Akköy	37.505	27.197	YS	FYK
Turkey	LGN	Akyatan	36.629	35.274	YS	BAR
Turkey	RIV	Asi	36.056	35.971	YS	FYK
Turkey	LAK	Bafa	37.501	27.434	YS	FYK
Turkey	LGN	Beymelek	36.265	30.053	YS	FYK
Turkey	LAK	Belevi	38.024	27.467	YS	FYK
Turkey	LGN	Dalyan	36.806	28.612	YS	BAR
Turkey	LGN	Dipsiz	36.738	34.912	YS	FYK
Turkey	LGN	Enez	40.715	26.070	YS	MIX, FYK
Turkey	LAK	Gala	40.773	26.230	YS	FYK
Turkey	LAK	Gölbaşı	36.507	36.491	YS	FYK
Turkey	LGN	Güllük	37.260	27.627	YS	FYK, BAR
Turkey	LGN	Homa	38.536	26.843	YS	FYK
Turkey	LGN	Hurmaboğazı	36.659	35.911	YS	FYK
Turkey	LGN	Karina	37.593	27.183	YS	FYK, BAR
Turkey	LGN	Köyceğiz	36.912	28.654	YS	FYK, BAR
Turkey	RIV	Meriç	40.729	26.059	YS	FYK
Turkey	LGN	Misakça	40.316	27.645	YS	FYK

Country	Habitat	Site	Lat	Long	Life stage	Fishing gear
Turkey	LGN	Poyraz-Arapçiftliği	40.378	28.478	YS	FYK
Turkey	LAK	Tabaklar	36.746	35.018	YS	FYK
Turkey	LAK	Tahtaköprü	36.869	36.688	YS	FYK
Turkey	RIV	Tarsus	36.898	34.932	YS	FYK
Turkey	LGN	Tuzla	36.696	35.058	YS	BAR
Turkey	LAK	Yarseli	36.178	36.323	YS	FYK
Turkey	LGN	Yelkoma	36.689	35.647	YS	FYK
Turkey	LGN	Yumurtalık	36.712	35.651	YS	BAR

Additional Results Part II – Annual total eel catches (all stages) by habitat and country

Table 10AR2.1. Total catches reported in lagoons, per year and Country (tonnes)

Year	Albania	Algeria	Egypt	France*	Greece	Italy	Spain	Tunisia	Turkey**
1951							90.00		
1952							102.20		
1953							80.20		
1954						17.62	97.70		
1955						15.37	102.90		
1956						17.95	106.12		
1957						19.35	80.00		
1958						20.09	115.00		
1959						20.53	100.00		
1960						23.12	98.00		
1961						89.25	153.84		
1962						128.15	114.94		
1963						166.48	136.85		
1964						260.02	91.50		
1965						254.87	130.44		
1966						173.23	222.18		
1967						132.94	199.85		
1968						215.51	220.93		
1969						182.47	188.40		
1970						163.71	201.26		
1971						123.88	210.21		
1972						231.04	172.01		25.00
1973						283.02	146.05		25.00
1974						212.57	143.09		25.00
1975						192.48	132.87		25.95
1976						204.55	129.20		3.46
1977						241.86	80.05		2.40
1978						316.32	67.03		6.00
1979						276.33	96.82		3.00
1980						260.08	89.80		
1981						218.61	97.71		20.00
1982						191.30	19.87		
1983						146.35	18.39		
1984						187.27	10.97		11.00
1985						207.07	14.48		
1986						154.50	12.11		10.70
1987						123.65	18.94		5.00
1988						115.81	12.69		
1989						146.76	3.94		
1990						186.63	8.30		20.00
1991						147.03	48.78		0.05
1992						121.08	53.01		
1993						107.77	65.67		0.01
1994						72.60	49.62		2.90
1995						76.13	67.94	106.00	
1996						33.11	60.47	80.00	

Year	Albania	Algeria	Egypt	France*	Greece	Italy	Spain	Tunisia	Turkey**
1997						53.20	74.03	75.00	0.33
1998			760.00			38.38	37.81	63.00	0.98
1999		1.38	382.00			60.72	42.15	86.00	6.63
2000		0.70	1687.00		0.93	45.23	38.20	27.62	12.63
2001			1710.00		6.48	45.25	77.84	42.79	10.49
2002			1327.00		4.22	49.38	64.48	120.66	2.75
2003		3.10	267.00		8.08	78.52	61.77	69.92	8.21
2004			450.00		7.25	53.33	48.03	47.06	25.25
2005			574.00		73.06	57.43	53.88	77.74	3.29
2006			1878.00		61.28	73.95	50.03	139.68	24.48
2007			1043.00		70.58	70.68	52.21	151.11	0.75
2008		1.59	533.00		49.53	55.46	30.78	94.80	10.00
2009		5.80	786.00		42.23	226.17	42.17	68.88	
2010		3.40	246.00		58.62	168.17	41.96	55.23	0.57
2011			197.00		34.26	109.68	27.92	52.18	7.05
2012		0.40	986.00	378.00	19.39	105.56	47.19	13.61	12.95
2013	41.48	3.00	617.00	431.50	28.51	97.71	39.54	92.31	6.53
2014	37.51	6.00	274.00	409.42	44.96	117.36	85.59	52.44	4.89
2015	49.19	3.00	532.00	422.68	56.50	108.67	34.26	63.06	10.46
2016	36.97	2.00	494.00	441.16	59.86	137.97	48.67	209.04	
2017	25.52	3.00	487.00	368.68	45.21	137.73	48.86	112.75	
2018	42.45	4.00	1162.00	501.13	0.64	109.78	36.83	145.46	
2019	56.70	2.00		342.66	0.39	109.53	35.23	115.83	
2020							50.16		101.25

***** *Total catches include a site where catches are aggregated from the Vendres lagoon and the next estuary area.*
****** *Data source literature and DCRF (only 2020)*

Table 10AR2.2. Total catches reported in rivers, per year and Country (tonnes)

Year	Egypt*	France*	Greece	Italy	Turkey*
1975					0.99
1976					1.10
1998	1 581.00				
1999	327.00				
2000	377.00	3.48			
2001	269.00	2.49			
2002	475.00	7.59			
2003	514.00	3.29			
2004	466.00	0.004			
2005	350.00	0.003			
2006	2 105.00				13.25
2007	976.00				1.90
2008	411.00				
2009	442.00			16.21	
2010	91.00			10.10	
2011	0.00			7.96	
2012	19.00			10.35	
2013	24.00		1.20	14.11	
2014	8.00		1.21	6.88	
2015	46.00			18.31	

Year	Egypt*	France*	Greece	Italy	Turkey*
2016	52.00			18.76	
2017	16.00		0.89	17.95	
2018	18.00		1.24	9.47	
2019			1.32	8.12	
2020					33.00

* ***Egypt.*** *Catches for the river Nile were provided aggregated both for the estuary area and the river segment.*
* ***France.*** *Recorded official data is very underestimated.*
* ***Turkey.*** *Data source literature and DCRF (only 2020).*

Table 10AR2.3. Total catches reported in lakes, per year and Country (tonnes)

Year	Albania	Algeria	Italy	Tunisia	Turkey*
1954					2.59
1955					7.51
1956					14.80
1973					3.50
1974					8.10
1975					5.79
1976					6.01
1977					13.87
1978					48.32
1979					3.05
1980					6.93
1981					29.52
1982					52.61
1983					23.11
1984					83.00
1985					80.86
1986					67.55
1987					61.57
1988					33.82
1989					24.35
1990					20.24
1991					14.84
1992					10.80
1993					13.47
1994					16.52
1995			33.67	17.60	
1996			6.55	28.40	
1997			13.06	10.00	
1998			11.02	15.30	14.38
1999		18.18		86.00	14.47
2000		16.52			0.03
2001		44.50	8.72	1.20	16.10
2002		25.39		1.80	16.94
2003		18.33		5.30	13.89
2004		26.30	3.44	6.90	6.30
2005		5.00	3.88	11.50	20.56
2006			4.57	11.70	
2007		13.60		11.20	11.44
2008		10.41		8.10	10.70
2009		8.40	26.19	12.50	

Year	Albania	Algeria	Italy	Tunisia	Turkey*
2010		3.40	31.84	9.20	0.60
2011			16.11	2.70	0.50
2012		0.40	15.28	1.44	1.00
2013	5.50		11.29	2.46	2.00
2014	5.50		10.31	0.82	2.00
2015	0.80		7.06	0.68	7.37
2016	4.00		12.21	1.43	
2017	21.50	6.90	8.65	2.36	
2018	17.50	17.00	4.26	5.12	
2019	13.30	11.00	8.97	2.81	
2020					98.50

* ***Turkey.*** *Data source literature and DCRF (only 2020).*

Table 10AR2.4. Total catches reported in estuaries, per year and Country (tonnes)

Year	Algeria	Italy	Spain
1998			1.20
1999	0.82		1.07
2000			0.50
2001			0.87
2002			0.82
2003	3.77		1.91
2004	2.70		1.04
2005	2.59		1.92
2006	2.65		1.37
2007	1.00		1.17
2008	1.95		1.41
2009		3.42	1.08
2010		0.31	1.38
2011		0.97	1.37
2012		2.79	1.00
2013		3.16	0.62
2014			0.57
2015			0.37
2016			0.46
2017	0.70		0.43
2018	11.96		0.59
2019			0.28
2020			

Table 10AR2.5. Total catches reported in Coastal Marine Waters, per year and Country (tonnes)

Year	Spain	Tunisia
2015	0.21	
2016	0.18	
2017	0.93	
2018	0.89	13.24
2019	0.21	9.61
2020	0.01	

Additional Results Part III – List of georeferenced sites for which time series have been used for the analysis of productivity (kg/ha), first and last year of catch data available, and missing years.

Table 10AR3.1. Time series retained for spatial coverage and length with of data available > 10 years.

Country	Site	Code	Habitat	Lat	Long	year-min	year-max	missing years
Albania	Butrinti	AL_Butr	LGN	39.783889	20.030556	2013	2019	
Albania	Karavasta	AL_Kara	LGN	40.9275	19.498611	2013	2019	
Albania	Kune	AL_Kune	LGN	41.76	19.595556	2013	2019	
Albania	Narta	AL_Nart	LGN	40.535471	19.422807	2013	2019	
Albania	Patoku	AL_Pato	LGN	41.628889	19.590833	2013	2019	
Albania	Shkodra	AL_Shko	LAK	42.188056	19.288889	2013	2019	
Albania	Vain	AL_Vain	LGN	41.733889	19.593056	2013	2019	
Albania	Viluni	AL_Vilu	LGN	41.873056	19.446667	2013	2019	
Algeria	Oubeira	DZ_Oube	LAK	36.846699	8.385897	1999	2018	8
Algeria	Tonga	DZ_Tong	LAK	36.859691	8.496872	1999	2018	9
Egypt	Burullus	EG_Buru	LGN	31.483333	30.866667	1998	2018	
Egypt	Manzala	EG_Manz	LGN	31.266667	32.2	1998	2018	
Egypt	Nile	EG_Nile	RIV	29.533436	31.270695	1998	2018	
France	Bages-Sigean	FR_Bage	LGN	43.081455	3.000161	2010	2019	
France	Berre	FR_Berr	LGN	43.463811	5.09515	2010	2019	
France	Complexe de Gruissan	FR_Grui	LGN	43.112632	3.081042	2010	2019	
France	Or	FR_Or	LGN	43.581649	4.02995	2010	2019	
France	Salses-Leucate	FR_Sals	LGN	42.848942	2.995667	2010	2019	
France	Thau	FR_Thau	LGN	43.403927	3.612072	2010	2019	
France	Vaccarès	FR_Vacc	LGN	43.543816	4.567106	2010	2019	
Greece	Vistonida	GR_Vist	LGN	41.040439	25.122965	2000	2019	
Italy	Bolsena	IT_Bols	LAK	42.59843454	11.93388102	1995	2019	6
Italy	Bracciano	IT_Brac	LAK	42.12206211	12.23255811	2009	2019	
Italy	Cabras	IT_Cabr	LGN	39.94823908	8.494409759	2009	2019	
Italy	Cedrino	IT_Cedr	RIE	40.376332	9.728988	2009	2019	2
Italy	Coghinas	IT_Cogh	RIE	40.93307048	8.80926555	2011	2019	
Italy	Colostrai	IT_Colo	LGN	39.35068575	9.59002993	2009	2019	
Italy	Comacchio	IT_Coma	LGN	44.60985557	12.17207631	1781	2019	7
Italy	Como	IT_Como	LAK	46.01100622	9.265483014	2009	2019	
Italy	Corru S'Ittiri-Corru Mannu	IT_Corr	LGN	39.75985193	8.529373938	2010	2019	
Italy	Feraxi	IT_Fera	LGN	39.333449	9.592152791	2009	2019	1
Italy	Flumendosa	IT_Flum	RIE	39.42903204	9.626541695	2011	2019	
Italy	Fondi	IT_Fond	LGN	41.32388201	13.33422694	2009	2019	
Italy	Gravile	IT_Grav	LGN	40.91617613	9.55868212	2010	2019	
Italy	Is Benas	IT_IsBe	LGN	40.03817039	8.449144272	2009	2019	
Italy	Iseo	IT_Iseo	LAK	45.72548232	10.05943753	2009	2019	1
Italy	Malfatano	IT_Malf	LGN	38.90065835	8.804455118	2009	2019	
Italy	Marceddì	IT_Marc	LGN	39.70808386	8.520000263	2009	2019	
Italy	Orbetello	IT_Orbe	LGN	42.43487008	11.2042058	1961	2019	
Italy	Pauli Bianco Turri	IT_Paul	LGN	39.72574172	8.511646385	2009	2019	
Italy	Po	IT_Po	RIE	44.96371709	12.48681618	2009	2019	
Italy	San Giovanni Muravera	IT_SGio	LGN	39.40229413	9.610175596	2009	2019	
Italy	Santa Gilla	IT_SGil	LGN	39.19851425	9.036935136	2009	2019	
Italy	Santa Giusta	IT_SGiu	LGN	39.86728589	8.591056813	2009	2019	
Italy	S'Ena Arrubia	IT_SEna	LGN	39.82250968	8.565915359	2009	2019	
Italy	Su Pedrosu Avalè	IT_SuPe	LGN	40.35297897	9.694261593	2009	2019	
Italy	Tortolì	IT_Tort	LGN	39.94654742	9.67562177	2009	2019	
Italy	Trasimeno	IT_Tras	LAK	43.1408955	12.1063703	2009	2019	
Italy	Venezia	IT_Vene	LGN	45.41300754	12.29955153	2009	2018	
Spain	Albufera de Valencia	SP_Albu	LGN	39.3374	-0.3538	1956	2019	
Spain	Ebro Delta	SP_Ebro	RIE	40.7194	0.6625	1966	2019	22
Spain	Laguna del Hondo	SP_Hond	LGN	38.181735	-0.752185	2009	2019	
Spain	Mar Menor	SP_MarM	LGN	37.7167	-0.7861	1962	2019	9
Spain	Marjal de Pego-Oliva	SP_MPeg	LGN	38.8756	-0.0591	1998	2019	
Spain	Santa Pola	SP_SPol	LGN	38.1893	-0.6159	2008	2019	
Tunisia	Bizerte	TN_Bize	LGN	37.19666667	9.856388889	2000	2019	2
Tunisia	Ghar El Melh	TN_Ghar	LGN	37.1499	10.1751	2000	2019	

Country	Site	Code	Habitat	Lat	Long	year-min	year-max	missing years
Tunisia	Ichkeul	TN_Ichk	LGN	37.1666667	9.6663889	2000	2019	1
Tunisia	Sidi El Barrak	TN_Sidi	LAK	37.0170694	8.9532694	2001	2019	1
Tunisia	Tunis North	TN_Tuni	LGN	36.8186389	10.2378694	2001	2019	6
Turkey	Bafa	TR_Bafa	LAK	37.50088333	27.43393611	1954	2019	45
Turkey	Enez	TR_Enez	LGN	40.71492222	26.07049722	1997	2015	5
Turkey	Homa	TR_Homa	LGN	38.536475	26.843286	1981	2015	19
Turkey	Koycegiz	TR_Koyc	LAK	36.91173611	28.65372778	1974	2015	4

CHAPTER 11. EEL AQUACULTURE IN THE MEDITERRANEAN

ABSTRACT

This chapter investigates eel aquaculture across the Mediterranean region, collecting detailed information on eel rearing techniques and production. Eel aquaculture data from nine countries (Albania, Algeria, France, Greece, Italy, Spain, Tunisia, Egypt and Türkiye) were collected, when possible, at the most detailed level. This includes data on individual sites or aquaculture companies. A quality check was carried out, which also involved scientific partners and national focal points, to validate data against official data submitted by the countries to the GFCM Information System for the Promotion of Aquaculture in the Mediterranean (GFCM-SIPAM) database.

European eel aquaculture is a capture-based activity as seed, both glass eels and young yellow eels, are sourced from the wild. For this reason, availability of seed material is presently considered a limiting factor to commercial aquaculture operations.

Data series on eel aquaculture production in European and GFCM countries were available from 1950 onwards, with Italy and the former Yugoslavia reporting around 160 tonnes, increasing over time to reach a peak production level of 10 663 tonnes in 2000, then steadily decreasing until 2012. The current production level from Europe is around 5 221 tonnes, with the Netherlands, Germany, Italy, Denmark and Greece being the leading producers.

Eel production in Mediterranean countries has followed the same trend as in Europe. The peak of total eel aquaculture production was reached in 1990 at 5 343 tonnes, with the countries responsible for the bulk of this production being Italy (4 050 tonnes), followed by France (810 tonnes), Tunisia (144 tonnes), Spain (125 tonnes), Morocco (60 tonnes) and Greece (45 tonnes). Eel aquaculture production in Europe started to decline in 1996, reaching a minimum value of 1 313 tonnes in 2011, while the latest official data shows current production at 1 540 tonnes.

Of the nine Mediterranean countries that participated in the GFCM research programme on European eel, only four reported aquaculture activities in their countries. The most significant aquaculture production occurs in Italy, with 464 tonnes in 2019, while Greece reported 146 tonnes and Egypt reported four tonnes. In Tunisia, this activity is limited to collecting seed from the sea and stocking it in the basins of inland dams that cannot be reached naturally by migrating elvers (young eels).

However, overlaps between aquaculture and fishery activities were revealed in the four countries that presented aquaculture data for European eel, resulting in mismatches between declared aquaculture and fisheries production data.

After quality checking, it was determined that only three countries (Italy, Greece and Egypt) practice European eel aquaculture in the Mediterranean region.

HIGHLIGHTS

- Three forms of eel rearing techniques are utilized: semi-intensive culture pond systems, intensive recirculation aquaculture systems (RAS) and the extensive culture system called *Vallicoltura*, a traditional form of eel culture practiced in the coastal lagoons and brackish waters of the Mediterranean region, especially in Italy.
- Several overlaps between extensive aquaculture and fishery activities were observed in four out of the nine participant countries that reported aquaculture activities in the Mediterranean region.
- The most significant aquaculture production occurs in Italy. The reported data covers the period 2008–2019, with reported production varying from 510.4 tonnes in 2011 to a maximum of 750 tonnes in 2015, and 464 tonnes in 2019.

- Greece reported aquaculture activities from the same period, 2008–2019, reaching maximum production of 428.2 tonnes in 2009 and a minimum of 128 tonnes in 2018, while the most recently reported production was 146 tonnes.
- Fragmentary aquaculture data were observed in Egypt, where European eel aquaculture has been practiced since at least 2010. Current production is 4 tonnes.
- After quality checking, aquaculture data reported by Tunisia were ascribed to fisheries catches, because reported eel aquaculture production was based on the transportation of glass eels from the sea to inland reservoirs, where the eels are fished.

11.1 INTRODUCTION

11.1.1 General aspects of eel culture

European eel farming is a capture-based aquaculture system. This is because the success in artificial maturation of the European eel (*Anguilla anguilla*) has been limited, in contrast to the Japanese eel (*Anguilla japonica*), for which the first glass eels were obtained in a laboratory in 2001 (Tanaka *et al.*, 2003).

Recently, two important research projects were funded in Europe: the international research project PRO-EEL, aimed at breeding European eel in captivity and supported by the European Commission; and ITS-EEL, a research and innovation project carried out by the Technical University of Denmark (DTU Aqua) and aquaculture industry partners. PRO-EEL has the objective of developing standardized protocols for the production of high-quality gametes (egg and sperm), viable embryos and feeding larvae of European eel. ITS-EEL aims to advance emergent technologies to breed European eel and scale up larval culture to enhance offspring survival and sustain the feeding larval (leptocephalus) stage , leading to production of glass eels.

This research has had some positive results. However, due to the complex reproductive physiology of eels, many advances will have to be made to achieve commercial production of European glass eels in captivity (Asturiano, 2020). Therefore, wild animals at different developmental stages, including larvae, small- to medium-sized juveniles or even large individuals from the wild, will continue to be required for all eel farming activities due to the insufficient availability of seed material for commercial aquaculture operations. However, this is considered an unsustainable aquaculture practice, leading to increased pressure on wild fish stocks, stock depletion, low recruitment and reductions in biodiversity, as well as having long-term impacts on the ecological dynamics of aquatic environments (Ottolenghi *et al*., 2004).

Capture-based eel aquaculture is practised across the world in Asia, Europe, Australia and North America, with production concentrated in China, Japan and Taiwan as well as the Netherlands, Denmark and Italy. The two main species of eel that supply international eel markets are Japanese and European eels, at the glass eel stage (Lee *et al.*, 2003; Nielsen and Prouzet, 2008). According to FAO, there is also commercial interest in the American eel (*Anguilla rostrata*) and the short-finned eel (*Anguilla australis australis*), while other eel species have only minor influence on the market (Monticini, 2014).

According to the International Council for the Exploration of the Sea (ICES) (2017), glass eel catches for aquaculture purposes reached a peak in the 1980s, followed by several fluctuations during the following years, and after a gradual decline reached a minimum in 2009. An increase in the use of glass eels for aquaculture was seen starting from 2014; however, shortly after this, in 2016, several countries that practised eel aquaculture reported problems meeting their glass eel demand. Another important supply source of seed for eel aquaculture is young yellow eels. This activity started in the 1990s, reaching a maximum in 2013 of around 16 million individual animals. In 2016, the number of glass eels and young yellow eels supplied as seed for aquaculture purposes was almost equal, at 10 million and 9.2 million individuals, respectively (ICES, 2017).

11.1.2 Rearing techniques

European eel aquaculture started around 40 years ago and currently supplies 5 496 tonnes/year worldwide (FAO FishStat, 2021). Two different eel rearing techniques are in used in the Mediterranean area. The first is intensive farming systems in raceways and ponds, where young eels are stocked into the holding system and artificial feed is administered on a daily basis. The second is extensive systems where eels in lagoons and coastal semi-enclosed basins characterized by very shallow water depths, with seed sourced from natural recruitment and eventually complemented by stocking, feed on natural trophic resources. The eels are then caught by different gears (fixed or mobile). Such traditional methods partially overlap with eel fisheries in lagoons that can be described as enhanced fisheries and are still present in Italy, France and Greece. In Italy, the most emblematic form of this is "*Vallicoltura*". Typical of the northern Adriatic, this system involves enclosing and skilfully managing portions of lagoons with the addition of different types of ponds, ditches and channels in order to attain adequate hydraulic management for exploitation of a range of fish species including eel, mullets, sea bass and seabream.

Extensive culture pond systems

This is the oldest and most traditional form of eel culture in Europe and uses ponds of 100 m^2—350 m^2. After reaching marketable size, eels are transferred to larger ponds of 1000 m^2–1500 m^2. This system uses static or flow-through water (Pillay, 1995). The optimal temperature ranges between 18 °C–25 °C (Grandi *et al.*, 2000).

"*Vallicoltura*" is one of the most ancient forms of aquaculture, developed in Italy in the upper Adriatic region. Today in Spain, Greece and Italy, eels are farmed mainly in extensive conditions. Juveniles of various fish species naturally enter brackish water and coastal lagoons and grow there consuming natural food. To exploit the seasonal movements of eels and many other euryhaline marine fish (i.e. species able to adapt to various salinity levels), complex mobile or permanent capture systems, known as "*lavorieri*", are placed in the tidal channels. These V-shaped gears can be opened or closed, allowing or hindering the passage of fish from the lagoon to the sea and vice versa. Silver eels are caught, in certain seasons of the year, when trying to migrate back to sea to reproduce. To enhance production, more management interventions in these environments have been carried out, including hydraulic management as well as bottom dredging or providing basins (Ciccotti, 2005; Kokkinakis, 2014; Vasconi *et al.*, 2019). Fish management has also evolved to include movements of fish, active restocking and over-wintering. When European eel juveniles were abundant, glass eels or 15 g to 35 g elvers — mainly imported from France, Denmark, the Netherlands and Sweden — were stocked at densities of 4 kg/ha to 15 kg/ha (FAO, 2021). Currently, stocking activities for aquaculture purposes in coastal lagoons in the Mediterranean area have been completely abandoned, and *valliculture* can be considered as a type of lagoon fishery.

Plate 11.1. Extensive Valliculture: Valli di Comacchio, Italy. Credit: Dino Marsan from web site, wikimedia.org.

Plate 11.2. Extensive pond farming system for eels.

Intensive culture, recirculation aquaculture systems

Recirculation aquaculture systems (RAS) are very efficient production systems that recirculate and reuse water through a closed cycle. The water passes through mechanical and biological filtration systems before reuse in the culture system. RAS can also control water temperature, allowing farmers to rear eels even in colder areas. This rearing technique utilizes square or circular tanks made of cement or fibreglass, with a 25 m^2 to100 m^2 surface area. The system operates at very high fish densities of up to 120 kg per m^3 of water (Ottolenghi *et al.*, 2004). The feeding system uses extruded dry food (1.5 mm to 3 mm particle size) applied through automatic feeders. More than 80 percent of eels farmed in Europe are produced through RAS systems (Fletcher, 2021).

Plate 11.3. Intensive eel culture with RAS system, Eurofarm S. A., Greece (Eurofarm, 2021).

11.1.3 General overview of eel aquaculture production in Europe and Mediterranean countries

The FAO FishStat database includes data on eel aquaculture for all countries where this activity exists starting from 1950, when 160 tonnes were reported (Italy, 150 tonnes and former Yugoslavia, 10 tonnes). The peak of European aquaculture production was reached in 2000, with a total of 10 663 tonnes. wThe main production countries were the Netherlands (3 700 tonnes), Italy (2 700 tonnes), Denmark (2 674 tonnes), Greece (602 tonnes) and Germany (150 tonnes). Since then, eel production has decreased gradually, reaching a minimum of 4 853.8 tonnes in 2012.

When considering only GFCM countries, the peak of aquaculture production, according to FAO FishStat, was reached in 1990 with 5 343 tonnes. The main production countries were Italy (4 050 tonnes), followed by France (810 tonnes), Tunisia (144 tonnes), Spain (125 tonnes), Morocco (60 tonnes) and Greece (45 tonnes). From 1990 onwards, eel aquaculture production has decreased gradually, reaching a minimum in 2011 of 1 274 tonnes (FAO FishStat, 2021).

However, there are discrepancies between FAO FishStat and other data sources. The Federation of European Aquaculture Producers (FEAP), for instance, reported statistics for Mediterranean countries, with a production peak of 2 387 tonnes in 2018. Meanwhile, the GFCM-SIPAM reported peak production of 2 962 tonnes in 2015. In 2019, eel aquaculture production in Europe was 1 480 tonnes according to FAO FishStat, 1 110 tonnes according to FEAP and 1 626 tonnes according to GFCM-SIPAM (Figure 11.1).

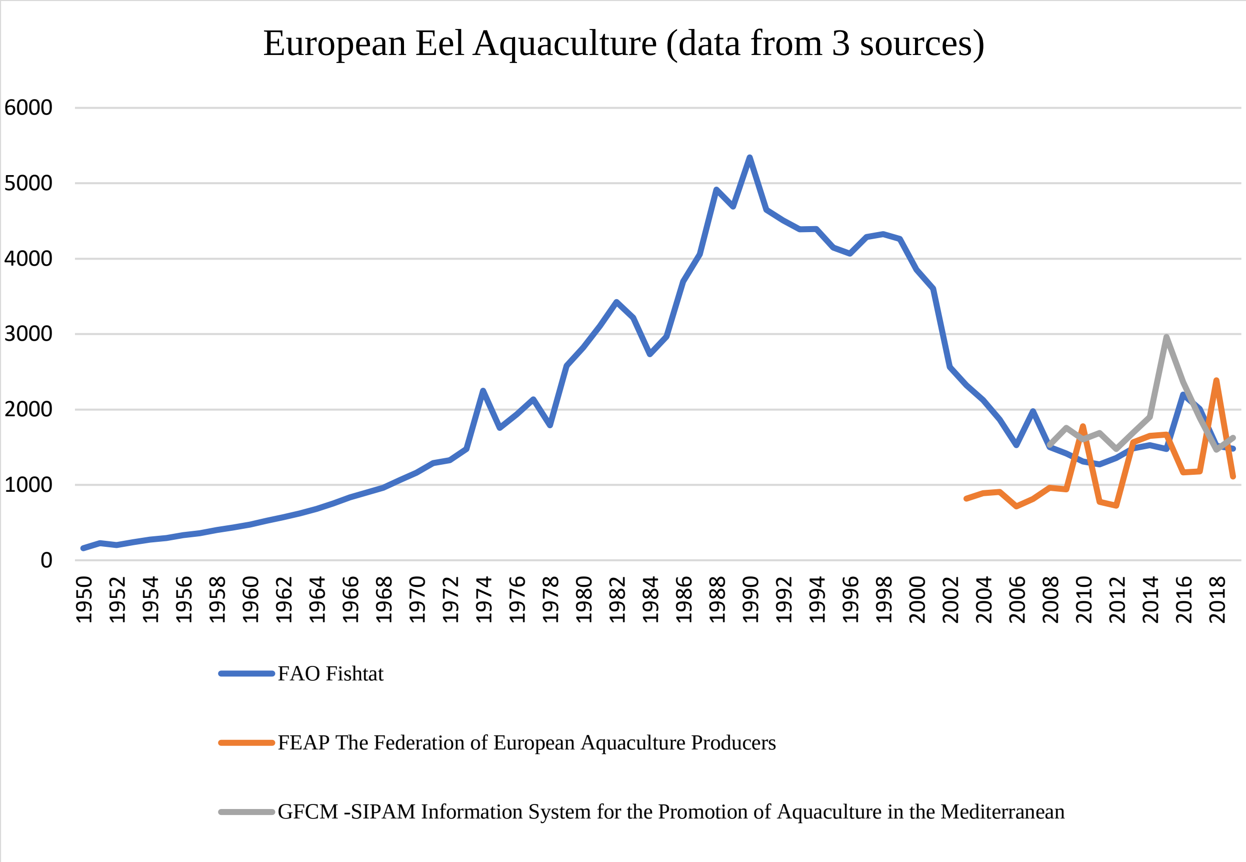

Figure 11.1. Eel aquaculture production (tonnes/year) from FAO FishStat, the Federation of European Aquaculture Producers (FEAP) and the Information system for the Promotion of Aquaculture in the Mediterranean (GFCM-SIPAM)

In light of these discrepancies, overlaps and uncertainties, an overview of eel aquaculture production in the Mediterranean countries was carried out, collecting data through official national statistics and statistical systems at the Mediterranean level and trying to perform a data quality check.

11.2. MATERIAL AND METHODS

11.2.1 Data collection

As a specific task of the research programme and specifically within WP3-Data Collection, data providers were asked to collect, report and revise aquaculture data through the WP3 Database.

The database was prepared in Excel format, with four spreadsheets (see Annex I).

- The general info sheet includes the official codes for: countries, EMUs, habitats, life stages, fishing gear types and definition of missing values.
- The readme sheet explains all the fields of the aquaculture database, with corresponding units of measurement for the numeric values (Supplementary Material on the Methodology, Table 11SM.1).
- The database includes four sections: the site information (country, region, EMU, habitat, site name, year, data source), the production values, including life stage and Y/S ratio, mean values for length and weight and the origin and destination of the seeds.

Data providers were also asked to compile the database by separating production by site, where possible, or by farm type, i.e. intensive, semi-intensive or extensive aquaculture.

The data could come from any available source, including EU projects or Data Collection systems (for example, DCF [Reg. 199/2008], EU-MAP [Decision EU 2016/1251], EUROSTAT.), national or local projects or statistical systems, scientific papers, reviews and reports, grey literature, fishery-dependent data or other data.

11.2.2 Quality checks

A further step in the investigation was aimed at comparing eel production data collected in the WP3-aquaculture task with the GFCM-SIPAM database with data submitted by contracting parties and cooperating non-contracting parties (CPCs), to verify their consistency and homogeneity in view of the harmonization of data for use in official data collection frameworks.

11.3. RESULTS

Of the nine partner countries, only four countries (Italy, Greece, Egypt and Tunisia) reported aquaculture activities and relevant production in WP3. For France, it was clarified that eel aquaculture occurs only on the Atlantic side of the country. The remaining countries (Spain, Algeria, Albania and Türkiye) reported only capture-based eel production and none produced through aquaculture rearing techniques.

11.3.1. European eel aquaculture in Italy

According to the data reported, the largest quantity of European eel aquaculture production in partner countries was from Italy, with data covering the period 2008–2019. Quantities rose from 510.4 tonnes in 2011 to a maximum of 750 tonnes in 2015. The most recently reported production was in 2019, at 464 tonnes. Aquaculture production in Italy stemmed from the three known forms of culture: extensive *Vallicoltura* (Plate 11.1), extensive pond systems (Plate 11.2) and intensive RAS systems (Plate 11.3).

The Italian data were validated after a careful quality check against the GFCM-SIPAM database. Production for the 11 years of available data was derived from 52 aquaculture companies distributed across all Italian regions.

11.3.2. European eel aquaculture in Greece

Greece also provided consolidated aquaculture data covering the period 2008–2019, with a peak of production in 2009 of 428.2 tonnes that decreased to a minimum of 128 tonnes in 2018. The most recently reported production was 146 tonnes in 2019.

Aquaculture production in Greece stemmed from intensive rearing techniques that utilize tank-based systems, growing eels at high densities and under controlled conditions in RAS systems and feeding eels with dry food, several times a day. There were no data on the number of companies that practice European eel aquaculture activities in Greece (Plate 11.3).

11.3.3. European eel aquaculture in Egypt

European eel aquaculture activity was also reported by Egypt indicating that 11 tonnes of eels had been produced in 2018. After quality checking and consultations with the scientific partner as well as different national contacts, it was clarified that Egyptian fish farms have been practicing eel aquaculture since at least 2010 (7 tonnes produced), with reported production varying from one tonne in 2013 to 11 tonnes in 2018. According to the GFCM-SIPAM database, the most recent production was four tonnes in 2019. This production derives from raceways and tanks as well as ponds, thereby covering all aquaculture systems from extensive and semi-intensive to intensive RAS systems. These data need to be further validated by the Egyptian authorities, and until then should be used with care (Figure 11.2).

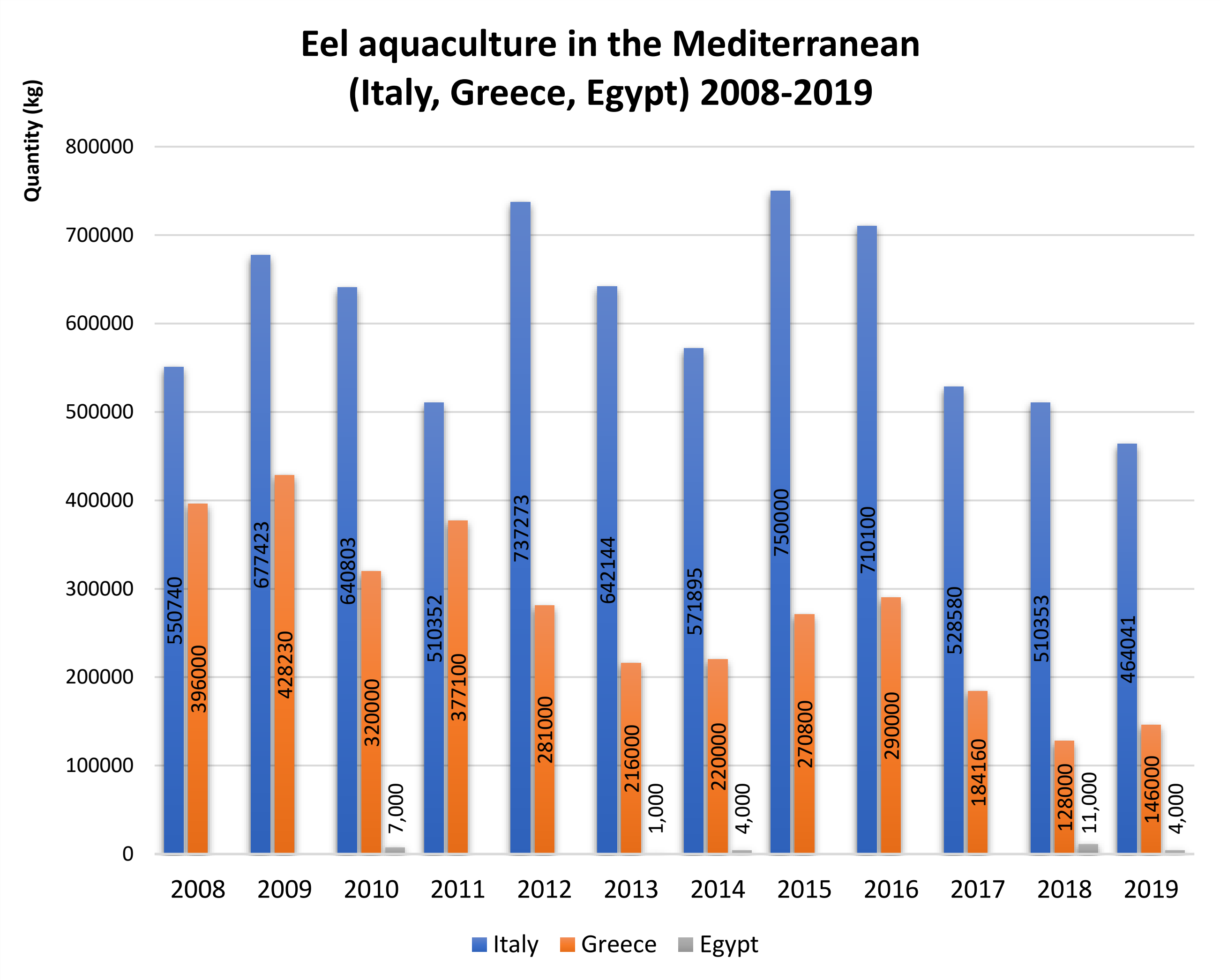

Figure 11.2. Eel aquaculture production (kg/yr) in Italy, Greece and Egypt, 2008–2019

11.3.4. Eel aquaculture in Tunisia

Eel production data were reported by the scientific partner in Tunisia, but after quality checking it was decided that these data would be considered as eel fishery and reported in the eel landings database. In Tunisia, until 2008, glass eels were collected at sea and stocked in reservoirs where growth occurred naturally. The human intervention took place because dams represented obstacles for recruitment and was used only to transfer seed into the upper dams that could not be reached naturally. The activity can thus be classified as enhanced fisheries in reservoirs, sustained by catching and transporting glass eels.

11.3.5. Other partner countries (Spain, France, Algeria, Albania)

The lack of eel aquaculture activity on the Mediterranean side of France was confirmed through GFCM-SIPAM data, while Spain, Algeria, and Albania did not report any data for eel aquaculture activities. For these three countries, eel aquaculture production data resulted from at least two sources: FEAP data and GFCM-SIPAM data. However, these data were not included in the WP3 database, as partners could verify the source of data–that is, the internal statistical system providing data to SIPAM–on quantities, culture typology and the exact locations of culture activities. This was particularly problematic for Spain, where some eel production refers to “Inland waters – Europe”, making it difficult to understand if the activities take place on the Atlantic or the Mediterranean side of the country. It was difficult to implement a deeper investigation of eel aquaculture production within the time frame of the research programme and also due to constraints related to Covid-19. Therefore, this investigation was delayed to a later time, and will involve both GFCM-SIPAM officers and national authorities performing aquaculture data collection in the countries.

11.4 DISCUSSION AND CONCLUSIONS

Of the nine Mediterranean countries that participated in the research programme, only Italy, Greece, Egypt and Tunisia reported clear data for aquaculture activities in their countries. Data collection for aquaculture was performed by these four countries, relying on official national statistics. A quality check was carried out, which also involved scientific partners and national focal points, to check this information against the official data submitted by the countries to the GFCM-SIPAM database. Quality checks were also performed with the aim of identifying potential critical issues in current aquaculture data collection systems. Italian producers account for the most significant aquaculture production in the Mediterranean region, where 2019 production was 510 tonnes. Greece followed with 146 tonnes in 2019, while fragmentary aquaculture data were observed from Egypt, starting from 2018 and reporting 4 tonnes in 2019.

The results of this task highlighted the need for a revision of the GFCM-SIPAM database and national statistical systems, also taking into account data collection methodologies for eel aquaculture. Revising the information required for understanding the type of eel culture, including the location and the seed source, is also needed. These were key factors determining why no data could be provided by Albania, Algeria and Spain, while for France it was ascertained that no eel aquaculture occurs on the Mediterranean side of the country.

From the quality check, relevant overlaps between extensive aquaculture and fishery activities were observed:

- In some sites categorized as managed lagoons, eel production was reported as extensive aquaculture and recorded twice–that is, also as fisheries catch (in Italy, for example).
- In some sites categorized as lake-reservoirs, where eel catches were enhanced, fisheries (glass eel restocking-based) were reported as aquaculture (in Tunisia, for example).

After quality checks, only Italy, Greece and Egypt were considered to provide sound data on eel aquaculture. Aquaculture data reported by Tunisia were revised as fishery catches, as aquaculture in this country is based on the transportation of glass eels to dams and lakes to enhance fisheries.

European eel aquaculture is a capture-based activity relying on seed from the wild, both of glass eels and young yellow eels. For this reason, the availability of seed material is considered a limiting factor to the growth of commercial aquaculture operations.

It was not possible to carry out further investigations at the level of single aquaculture companies, as the required information was not available. Therefore, at present, no information can be given about the seed origin, type and quantities.

The results highlight that information and detailed data on seed (glass eels and juvenile yellow eels) quantities and origin should be included in the current statistical systems that collect aquaculture data. The present traceability system focuses only on international trade, but illegal fishing and illegal trafficking may still be present, linked to aquaculture activities.

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Supplementary Material on the Methodology – ReadMe spreadsheet for the WP3 database relative to eel aquaculture with the list of variables and relative information for compilation

Table 11SM.1. ReadMe spreadsheet for aquaculture data

SITE INFORMATION	CODE	EXPLANATION	UNITS	TYPE OF UNITS	NOTES
Country	**Country_fullname**	Full name of your country		Character	
Country code	**Country_code**	Two-letter code of your country		Character	
EMU	**EMU_nameshort**	See ***EMU*** codes in the *General INFO* spreadsheet		Character	
Farm typology	**Farm_type**	Tank (intensive or semi-intensive aquaculture), pond (extensive aquaculture)		Character	
Year	**Year**	Four digits (YYYY) - add successive rows for different years		Number	
Info source	**Info_source**	Origin of the data collected: EU project (e.g. DCF [Reg. 199/2008], EU-MAP [Decision EU 2016/1251], etc.), national/regional/local project, other project (e.g. LIFE, Interreg, etc.), scientific papers, grey literature, other data (specify)		Character	
EEL DATA	**CODE**	**EXPLANATION**	**UNITS**	**TYPE OF UNITS**	**NOTES**
Life stage	**Life_stage**	See ***LIFE STAGE*** codes in the *General INFO* spreadsheet		Character	
Eel aquaculture	**Aqua_Kg**	Kilograms of eels placed in aquaculture per year	kg	Number	
Ratio Y/S	**YS_ratio**	If the catches include both yellow (Y) and silver (S) eels, specify the % ratio Y/S		Number	*Indicate the ratio yellow/silver when there are extensive aquaculture situations, or in the presence of fattening activities of silver eels, in*

					which there can be both yellow and silver eels in the same site
Mean length	**Length_ave**	Average length **(in millimeters)** per site / year	mm	Number	
Mean weight	**Weight_ave**	Average weight **(in grams)** per site / year	g	Number	

ORIGIN AND DESTINATION	CODE	EXPLANATION	UNITS	TYPE OF UNITS	NOTES
Origin of the stock	**Country_Ori**	Country origin of the stock		Character	
Enterprise name	**Company**	Name of the company		Character	
Destination of the production	**Dest**	Trade, restocking, export		Character	
Comments, notes and other data	**Notes**	Report here if your data are different from those specified in the database, if there is a particular situation in your Country not described here, or any other information you think could be useful to be added to the database		Character	

CHAPTER 12. MANAGEMENT AND PROTECTION MEASURES FOR STOCK RECOVERY

ABSTRACT

The purpose of Work Package 1 of the research programme was to identify and record all the measures that participating Mediterranean countries have implemented, directly or indirectly, for the i) management; and ii) protection of European eel. All measures targeting the reduction of human induced mortality and the increase of spawner (silver eel) escapement were included in the first category while the second category included measures targeting the protection of habitats or species other than eel, that are considered beneficial for eel, for example, the European Union Habitat Directive. Towards this goal, questionnaires were circulated to all the national focal points and to as many stakeholders as possible with direct or indirect involvement in eel fisheries or protection including regional and local authorities, management bodies of protected areas and fishing cooperatives. The collected information revealed a great variety and variability in measures, and related targets such as minimum landing sizes, gear restrictions and closure periods. However, comparable measures or sets of measures were implemented by most of the participant countries, within the different frameworks foreseen at the European Union or national level. The complexity and diversity of measures implemented in Mediterranean countries for the management and protection of the stock and its recovery are noticeable. Some of these stemmed from measures applied for the regulation of fisheries other than eel, while others are specific to eel, but even then, the range of options was wide. It was therefore impossible within this review to evaluate and discuss the efficacy of single measures. On the other hand, the comprehensive review provided by this chapter offered a basis for work on the assessment of alternative management scenarios foreseen in Work Package 4 and described in Chapter 13 and can serve to open a wider discussion about potential management scenarios. Such management scenarios have the primary aim of simplifying the management settings through the standardization of applicable measures. A discussion with scientific partners allowed the identification of some simple potential scenarios, especially for lagoons, taking into account specific fishing closures for specific stages, measures on specific gears (for example, restrictions or landing sizes), different levels of reduction of fishing effort relative to the main fishing gear in use, habitat related measures and alternative measures. The relatively short time frame for the implementation of management frameworks (some from 2008, following the European Union Eel Regulation, others even more recent), that would require exhaustive time series of data at a detailed spatial scale, did not allow an evaluation of the effectiveness of existing management plans. Future work should focus on the identification of specific methodologies and methods to evaluate the implementation of management frameworks and specific measures and their effectiveness at the Mediterranean level which should be integrated with the current work undertaken by joint the European Inland Fisheries and Aquaculture Commission (EIFAAC)/International Council for Exploration of the Sea (ICES)/GFCM Working Group on European Eel (WGEEL) over the entire distribution area of European eel.

HIGHLIGHTS

- A comprehensive review and analysis of management frameworks and management measures in place specifically in the Mediterranean were carried out, related both to fisheries management and measures for the stock recovery.
- Information on the management measures within other management frameworks not specific to eel but potentially beneficial to the eel stock was given.
- Data and information on management measures were analysed by country, eel managememt unit, type of fishery (commercial and recreational) and habitat typology.

- Due to the different management frameworks and the lack of coordination, a very heterogeneous picture emerged from this comprehensive survey.
- Measures aimed at regulating fisheries overlapped with those specifically targeting eel and their recovery, resulting in a very wide range of measures. A more consistent approach to eel management should be contemplated in the perspective of a coordinated management approach.
- The review allowed for the identification of potential management scenarios, especially for lagoons, taking into account different sets of measures, to be appraised within the assessment work described in Chapter 13 (Work Package 4).

12.1. INTRODUCTION

12.1.1. Background

The collapse of the population of European eel was attributed to a combination of both natural and anthropogenic impacts, which affected both the eel population, over multiple life stages, and its habitats. Overfishing, habitat degradation, contamination and the spread of infectious diseases and the swimbladder parasite *Anguillicola crassus*, in combination with climate change (mainly in the oceanic environment), may have contributed greatly to the collapse of European eel stock. All these factors affected, on one hand, the spawning stock size and on the other hand, the quality of the escaping spawners (silver eel), thus affecting spawning success and minimizing recruitment (Belpaire *et al.* 2016; Drouineau *et al.*, 2018)

By 2008, European eel was classified as critically endangered in the International Union for Conservation of Nature (IUCN) Red List (Jacoby and Gollock, 2014), while in 2007, the European Union (EU) issued Regulation (EC) No. 1100/2007, forming the basis for all EU Member Countries exploiting eel through fisheries (targeting all or some life stages of the species) or aquaculture to establish measures through national eel management plans (EMPs) for recovery of the stock. The goal of EMPs was, and is, to reduce the anthropogenic mortality (including fisheries, habitat degradation, and the impact of turbines) and thereby increase the escapement of silver eel for their spawning migration to the Sargasso Sea, contributing to recovery of the species. Furthermore, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), under Appendix II, established restrictions on eel exports issuing permits for eel trade only within the European Union. Since 2010, the critical status of the stock has been recognized as well as the necessity for Mediterranean countries to participate in the European actions for the protection and recovery of European eel (Aalto *et al.*, 2016).

Since European eel is a panmictic species with a single breeding stock (Dannewitz *et al.*, 2005), all countries within the eel distribution area need to reconsider their management measures. Unless minimum measures are taken by all countries throughout the distribution area, management measures taken independently by a single country, no matter how strict, are unlikely to be sufficient for conservation of the species. It should therefore be noted that the implementation of sustainable management for recovery of such a widely distributed species is not easy and requires appropriate coordination and cooperation. Despite clear evidence for a single breeding stock (Andrello *et al.*, 2011), appropriate management measures may be set and evaluated at a regional level, as suggested for the Atlantic, North-Baltic and Mediterranean regions (Wirth and Bernatchez, 2001, Maes and Volckaert, 2002). Currently, most EU countries have started management actions (according to Regulation (EC) No. 1100/2007) to reduce fishing mortality and increase silver eel escapement but the regulation does not cover non-EU countries. At the Mediterranean level, the GFCM, through Recommendation GFCM/42/2018/1 on a multiannual management plan for European eel in the Mediterranean Sea, opened an opportunity for Mediterranean countries to address eel management measures in a coordinated way. This chapter presents eel-specific management measures reported by the nine project partners and analysed by country and habitat.

European eel management is also affected by many other laws and regulations and further influenced by international conventions as well as advisory and management bodies in the fields of nature conservation and fisheries, which support policies and authorities in eel management and protection. In the following section, these drivers for eel management (specific and non-specific) will be described.

The aim of this chapter is to list and critically examine eel management and conservation measures, also addressing their present implementation and their potential effectiveness. In that respect, the management settings were reviewed considering the frameworks in place that are specific to eel and also those that are more general that might be beneficial for its protection.

The terminology used in this chapter is important, especially with respect to the analysis of local management. Thus, for the purposes of this chapter, the term "regional" refers to within country administrations or other entities (for example, the *prud'homies* in France) that manage eel locally under specific management plans including EU EMPs, national management plans or at the level of eel management units (EMUs).

Eel management plans are management plans formally adopted by EU Member States at the national level (and implemented through specific measures either at national or at EMU level depending on the Member State), in response to the requirements of Council Regulation (EC) No. 1100/2007. National management plans are management plans adopted by countries at the national level: they include EMPs but also management plans implemented at the national level by countries not covered by Council Regulation (EC) No. 1100/2007.

Eel management units were defined under Council Regulation (EC) No. 1100/2007 as individual river basins lying within their national territory that constitute natural habitats for the European eel (eel river basins) which may include maritime waters. If appropriate justification is provided, a Member State may designate the whole of its national territory or an existing regional administrative unit as one eel river basin.

12.1.2. Eel-specific frameworks

GFCM

In a transversal GFCM workshop on the European eel (Salammbô, Tunisia, 23–25 September 2010), the experts recommended the development of management plans for European eel covering all subregions of the Mediterranean and also the engagement of the Mediterranean in a joint working group on eel. The creation of a joint European Inland Fisheries and Aquaculture Commission (EIFAAC)/International Council for Exploration of the Sea (ICES)/GFCM Working Group on European Eel (WGEEL) was subsequently approved by the forteenth session of the Scientific Advisory Committee on Fisheries (SAC) and the thirty-sixth annual session of the GFCM in 2012. At its thirty-seventh annual session in 2013, the GFCM agreed to support an eel pilot action, to contribute towards the participation of Mediterranean countries in the actions for the European eel at a stock-wide level.

At the forty-first annual session of the GFCM in 2017, the status of the European eel was recognized as critical and the need for the development of a regional management plan was underlined. In this context, the European Union, jointly with Tunisia, expressed the intention of proposing a management plan for the European eel in 2018. This management plan was to be based on the conclusions of a dedicated working group on European eel.

Following a GFCM workshop on the management of European eel (WKMEASURES-EEL) in 2018, during which technical elements for the management of European eel in the Mediterranean Sea were drafted, the forty-second annual session of the GFCM in 2018 adopted Recommendation GFCM/42/2018/1 based on a joint proposal of Algeria, the European Union and Tunisia. This multiannual management plan, applicable to all habitats where fishing activities occur in the Mediterranean Sea (freshwater, marine and transitional waters), was designed in a stepwise manner to provide and maintain high long-term yields and to guarantee a low risk of stock collapse while maintaining sustainable and relatively stable fisheries. Thus, the following transitional measures were adopted while collecting further scientific information towards a future long-term multiannual adaptive management plan:

- A 30 percent reduction in fishing effort compared to the reference period 2006–2008 (or to another three-year reference period defined by contracting parties and cooperating non-contracting parties [CPCs]) applicable on a progressive basis with an annual 10 percent reduction over a period of three years starting from 1 January 2019.
- An annual fishing closure of three consecutive months where landing European eel shall be prohibited.
- The possibility of establishing fisheries restricted areas (FRAs) to further protect European eel.

During this transitional period, efforts would be made towards enhancing data collection, through the inclusion of past data, as far back as possible, and from areas where European eel is known or is likely to occur in their respective waters. Importantly, the recommendation established the need to design and launch, in 2019, a research programme (RP) on European eel in the Mediterranean Sea, to be completed before the forty-fifth session of the GFCM. Based on the results of the RP and of a dedicated working group on the management of European eel, in 2023, not later than six months before the annual session of the GFCM, the SAC would advise on appropriate measures to achieve the long-term objectives towards adopting long-term management measures in the same year.

The first Working Group on the management of European eel (WGMEASURES-EEL) in 2019 discussed and determined the way forward, including:

- Draft a work plan for the consideration of the SAC to address Recommendation GFCM/42/2018/1, including a roadmap towards the evaluation of management measures.
- Identify gaps and needs for research towards providing terms of reference to support the implementation of an RP.
- Establish a network of people and entities working on European eel.

European Union

The European Commission adopted Council Regulation (EC) No. 1100/2007 establishing measures for the recovery of the stock of the European eel (18 September 2007). The regulation "ensures that there is coordination between measures taken under this regulation and those taken under the Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora and Directive 2000/60/EC" (EU, 1992). Within the European Union, the eel stock, fisheries and other anthropogenic impacts should be managed in accordance with Council Regulation (EC) No. 1100/2007, "establishing measures for the recovery of the stock of European eel" (EU, 2007).

European Union Member States should develop EMPs after implementation of Council Regulation No 1100/2007 relating to the recovery of the European eel. These plans include management measures such as reduction in fisheries, improving river continuity, reducing pollution, bypassing turbines and pumps, easing of barriers and restocking. In accordance with this regulation, each EMP set the main objective to "reduce anthropogenic mortalities so as to permit with high probability the escapement to the sea of at least 40 percent of the silver eel biomass relative to the best estimate of escapement that would have existed if no anthropogenic influences had impacted the stock" (EU, 2007). Council

Regulation (EC) No. 1100/2007 stated that, apart from fisheries, eel mortality is caused by hydroelectric turbines, pumps or predators and measures should be applied for the protection of the stock. Management actions in EMPs do not take eel condition or quality into account (Belpaire *et al.*, 2019).

In 2019, implementation of the eel regulation was evaluated to assess the measures established for the protection and sustainable use of the European eel stock. The importance of the regulation in catalysing activity towards the recovery of the European eel was highlighted, but considering that the European eel remained in a critical condition and recovery could take decades, more ambitious requirements were declared (European Commission, 2020).

Implementation of the EMPs is evaluated triennially during the Workshop for the Review of Eel Management Plan Progress Reports (WKEMP). This independent review of EMP progress was a request from the European Commission to ICES with the main aim of the review being the delivery of solid estimates of stock parameters by EMU in terms of biomass and mortality, to reflect the state of the stock and the exploitation status in Europe. The WKEMP approached this task by reviewing the national reports on implementation of eel management plans, which were requested by the European Commission in 2021 in line with the Council Regulation (EC) No. 1100/2007. The workshop met in late 2021 and early 2022 and used data and information provided by the 2021 WGEEL, including material provided in response to the eel data call in 2021.

European Inland Fisheries and Aquaculture Commission and the International Council for Exploration of the Sea

In 1968, EIFAAC, a regional commission of FAO, introduced the item “Biology and management of the eel” at its fifth session held in Rome (Italy). Following this meeting, countries interested in eel held WGEEL meetings of eel experts (Lecomte-Finiger, 2002). The first time ICES held a symposium on eel was in Helsinki (Finland) in 1976 (Lecomte-Finiger, 2002). The WGEEL meetings were held nearly every year by EIFAAC/ICES to report on eel-specific issues, such as annual stock assessment, new science, emerging threats and opportunities (ICES, 2013; ICES, 2014).

Following the drastic decline in recruitment of European eel after the 1980s, many actions and tools were developed as well as methods to compile and analyse comprehensive data on its single stock. In addition, the EIFAAC/ICES group reviewed the impacts of both anthropogenic and non-anthropogenic factors on the stock. European Union member states with some non-EU member states reported quantitative estimates of the stock indicators (ICES, 2013). The incomplete reporting, due to there being no legislative requirement for the collection of data from outside the European Union, was brought to the agenda and information from some GFCM countries was included in the annual report in 2014 for the first time (ICES, 2014).

The joint ICES/EIFAAC/GFCM WGEEL was approved in 2012 at the fourteenth session of the SAC and subsequently the thirty-sixth annual session of the GFCM and has been active in this capacity since 2014, with the aim of i) providing updates on available information on European eel and reporting on any updates to the scientific basis of the advice; ii) assessing the state of the European eel and its fisheries; and iii) producing a first draft of the advice on the status of European eel for the consideration of relevant scientific bodies of the three organizations. The advice produced by WGEEL is then endorsed within each organization, which also use this advice on status of stocks to provide advice on potential management measures to be implemented. For example, under the GFCM, this occurs through the WGMEASURES-EEL whose recommendations are reviewed by the SAC which then formulates advice for the consideration of the GFCM annual session.

Convention on International Trade in Endangered Species of Fauna and Flora

European eel is exploited and traded on a global scale for direct consumption, culture or stocking in various life stages, ranging from glass to silver eel (Jacoby *et al*., 2015) and owing to concerns that the declining trend in the European eel population may be attributable to catches for international trade with a series of other impacts, this species was proposed for listing in Appendix II of CITES at the fourteenth Conference of the Parties to CITES in June 2007. Appendix II of CITES includes species that are not necessarily threatened with extinction, but where trade must be controlled to avoid utilization incompatible with their survival. This listing came into force on 13 March 2009 (CITES, 2007), along with the equivalent Annex (B) of the EU Wildlife Trade Regulations. The CITES Appendix II procedure requires a positive non-detriment finding (NDF) before trade of European eel can be permitted and the convention seeks to ensure in an NDF assessment that international trade of this species is sustainable. An NDF is made by the national scientific authority, following a science-based risk assessment.

In December 2010, the EU Scientific Review Group concluded that it was not possible to perform an NDF for the export of European eel and subsequently a zero-import and export policy was set for the European Union (EC, 2010; EC, 2014). On that basis, EU CITES management authorities were not able to allow exports of European eel from the European Union and commercial trade in all commodities of European eel to and from the European Union were banned from 3 December 2010 (EC, 2010; EC, 2014; EC, 2016; Shiraishi and Crook, 2015). However, trade continues within the European Union and trade from non-EU range states (states where European eel is found) to non-EU countries is permitted (Crook, 2010).

In 2021, CITES sought information from parties on the status, management and trade of eel, including European eel. Parties were invited to provide any relevant information on the implementation of any NDF studies on European eel. In this context, CITES Decision 18.197 directed the range states of European eel to do the following:

- Submit any NDF studies on European eel they have undertaken to the Secretariat for inclusion on the CITES website; explore the different approaches that might be taken for making NDFs for European eel traded as fingerlings compared with those traded as other live eel; collaborate and share information with other parties regarding such studies and their outcomes, especially where the parties share catchments or water bodies; seek review and advice from the Animals Committee or other suitable body on any NDFs for European eel where appropriate.
- Develop and implement European EMPs and enhance collaboration within and between countries where water bodies are shared.
- Share information on stock assessment, harvests, the results of monitoring and other relevant data with the WGEEL, so that a full and complete picture of the state of the European eel stock can be established.
- Develop measures or implement more effectively, existing measures to improve the traceability of eel in trade.
- Provide the Secretariat with information regarding any changes to measures they have in place to restrict the trade in live glass or fingerling European eel.

United Nations Environment Programme Mediterranean Action Plan Regional Activity Centre for Specially Protected Areas

Under the umbrella of the Regional Seas Programme of the United Nations Environment Programme Mediterranean Action Plan (UNEP/MAP), the Convention for the Protection of the Mediterranean Sea against Pollution (the Barcelona Convention) was adopted in 1976 and renamed the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean in 1995. One of the seven protocols of the Barcelona Convention concerns the Specially Protected Areas and Biological Diversity in the Mediterranean (SPA/BD) protocol with the objective of providing the regional framework for the conservation and sustainable use of biological diversity in the Mediterranean. In this context, Annex III of the SPA/BD protocol lists species whose exploitation is regulated, including European eel.

Convention on Migratory Species

In 2014, European eel was listed in Appendix II of the Convention on Migratory Species (CMS) covering migratory species that have an unfavourable conservation status and requiring international agreements for their conservation and management, as well as those that have a conservation status which would significantly benefit from the international cooperation that could be achieved by an international agreement. The convention encourages range states to conclude global or regional agreements for the conservation and management of individual species or groups of related species listed in Appendix II. After the first meeting in 2016, in 2017, the twelfth session of the Conference of the Parties (COP) to CMS adopted a concerted action for European eel, which envisaged a number of future actions, including a second meeting of range states as well as the identification of actions complementing both the 2016 CITES COP17 decision and the IUCN World Conservation Council 2016 Resolution that relate to anguillid eel.

Meetings in 2018 and 2019 had the aim of exploring all options that might help to strengthen conservation efforts for the European eel. The Concerted Action on the European eel was completed, and, at the third meeting of the range states (2019), it was decided to draft a COP document (UNEP/CMS/COP13/Doc.26.2.9) that proposes a way forward and would be considered for adoption at CMS COP13 in February 2020.

International Union for Conservation of Nature

The first listing of European eel in the IUCN Red List as Critically Endangered (CR; A2bd+4bd) was in the 2008 IUCN Red Data Book and was based on a first assessment that did not change in 2010 (Freyhof and Kottelat 2008; Freyhof and Kottelat, 2010). Declining trends in recruitment of glass eel with declining yield and stock abundance since 1960, were the major indicators used to evaluate the population status through three generations.

In 2014, the status was re-evaluated, highlighting a range of potential threats to European eel due to its complex life history including habitat loss and modification, migration barriers, pollution, parasitism and fluctuating oceanic conditions, as well as exploitation, all of which have resulted in a significant depletion of stock across its range (Jacoby *et al.,* 2015). The listing was confirmed as CR in 2013 (Jacoby and Gollock, 2014) and 2018 (ICES, 2021) due to a proportional decline in population on a continental scale over the last three generations (Pike, Crook and Gollock, 2020).

12.1.3. Other non-specific international instruments that might be beneficial to eel

Ramsar Convention

The Convention on Wetlands (Ramsar, Iran, 1971) is an intergovernmental treaty whose mission is "the conservation and wise use of all wetlands through local and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world". The Ramsar Convention on Wetlands was developed as a means to call international attention towards the rate at which wetland habitats were disappearing.

However, the convention benefits not only wetlands, but also the fauna that inhabit them, such as fish, water birds, insects and mammals, as well as migratory species whose conservation and management require international cooperation. In this framework, Secretariats for the Ramsar Convention and CMS signed a memorandum of understanding in February 1997, which sought to ensure cooperation between them for joint promotion of the two conventions through joint conservation action, data collection, storage and analysis, and new agreements on migratory species, including endangered migratory species. Any action and measure targeting sites designated under the Ramsar Convention might, directly or indirectly, be beneficial to eel.

NATURA 2000 Convention

In 1979, the EU Birds Directive (Council Directive 79/409/EEC of 2 April 1979, amended in 2009 as Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds) established an EU-wide protection regime for all bird species naturally occurring in the European Union. This was the first EU legislation on the environment, aiming to protect the more than 500 wild bird species naturally occurring in the European Union.

This approach was extended through the 1992 EU Habitats Directive (Council Directive 92/43/EEC of 21 May 1992), which also provided for the establishment of a representative system of legally protected areas throughout the European Union, the NATURA 2000 Ecological Network. According to the European Union, the Habitats Directive ensures the conservation of a wide range of rare, threatened or endemic animal and plant species. Some 200 rare and characteristic habitat types are also targeted for conservation in their own right (EU Nature Law). These areas are named sites of community importance (SCI) and aim for the conservation of the 233 habitat types listed in Annex I of the Directive and the 900 plus species listed in Annex II. The target of both the Natura 2000 network and the 1992 Habitats Directive is to ensure the long-term sustainability of the habitats and species they have been set up to protect.

Certain articles of the Habitats Directive require member states to report on the conservation status of habitats and species and on compensation measures taken for projects having a negative impact on Natura 2000 sites. For example, Article 6 is one of the most important articles as Member States are required to take measures within Natura 2000 to maintain and restore the habitats and species to a favourable conservation status, avoiding activities that could significantly disturb these species, result in deterioration of their habitats or damage habitat types. The protection of habitats and their restoration to a favourable conservation status, benefits, indirectly, the European eel, even though it is not included in the list of the species of community interest in Council Directive 92/43/EEC, since the habitats in which they live are protected by the directive or are being restored through management plans.

Other national measures

Aside from international networks and directives, each country has its own national regulations directly targeting the protection of European eel, or indirectly targeting it by bringing forward measures for the protection of habitats or other species, such as fisheries closures or fishing gear bans. There are cases of total closure due to high concentrations of pollutants, but closures mainly aim at increasing spawner escapement or recruitment. Fisheries measures can apply to specific life stages or all life stages, and to specific eel habitats or to all habitats.

Similarly, fishing gear bans are set to protect European eel (or a specific life stage) or other species when eel is considered a bycatch. Examples are mechanized dredges, devices generating electric shocks, toxic and corrosive substances, explosive devices, drifting gillnets and shrimp trawl gear.

12.2. MATERIALS AND METHODS

12.2.1. Data collection

Two questionnaires were prepared to identify the management measures that each country had established at national or regional level or as part of their EMPs, for eel protection and recovery. The aim was to identify measures affecting both commercial and recreational fisheries and then identify measures establishing restrictions on eel fisheries, such as minimum landing size (MLS), life-stage restrictions or fisheries closures.

Each questionnaire was addressed to various levels of administration, including the national administration or relevant ministry and regional and local stakeholders such as regional authorities, municipalities, management bodies of protected areas and fishing cooperatives, in an effort to collect all the required information to create a database of management measures in place for the protection of European eel.

Data were received from all nine participant countries and management measures were categorized with the aim of comparing recreational and commercial fishing measures, EMPs and national or regional measures and eel-specific compared to non-specific measures.

12.2.2 Database

The two databases were prepared in Excel format, with eight spreadsheets each:

- A readme sheet explained all the fields of all the possible answers provided in drop down menus.
- The general information sheet included the names and email addresses of the data processors, the source of the data, a brief description on how the data were gathered and subsequently treated.
- Both databases (for focal points and regional local stakeholders) included six sections, gathering information on:
    - habitats (country, region, type of habitat in each country, presence of transboundary habitats in general, presence of eel-specific habitats and transboundary eel habitats);
    - eel fisheries (type of fisheries, eel stage targeted, trade, CITES, closures, and illegal, unreported, unregulated fishing);
    - EMPs (established or not, year, administrative level [national or regional], EMUs, prohibitions [life stages, habitats, fisheries] and assisted migration actions);
    - eel specific management measures other than EMPs (national or regional laws, prohibitions [fisheries closures, life stages, habitats, minimum landing size]);
    - releases or restocking, (opposed by EMP or other laws, life stages released or restocked, habitat, frequency), and;
    - general national measures, (fisheries prohibitions due to a specific network such as, NATURA 2000 or Ramsar and species protection measures, habitat protection or fishing gear prohibitions).

12.2.3. Quality check

Before starting quantitative analysis of the fishery data, a quality check on the data collected was carried out. In particular, corrections concerned duplicate rows, site names with spelling errors, data inconsistencies, errors in habitat attribution and empty cells.

All data gathered by the participant countries were merged into one file, including data from Work Package 3, such as coordinates of the indicated habitats in each EMU or at local regional level. The complete database was then forwarded to the appointed national focal point for revision and an indication of whether they were correct or not. In case data were not correct, the national focal points were contacted to verify the information that was provided through the questionnaires.

12.2.4. Data analysis

The questionnaires were transformed to a database in an Excel file. The same sites, EMU, region (local entity), coordinates and habitat type in the Work Package 3 databases for fisheries and habitat were used. In the evaluation of measures, EMPs, national management measures (NMM) and regional (local) management measures (RMM) were considered.

Within each measure type, the following sublevels were analysed: MLS, life stage-related restrictions, gear mesh size restrictions, assisted migration, restocking and time-based closure periods (duration, and start and finish dates).

All the fishery sites were assumed to be habitat sites, so each site appeared only once in the database.

The analysis was performed in this way for both commercial and recreational fisheries.

12.3. RESULTS

12.3.1 Overview of fishery-related measures

Table 12.1 reports all the eel specific measure-types in GFCM countries. Of the nine country partners, Algeria, France, Greece, Italy, Spain and Tunisia had EMPs while eight of the country partners (all except Egypt) had national management measures and Algeria, France, Italy, Spain and Tunisia had regional (local) management measures that applied to eel. Under each of these levels, measures were evaluated in terms of both commercial and recreational fisheries. According to the replies of administrative and scientific partners, country management plans were summarized generally as tables at the Mediterranean level.

Table 12.17. Eel-specific measures in GFCM countries (partner countries capitalized)

	Eel management plan present (year implemented)	National management measures present	Regional management measures present
ALBANIA	Yes (2019)	Yes	No
ALGERIA	No	Yes	Yes
Bulgaria	No	No	No
Croatia	Yes	No	No
Cyprus	No	No	No
EGYPT	No	No	No
FRANCE	Yes (2010)	Yes	Yes
GREECE	Yes (2009)	Yes	No
Israel	No	No	No
ITALY	Yes (2011)	Yes	Yes
Lebanon	No	No	No
Libya	No	No	No

	Eel management plan present (year implemented)	National management measures present	Regional management measures present
Malta	No	No	No
Monaco	No	No	No
Montenegro	No	No	No
Morocco	No	No	No
Romania	No	No	No
Slovenia	No	No	No
SPAIN	Yes (2010)	Yes	Yes
Syrian Arab Republic	No	No	No
TUNISIA	Yes (2010)	Yes	Yes
TÜRKIYE	No	Yes	No

12.3.2. Eel management plans

Through the distribution of the second questionnaire to the local and regional level stakeholders, it was possible to identify all the management measures established at EMU (regional/local) level by the six countries with active EMPs. The number of EMUs in these countries is shown in Figure 12.1 and the number by habitat is given in Table 12.2. It is important to note that for Spain and France, only the EMUs in the Mediterranean were taken into consideration. For Greece, although the national EMP established four EMUs, data were available only for three of them, while in the fourth no fisheries or data existed.

The EMP measures for the commercial fishery are summarized in Table 12.3. Spain had 12 EMUs with six of them in the Mediterranean. France had nine EMUs and only two in the Mediterranean. Among all countries with EMPs, all EMUs have fisheries restrictions, except for three EMUs in Spain (Valencia, Catalonia_Int and Catalonia_Ebro) and two in Italy (Lazio and Toscana). Eel fishery prohibitions by life stage depended on the country and the EMU within a country. For example, in France, fisheries restrictions existed for all life stages, while in Greece and in one EMU in Spain, there was total closure of glass eel fisheries and some restrictions on yellow and silver eel fisheries (fishing time restrictions, MLS). In Tunisia and Albania, as well as in two EMUs in Spain and seven EMUs in Italy, there were restrictions in glass eel fisheries, while the EMPs established in Tunisia and in Albania also included actions for assisted migration.

The allowed MLS under EMPs varied between 12 cm and 70 cm. Eel stage restrictions under EMPs varied between glass eel only, to all of the stages together, depending on the country and habitat, as they did at the EMU level. The gear mesh size restrictions under EMPs varied between 10 mm and 40 mm. The duration of temporal restrictions on EMPs varied from one month to 12 months, while the time of beginning and end differed according to site, habitat and stage.

All countries have established measures with restrictions on commercial fisheries based on the life stage. These restrictions are translated either as complete fisheries prohibitions for specific life stages or restrictions based on MLS or on specific closure periods or a combination of the these. The MLS established in five countries and in 14 EMUs, for glass eel varied between 12 mm and 38 mm targeting the protection of recruits (glass eel) and the standing yellow eel population. These life stages are also the target of life stage restrictions in all 24 EMUs.

Greece, Italy, Spain and France reported time-based (temporal) restrictions or fisheries closure periods, which ranged from 2.5 months up to 12 months, with Spain and France reporting different closure periods for different life stages.

Four regions in Albania, four regions in Greece, two regions in Italy, three regions in Spain and two regions in France assist migration of various eel life stages under their EMP actions. In Albania, the release activity is in freshwater for one local region and the others in coastal waters for all stages every year in winter. In Greece, silver eel are released into coastal habitats every year in winter and glass eel are released in freshwater habitats annually or depending on the availability of imports. In Italy, on-grown glass eel (wild-caught glass eel on-grown in aquaculture before restocking) are released every year in winter and spring. In Spain, glass eel, on-grown glass eel and silver eel are released in three regions. In the French Mediterranean area (Rhone EMU), a proportion of the silver eel captured in lagoons is released every year between November and January, close to the sea. In France, there are also national laws for restoring river continuity (related to the EU Water Directive Framework) that advocate for the installation of fish passes at dams.

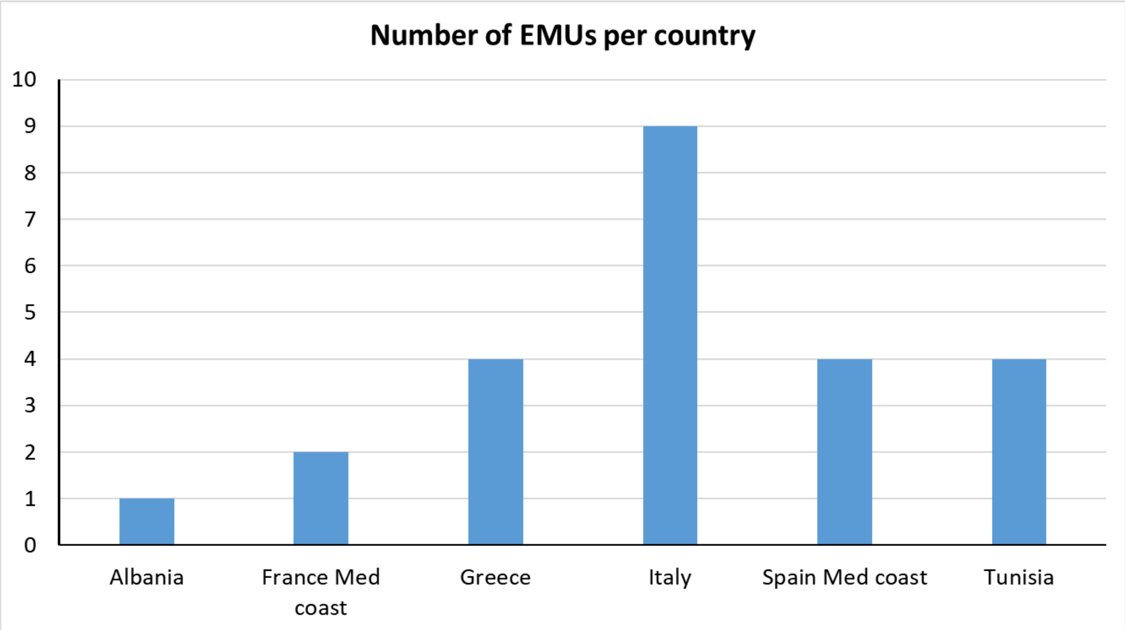

Figure 12.20. Number of eel management units per country with established eel management plans

Note: Greece has four eel management units established based on the Hellenic eel management plan but only three of them have eel fisheries activity or data on species existence.

In total, information on 24 EMUs was provided including management measures for both commercial and recreational fisheries. Additionally, stakeholders provided information on management measures at site level. The 24 EMUs include 568 sites in different habitats, 39.98 percent of which were in lagoons (Table 12.2, Figure 12.2).

Table 12.18. Number of sites per habitat type included in the 24 EMUs, where management measures were established

Habitat Type	
Lagoons	227
Lakes	94
River Estuaries	26
Rivers	132
Coastal Marine Waters	89
Total	**568**

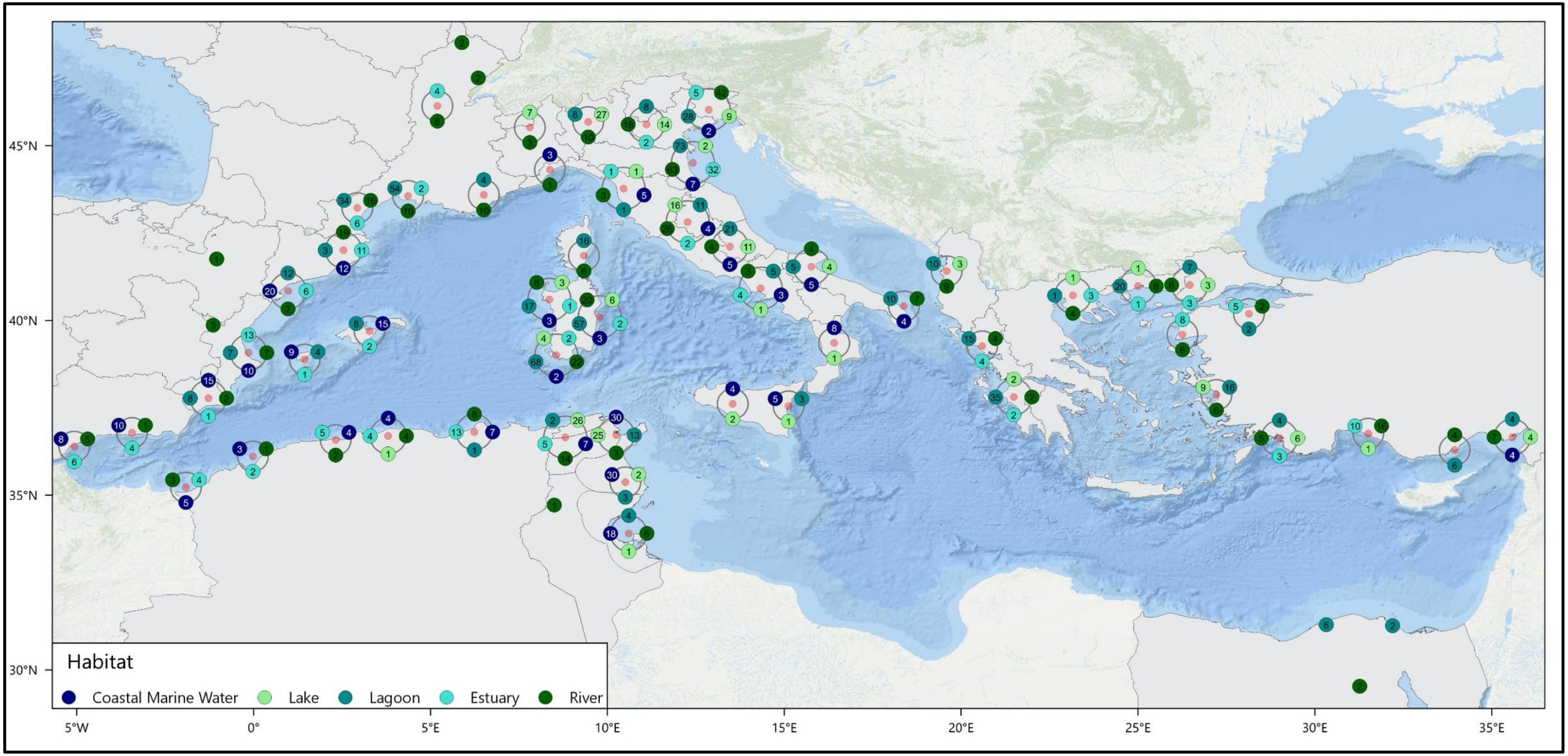

Figure 12.21. Map of the various sites indicating habitat type (coloured dots) and the number of sites (numbers on the dots) included in the 24 eel management units, where management measures were established

Table 12.19. Management measures regarding commercial eel fisheries in each eel management unit, in the countries with established eel management plans

Eel management plans for commercial fisheries						
Country	**Eel management code**	**Habitat type[a]**	**Eel size restriction (minimum landing size, cm)**	**Eel stage restriction**	**Gear mesh size restriction (mm)**	**Gear restriction**
Albania	AL_total	LAK	Yes	G	Yes	No
		LGN				
France	FR_Cors	LGN	Yes	G (forbidden)	Yes	Yes
				YS (restrictions)		
	FR_Rhon	LGN	Yes	G (forbidden)	Yes	Yes
		RIE		YS (restrictions)		
Greece	GR_EaMT	RIV	Yes	GY	Yes	Yes
		LAK				
		LGN				Yes
	GR_NorW	LGN	Yes	GY	Yes	Yes
	GR_WePe	LGN	Yes	GY	Yes	Yes
Italy	IT_Emil	LGN	ND	ALL	ND	ND
		RIE				
		RIV				
	IT_Frio	LGN	ND	ALL	ND	ND
		RIE				
		RIV				
	IT_Lazi	LAK	ND	G (only for restocking)	ND	ND
		LGN				
		RIV		YS (restrictions)		
	IT_Lomb	LAK	ND	ALL	ND	ND
	IT_Pugl	LGN	ND	ALL	ND	ND
	IT_Sard	LGN	ND	ALL	ND	ND
		RIV				
	IT_Tosc	LAK	ND	G (only for restocking)	ND	ND
		LGN				
		RIV		YS (restrictions)		
	IT_Umbr	LAK	ND	ALL	ND	ND
	IT_Vene	LAK	ND	ALL	ND	ND
		LGN				
		RIE				
		RIV				
Spain	ES_Bale	LGN	Yes	All	ND	ND
	Es_Anda		Yes	All		

Eel management plans for commercial fisheries						
Country	**Eel management code**	**Habitat type[a]**	**Eel size restriction (minimum landing size, cm)**	**Eel stage restriction**	**Gear mesh size restriction (mm)**	**Gear restriction**
				The fishery is permanently closed		
	ES_Cata	CMW	Yes	All[b]	ND	ND
		LGN				
	ES_Murc	LGN	Yes	G	ND	ND
	ES_Vale	LGN	Yes	All[b]	ND	ND
		RIE				
Tunisia	TN_All					
	TN_EC	CMW	Yes	G	Yes	
					Yes	
		LAK			Yes	
	TN_NE	CMW	Yes	G	Yes	
		LAK			Yes	
		LGN			Yes	
	TN_Nor	CMW	Yes	G	Yes	
		LAK			Yes	
		LGN			Yes	
	TN_SO	CMW	Yes	G	Yes	
					Yes	

Notes: [a] Habitat type: LAK = lake, LGN = lagoon, RIE = estuary, RIV = river, CMW = coastal marine waters. Eel stages: G = glass eel, Y = yellow eel, S = silver eel, ND = No data.

b In Valencia there is a glass-eel fishery in the Albufera, Ter river and also in the Ebro Delta.

Information on the management measures established for the recreational fisheries were also recorded but resulted in few data as either recreational fishing was completely forbidden or information did not exist (Table 12.4). Only France and Italy provided information on specific measures established for eel recreational fisheries, such as MLS, life stage restrictions and time restrictions.

Table 12.20. Management measures regarding recreational eel fisheries in each eel management unit, in the countries with an established eel management plan

Eel management plans for recreational fisheries						
Country	**Eel management code**	**Habitat type[a]**	**Eel size restriction (minimum landing size, cm)**	**Eel stage restriction**	**Mesh size restriction (mm)**	**Gear restriction**
Albania	AL_total	LAK	ND	ND	ND	ND
		LGN				
France	FR_Cors	LGN	YES	G (forbidden) YS (restrictions)	No	Yes
		RIE	YES	G and S (forbidden) Y (restrictions)		
	FR_Rhon	LGN	YES	G (forbidden)	No	Yes
		RIE		YS (restrictions)		
Greece	GR_EaMT	RIV	NP	NP	NP	NP
		LAK				
		LGN				
	GR_NorW	LGN				
	GR_WePe	LGN				
Italy	IT_Emil	LGN	ND	ALL	ND	ND
		RIE				
		RIV				
	IT_Frio	LGN	ND	ALL	ND	ND
		RIE				
		RIV				
	IT_Lazi	LAK	ND	G (only for restocking)	ND	ND
		LGN				
		RIV		YS		
	IT_Lomb	LAK	ND	ALL	ND	ND
	IT_Pugl	LGN				
	IT_Sard	LGN	ND	ALL	ND	ND
		RIV				
	IT_Tosc	LAK	ND	G (only for restocking)	ND	ND
		LGN				
		RIV		YS		
	IT_Umbr	LAK	ND	ALL	ND	ND
	IT_Vene	LAK	ND	ALL	ND	ND
		LGN				
		RIE				
		RIV				
Spain	ES_Bale	LGN	ND	ND	ND	ND
	ES_Cata	CMW	ND	ND	ND	ND
		LGN				
	ES_Murc	LGN	ND	ND	ND	ND
	ES_Vale	LGN	ND	ND	ND	ND

Eel management plans for recreational fisheries						
Country	Eel management code	Habitat type[a]	Eel size restriction (minimum landing size, cm)	Eel stage restriction	Mesh size restriction (mm)	Gear restriction
		RIE				
Tunisia	TN_All					
	TN_EC	CMW	NP	NP	NP	NP
		LAK				
	TN_NE	CMW	NP	NP	NP	NP
		LAK				
		LGN				
	TN_Nor	CMW	NP	NP	NP	NP
		LAK				
		LGN				
	TN_SO	CMW	NP	NP	NP	NP

Notes: [a] Habitat type: LAK = lake, LGN = lagoon, RIE = estuary, RIV = river, CMW = coastal marine waters. Eel stages: G = glass eel, Y = yellow eel, S = silver eel, ND = No data, NP = not pertinent.

12.3.3. National management measures

Regarding commercial fisheries, eight countries (all partner countries except Egypt) have national eel-specific measures.

In Algeria, Greece and Tunisia, the minimum eel size allowed is 30 cm, while in France it is 12 cm, in Albania it is 35 cm and in Türkiye it is 50 cm. In Spain, eel size restrictions varied between 35 cm, 38 cm and 70 cm, depending on the local region and the habitat type. Additionally, in each country there are different eel stage restrictions for glass, yellow and silver eel. Four countries reported gear restrictions or gear size restrictions. Of these countries, in Albania there are no gear restrictions but there is a size restriction of 12 mm, in Greece there is a 20 mm restriction for fyke nets and single stranded nets and in Tunisia 10 mm for square meshes, 15 mm for triangular meshes and 40 mm for gillnets authorized in dams. In France there was a maximum of 60 *verveux*, a cone-shaped net bag or *nasse* (eel pot) allowed per boat per day. Through national laws, eel fishery closure periods were also established. Except for Albania, all seven countries had fishery closure periods for eel. The duration of these closure periods varies from 2 months in Tunisia to 12 months (total eel fishery closure) in some regions of Italy, Spain (Andalucía) and Türkiye. Temporal restrictions start and end dates were also different for each country while in France and Spain there were different closure dates for different eel stages (that is, different start and end dates for glass, yellow and silver eel) and there were also variations in closure periods for different regions or habitat types.

Fisheries closures are management measures established by countries in an effort to minimize fishing mortality and increase recruitment and spawner escapement. There were two main types; partial closures applied in some months each year, often during the spawning migration and total closures applied over the whole year for a specific life stage or for all stages.

The total and partial closures were applied to specific habitats where fisheries were present, or to all habitats, or to a combination of habitats, with diverse durations (for example, 1.5 months to 5 months or total closure) and targeted life stages across the participant countries or even between different EMUs, regions or autonomous communities (Table 12.5).

All participant countries have established MLS. However, these varied from 12 cm up to 70 cm between countries and also between different local regions within each country. For example, in Spain, five different MLS were established depending on the autonomous region, with fisheries prohibitions in force for eel with total lengths of greater than 12 cm, between 12 cm and 25 cm, less than 35 cm, less than 38 cm and less than 70 cm.

These differences in MLS were also used to establish restrictions on fishing for different life stages fished. All participant countries indicated glass eel prohibitions in at least one EMU or local region or Autonomous Community. Apart from glass eel and depending on the type of fisheries closure (partial or complete) restrictions also existed for other life stages (yellow eel or silver eel or both) or for all life stages (Table 12.5).

The national management measures (NMM) for commercial fisheries are summarized in Table 12.5 including NMM for seven of the nine partner countries (all except Albania and Egypt). The allowed minimum eel size restriction under national management varied from 12 cm to 70 cm, eel stage restrictions ranged from just glass eel to all life stages and gear mesh size restrictions varied between 12 mm to all sizes. The duration of temporal restrictions under national management are from two months to 12 months, while the beginning and end of temporal restrictions differ according to site, habitat and life stage.

Regarding recreational fisheries, there are national measures established in Algeria, France and Türkiye. In all these countries, the minimum eel size allowed, eel stage restrictions and closure periods were the same as those applied in commercial fishery, except for France where the silver eel fishery was prohibited for recreational fishers. In Türkiye there were restrictions for fyke nets, longlines, spear-guns, pots and traps.

National management measures for recreational fisheries are summarized in Table 12.5. This table includes NMM for four (Algeria, France, Italy and Türkiye) of nine countries. The allowable minimum eel size under NMM varies from 12 cm to 50 cm, while eel life stage restrictions varies from glass eel to all stages. Gears are restricted to only lines with a maximum of 12 hooks in total and all types of gears. The duration of the temporal restrictions varied from 3 months to 12 months. The beginning and end of time restrictions differed according to site, habitat and stage.

12.3.4. Regional management measures

The regional management measures (RMM) for the commercial eel fishery in Algeria, France, Italy, Spain and Tunisia are summarized in Table 12.5. In France, these RMMs are in addition to NMMs. Regions must first follow the national rules and if they want to do more, they can. However, in Italy, the RMMs are effectively an alternative set of measures.

Eel size and stage restrictions were the same as those provided by national laws of each country. In Italy, the national plan only concerned glass eel in marine waters, while all other stages and waters were under regional competence. In Algeria and in Tunisia, gear and time restrictions were also the same as those implemented by their national laws for commercial fisheries. The situation differs in Italy where there were many regional laws that established different temporal and gear restrictions for different habitat types in each region. In the French Mediterranean area, fishers are regrouped under *prud' homies*. One role of these communities is to preserve the resource and some of them decided on more restrictive measures concerning eel fishing periods, number of gears and fishing sites for some lagoons.

Under local regional management, the minimum size of eel varied from 25 cm to 70 cm, eel stage restrictions were applicable to glass eel, yellow and silver eel or to all stages, gear mesh size varied between 4 mm and 34 mm and the duration of temporal restrictions varied from 1 month to 10 months while the beginning and end of temporal restrictions differed according to sites, habitats and life stages.

Italy and France were the only countries that have regional laws for recreational fisheries. In Italy, these measures were the same as those applied in commercial fisheries, while in France, in addition to the national regulations and depending on the river and local fisher associations, restrictions such as closure periods, type and number of gears allowed, can differ.

Table 12.21. Eel management plans, national management measures and regional management measures for commercial and recreational fisheries, established by the Mediterranean countries towards the protection and recovery of eel stock

Measures	Fisheries	Year implemented	Eel size restriction	Eel stage restriction	Gear size restriction	Gear restriction	Time restriction duration
Eel management plans	Commercial		12 cm, 30 cm, 35 cm, 38 cm, 70 cm	G, GY, All, YS, G (only restocking)	10 mm, 12 mm, 15 mm, 20 mm, 40 mm	Fykenets, longlines, single stranded nets, capechades, number of gear per boat per day, number of gear per fisher by day	2 months, 2.5 months, 3 months, 7 months, 9.5 months, depending on the category of the river and the department
	Recreational		12 cm, 35 cm	G, All, YS (restrictions), G (only restocking)		Only lines with a maximum of 12 hooks in total, ALL	3 months, depending on the category of the river and the department
National management measures	Commercial		12 cm, 30 cm, 35 cm, 38 cm, 50 cm, 70 cm	G, All, YS	Gear depend sizes, 4 mm, 12 mm, 18 mm, 2 mm, 34 mm, 16 mm, 25 mm, 34 mm	Size depend gear fykenets, longlines, single stranded nets, monofilaments, filets à merlu, filets trémails, palangres, capechades et trabaques, verveux et palangres, bordigues, lignes à hameçon, number of gear per boat per day, number of gear per fisher by day	2 months, 3 months, 5-6 months, 7 months, 8 months, 9.5 months, 12 months depending on stages
	Recreational		12 cm, 50 cm	G, YS (restrictions), All		Only lines with a maximum of 12 hooks in total, fykenet, longline, harpoon, pots, traps, etc., all kinds of gear	Depending on the category of the river and the department, 3 months, 3 months (Y), 7 months (S), 7 months, 7.5 months, 8 months, 10.5 months, 12 months
Regional management measures	Commercial		28 cm, 30 cm, 35 cm, 38 cm, 40 cm, 70 cm,	G, YS, All	34 mm / 16 mm and 25 mm for bordigues, 18 mm for capechad and 4 mm for verveux, 34 mm, 10 mm for square meshes,, 15 mm for triangular	Bordigues, capéchades, nasses, palangres, monofilaments, trémails, lignes à hameçon, trabaques, nasses, verveux et palangres, number of gear per fisherman, number of nets, size and mesh size of net	1 month, 2 months, 3 months, 4 months, 6 months, 7 months, 8 months, 9.5 months, 10 months, 12 months, depends on stages
	Recreational		Maximum size 25 cm, 28 cm, 40 cm, YES: NR ABOUT SPECIFIC SIZE	G, YS, ALL	YES: NR ABOUT SPECIFIC RESTRICTIONS	ALL	1 month, 3 months, 5 months, 6 months, 7 months

12.3.5. Analysis of eel management measures by habitat type

European eel management measures were analysed for the four habitat types: lake (LAK), lagoon (LGN), coastal marine waters (CMW) and river-estuary (RIV-RIE). There were more LGN and RIV-RIE habitats compared to other habitats (Table 12.6) while the percentages of sites with reported management measures in all assessed habitats are summarized in Figure 12.3.

Table 12.22. The number of sites by habitat and country for which management measures were reported, total numbers and distribution (percent) by habitat

Habitats	AL	DZ	EG	ES	FR	GR	IT	TN	TR	Total	Percent
Coastal marine waters		24		100			63	49		236	18.5
Lake	2	3				3	91	30	17	146	11.4
Lagoon	11	2	8	41	53	47	195	21	22	400	31.3
Estuary		31		44	6	11	38	4	17	151	27.1
River	10	20	2	30	38	20	149	49	28	346	27.1
Total	**23**	**80**	**10**	**215**	**97**	**81**	**536**	**153**	**84**	**1279**	**100**

Notes: AL = Albania, DZ = Algeria, EG = Egypt, ES = Spain, FR = France, GR = Greece, IT = Italy, TN = Tunisia, TR = Türkiye.

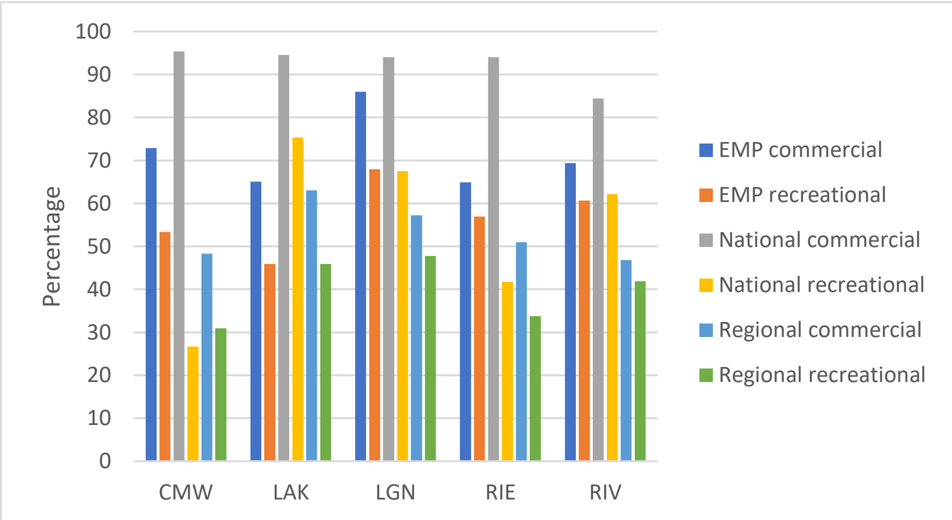

Figure 12.22. Relative distribution (percent) of commercial and recreational eel management plans, national management measures and regional management measures by habitat type for sites in which management measures were reported

Notes: CMW = coastal marine waters, LAK = lake, LGN = lagoon, RIE = estuary, RIV = river.

Lake habitats

In total, 146 lake sites were analysed for measures in EMPs, NMMs or RMMs (Figure 12.4). Algeria reported one lake and Tunisia reported seven lakes which were not fished and for which there were no eel-specific measures in place. The most typical measure in lake habitats is an MLS, which varies from 25 cm to 50 cm. Stage restrictions were reported, mostly for glass eel but also covering yellow eel in some countries.

Eel management plans and NMMs are the same in most countries (Table 12.7). Six countries reported eel-specific measures for lake habitats. Only France, Spain and Egypt have no lake habitats for eel (Table 12.7, Table 12AR1.1). All the three types of measures are more or less similar and include MLS varying between 30 cm and 50 cm, depending on the country and site. Mesh size restrictions depend on the gear type in some sites and vary between 10 mm and 40 mm. Some gear restrictions with particular mesh sizes were reported (Table 12AR1.1). The complexity of the regional measures established in each country must be noted, due to the great variety of gear used and local restrictions and measures established, which could not be captured in the questionnaires used to gather information on the habitat-based management measures. Temporal fisheries closures normally cover three consecutive months. Only Algeria and Egypt did not report any particular closure times for eel fisheries. Other countries reported various closure times depending on site (Table 12.7).

Reported measures on recreational fisheries are limited. Only Italy and Türkiye reported MLS, life stage and time restrictions (Table 12.7).

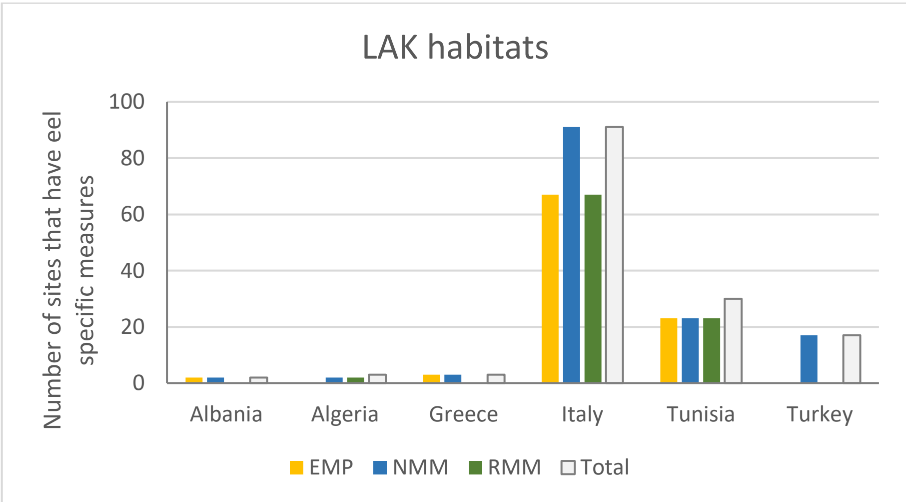

Figure 12.23. Number of sites with eel-specific measures by country in lake habitats

Notes: EMP = eel management plan, NMM = national management measures, RMM = regional management measures.

Table 12.23. European eel measures for commercial and recreational fisheries for lake habitats

Countries	*Regulation* [a]	*Minimum eel size (cm)*	*Stage restriction*	*Mesh size restriction (mm)*	*Gear restriction*	*Minimum 3-month closure*	*Banned sites*
Commercial fisheries							
Albania	EMP, NMP	35	G	12	No	No	No
Algeria	NMM, RMM	30	G	Yes	Yes	Yes	No
Greece	EMP	30	GY	20	Yes	Yes	No
Italy	EMP, NMM, RMM	25 (maximum size), 40	Yes	Yes	Yes	Yes	No
Tunisia	EMP, NMP, RMP	30	G	Yes	ND	2 months	No
Türkiye	NMM	50	NP	NP	Yes	Yes	Yes
Recreational fisheries							
Algeria	NMM	Yes	No	No	No	No	No
Italy	EMP, NMM, RMM	25	YS, G, all	ND	ND	Yes	No
Türkiye	NMM	50	NP	NP	Yes	Yes	Yes

Notes: [a] EMP = eel management plan, NMP = national measures, RMM = regional measures, G = glass eel, Y = yellow eel, ND: no data, NP: not pertinent.

Egypt, France and Spain have no lake habitat.

Albania has one important lake habitat site (Shkodër) for eel fisheries which represents less than 25 percent of its total catch of eel. Fisheries measures were introduced as part of the EMP established in 2019 as well as under NMMs. The reported fisheries measures in this site include a minimum eel landing size (35 cm), a life stage restriction for glass eel and a gear mesh size of 12 mm. The main fishing gear was reported as eel longlines (ELL) in the lake habitat and there were no other measures related to this fishing gear reported in this region. Releases, which were 20 percent of the mean landings per year in last five years were reported. There are no specific recreational eel fisheries measures.

Algeria has two important lake habitat sites, Oubeira and Tonga, which are responsible for nearly 75 percent of total Algerian eel production and are managed under NMM and RMM regulations. There are specific restrictions to the type and mesh size of the fishing gear; fyke nets are the main fishing gear and there is an established MLS of 30 cm. National management measures and RMM also place catch restrictions on glass eel fisheries. A seven-month closure, from October to May, was reported for Tonga Lake only. No specific measures for recreational fisheries were reported.

Lakes are of minor importance for Greek eel fisheries as they represent less than one percent of total eel production. In addition to two unfished sites (Lake Mikri Volvi basin and Lake Vsitonida Basin) only Ismarida Lake was reported as a fishery site for eel. All three lakes are under EMP protection, which was implemented in 2009 as well as under NMM. The fishery measures cover all types of fishery restrictions including a closure time from September to November.

A total of 12 lakes were reported as eel fishery sites in Italy. However, eel catches from lake habitats represent a minor contribution (less than five percent) of the total catch. All these sites are under the protection of EMP, NMM and RMM regulations. There is no data on eel size restrictions, but there are life stage restrictions for all sites. The main fishing gear in lake habitats are ELL and trammel and gill nets (NTS) and no gear-specific regulation was recorded in the questionnaire. The three-month closure is the same for all the lake sites from January to March. However, there are more detailed restrictions for each site in RMMs such as the number of fyke nets allowed and closure times. The recreational fishing measures are the same as the commercial measures for these lakes.

In Tunisia, about ten percent of total catches are from 26 lake habitat sites where there are EMPs, NMMs and RMMs, including a 30 cm MLS and a ban on glass eel fisheries. The main fishing gear are NTS with regulated gear mesh sizes (10 mm for square meshes, 15 mm for triangular). The closure period is only two months from March to April. There are no specific recreational measures for these sites.

There are eight commercial and one recreational fishery lake habitats in Türkiye and nearly 70 percent of the total catches of Türkiye were reported from lake habitats. Barriers (BAR) and fyke nets (FYK) are the main fishing gears in these sites. National management measures regulate eel commercial and recreational fisheries. With regard to barrier traps, there is a maximum distance of 3 cm between the trap sticks. The most prominent measure is an MLS of 50 cm. There are further restrictions concerning gear type and number of allowed gear per fisher particularly for recreational fisheries. There are two, three-month closures periods, from December to March and from September to December, while recreational fishing is forbidden in two of these nine lake habitats.

Lagoon habitats

A total of 193 lagoon sites were analysed in terms of EMP, NMM and RMM (Figure 12.5). Almost all lagoon habitats are covered by least one type of measure or particular fishery regulation. Egypt and Tunisia reported eight and 16 fishery lagoon habitat sites, respectively, without any eel specific measures. Except for Egypt and Algeria, all countries have a three-month closure period for lagoon habitats (Table 12.8). In addition, France, Italy, Spain and Türkiye also have sites that are closed for fisheries in their lagoon habitats.

Eighty-six percent of all lagoon sites have EMP measures. Eel size restrictions range from ten cm to 70 cm, covering all eel stages. Gear mesh sizes and gear type measures were reported together with maximum allowable numbers in some countries (Table 12AR2.1), while three countries (Spain, France-MED and Italy) reported measures on recreational fisheries.

National measures for commercial fisheries apply to 94 percent of all lagoon sites, with measures including minimum conservation size of eel, eel life stage restrictions, gear restrictions and closure periods very similar to those reported in EMP measures (Table 12AR2.1). Four countries, Algeria, France-MED, Italy, Spain and Türkiye apply measures on recreational fisheries at national level.

Only 57 percent of all recorded lagoons have local or regional level measures. Algeria, Spain, France-MED, Italy and Tunisia have regional measures on commercial eel fisheries in terms of size, stage, or gear restrictions. A wide range of MLS was reported for lagoons. This wide range is also seen in the duration of temporal fishing closures (Table 12AR2.1).

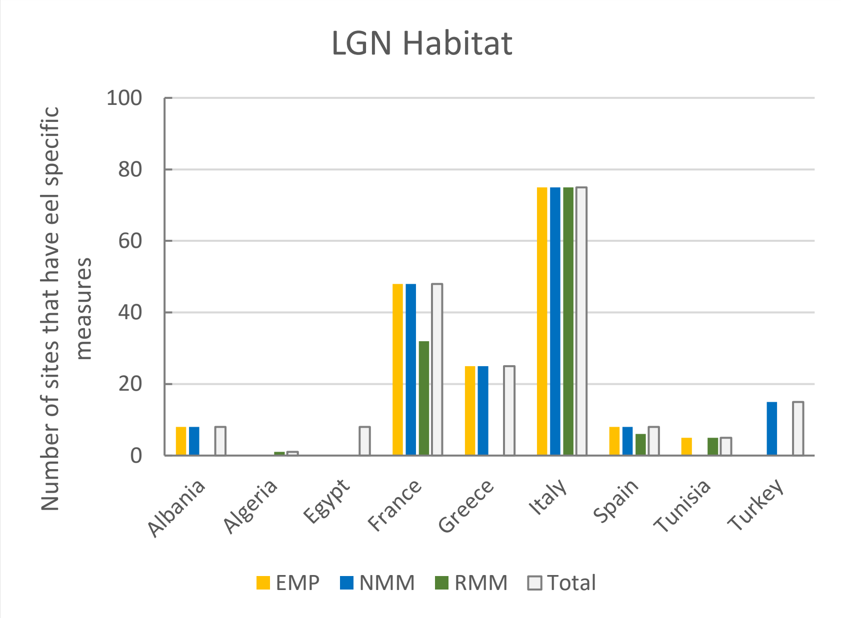

Figure 12.24. Number of lagoon habitat sites with specific eel measures by country

Notes: EMP = eel management plan, NMM = national management measures, RMM = regional management measures.

Table 12.24. European eel measures for commercial and recreational fisheries for lagoon habitats

Countries	*Regulation*	*Minimum landing size (cm)*	*Stage restriction*	*Mesh size restriction (mm)*	*Gear restriction*	*Minimum 3-month closure*	*Banned sites*
Commercial fisheries							
Albania	EMP	35	G	12	No	No	No
Algeria	NMM, RMM	30	G	Yes	Yes	Yes	No
France	EMP, NMM, RMM	12	All	Yes	Yes	Yes	Yes
Greece	EMP, NMM	30	GY	20	Yes	Yes	No
Italy	EMP, NMM, RMM	28, 30, 40	All, SY, G	ND	ND	Yes	Yes
Spain	EMP, NMM, RMM	10 (G),12 (G), 25 (Y/S), 35 (S), 38, 70	G, All	Yes	Yes	Yes	Yes
Tunisia	EMP, NMM, RMM	30	G	Yes	Yes	Yes	No
Türkiye	NMM	50	G	Yes	Yes	Yes	Yes
Recreational fisheries							
Algeria	NMM	30	G	Yes	Yes	Yes	No
France	EMP, NMM, RMM	ND	All	Yes	Yes	Yes	Yes
Italy	EMP, NMM, RMM	ND	All	Yes	Yes	Yes	No

Countries	Regulation	Minimum landing size (cm)	Stage restriction	Mesh size restriction (mm)	Gear restriction	Minimum 3-month closure	Banned sites
Spain	EMP, NMM, RMM	35	All	No	No	No	yes
Türkiye	NMM	50	ND	ND	ND	Yes	Yes

Notes: EMP = eel management plan, NMP = national measures, RMM = regional measures, G = glass eel, Y = yellow eel, ND = no data, NP = not pertinent.

Nearly 80 percent of total eel catches from Albania were reported from eight lagoon sites. Karavasta, Narta and Vain are the most prominent sites in terms of eel fisheries. The EMP and NMM regulations are related to MLS, eel stage restrictions and partly also to gear restrictions. The main fishing gear were FYK and BAR. No site or gear specific measures or closure periods for eel fisheries were reported.

Nearly 20 percent of Algerian total catch of eel was reported from Mellah. Fyke nets are the main fishing gear (Chapter 8, Figure 8.15). National management measures and RMM are related to MLS, stage restrictions and also gear type and gear mesh size restrictions. There is no three-month closure period for Mellah. There is another lagoon site (Tamellaht), where no commercial fisheries exist, even though in the NMM there is an indication of a seven-month closure period from October to May.

Nearly 70 percent of total Egyptian catches were reported from four lagoon sites where mixed gears (MIX) are used and no specific measures for eel were reported.

More than 99 percent of total French catches of eel were reported from lagoon sites. In total, 48 sites were analysed, with some sites combined as complex systems. Twelve of these systems were analysed for eel fisheries (Chapter 11, Figure 12.15). Eel longlines, fences (FEN) and MIX are the main gear used in these lagoons. Bages-Sigean, Berre and Or are the prominent fishing sites in the Rhone EMU where there were EMP, NMM and RMM regulations. The MLS is 12 cm and there are restrictions for yellow eel fisheries, while glass eel fisheries are forbidden. There are some regulations on gear type and number of gear per day per fisher. There is a three-month closure period for yellow eel from 1 December to 29 February and a seven-month closure for silver eel from 1 March to 30 September. In France, even limited seasonality data indicated a high ratio of silver eel catches in October, November and December, extending to April. Therefore, the seven-month closure for silver eel does not cover the silver eel migration period.

In Greece, eel caught from twenty-four lagoons, mostly by barriers, account for more than 99 percent of the total catch. Kotychi and Tsoukalio are the prominent fishing lagoons where EMPs and NMMs regulate the eel fisheries. In addition to an MLS of 30 cm, there are stage and gear restrictions together with a 2.5-month closure period from 1 April to 15 July in the EMP regulation. However, the same sites have a three-month closure period from September to November under the NMM. Literature on seasonality of silver eel catches indicates that the prominent season for silver eel migration starts in October and extends to March (Chapter 6, Table 6.5). Therefore, the three-month closure from September to November is only partly compatible with the seasonality of silver eel.

More than 95 percent of total Italian catches were reported from 76 lagoons in Italy using various fishing gear with Comacchio, Orbetello and Sabaudia as the foremost sites in terms of catches. Eel management plans, NMM and RMMs have similar regulations such as life stage restrictions. There are no data about mesh size and MLS restrictions. The three-month closure period extends from January to March. Despite being limited, the data on seasonality of silver eel catches indicate that silver eel escapement occurs mostly in October and November and extends to March. Therefore, it seems that the three-month closure period is only partly compatible with the seasonality of silver eel.

Almost all eel catches in Spain using FEN and FYK are from lagoon sites (Chapter 10, Figure 10.18), with the most prominent sites, Mar Menor, Ebro Delta and Albufera Valencia, among the seven main lagoon sites. Eel management plans, NMM and RMMs regulate the eel fisheries in these lagoons where the MLS varies from 35 cm to 70 cm. In Mar Menor, Ebro Delta and Albufera Valencia the MLS were reported as 38 cm, 35 cm and 70 cm, respectively. There are some life stage restrictions but no data on gear or gear mesh size restrictions. There are various temporal restriction durations and closure periods, depending on stages, for instance, eight months (1 April to 30 November) for glass eel and five to six months (1 May to 30 September/31 October) for yellow and silver eel in the Albufera Valencia site EMP regulation. For Mar Menor, there are two closure periods from 16 January to 28 February and 1 April to 30 November. In Ebro lagoon, the closed periods are from 11 March to 21 March and from 19 October to 31 October for glass eel fisheries and 1 March to 14 October for yellow and silver eel fisheries. There are no seasonality data on glass eel recruitment and silver eel escapement in these lagoons, so it is hard to say if the closure periods are compatible with migration times. There are eel-specific measures related to MLS, time restrictions and closed fisheries in the other lagoons considered as eel habitats.

Nearly 90 percent of total Tunisian eel catches come from lagoon habitats with Ghar El Melh, Ichkeul and Tunis as the most prominent fisheries. Fences and MIX are the main gears and also have the highest catches. Measures from EMP, NMM and RMM are similar those in lake habitats, with an MLS of 30 cm, 10 mm mesh size restriction for square meshes, 15 mm for triangular meshes, and a two-month closure period from March to April. The seasonality of silvering data from Bizerte, Tunis and Ariana Lagoons indicates that silver eel migration is concentrated from October to March. Therefore, the closure period is not compatible with the silver eel migration season.

About 30 percent of total Turkish eel catches come from lagoon habitats, where BAR, FYK and mostly MIX are used and the Güllük lagoon is the most prominent in the yellow and silver eel fishery. There are NMM that include an MLS of 50 cm and a three-month closure period from September to December. There are completely closed sites for fisheries. There are special regulations for recreational fisheries, which include gear restrictions in addition to commercial fishery regulations. There is also a three-month closure period from December to March for recreational fisheries. The literature records from Gediz Delta (Kırdeniz-Homa Lagoon) reported silver eel catches mostly from October to March (Salman *et al*., 2017). Therefore, the three-months closure period is compatible with silver eel migration seasonality.

Coastal marine water habitats

A total of 236 coastal marine water habitat sites in Algeria, Italy, Spain and Tunisia were analysed (Figure 12.6), although Algeria and Italy reported only the habitat typology without any eel fishery, but they have some of the measures. In Spain and Tunisia, EMPs, NMMs and RMMs nearly all include fisheries restrictions (Table 12.9), but with variations in closure periods (Table 12AR3.1). The MLS for eel varies from 10 cm to 35 cm and life stage restrictions mostly cover glass eel. Glass eel catches were only allowed for restocking purposes in some sites (Table 12AR3.1). Measures on recreational fisheries were more or less similar to those in commercial fisheries. Regional commercial measures covered size, stage, gear and gear size restrictions (Table 12AR3.1) which were similar to other restrictions. There was a two-month closure period (from March to April) in Tunisia that is not compatible with the silver eel migration seasonality. In Spain, the total contribution of coastal marine water habitats to annual eel catches is very low. There is only one fishery site (Ebro) with two closure periods, 11 March to 21 March and from 19 October to 31 October for glass eel and 1 March to 14 October for yellow eel. These closure periods are compatible with the seasonality of silver eel migration.

Only Spain has established recreational fisheries measures in coastal marine water habitats. The MLS is 35 cm along with some gear restrictions and mesh size restrictions. In terms of recreational fisheries, Spain has completely closed fisheries in some sites (Table 12.9).

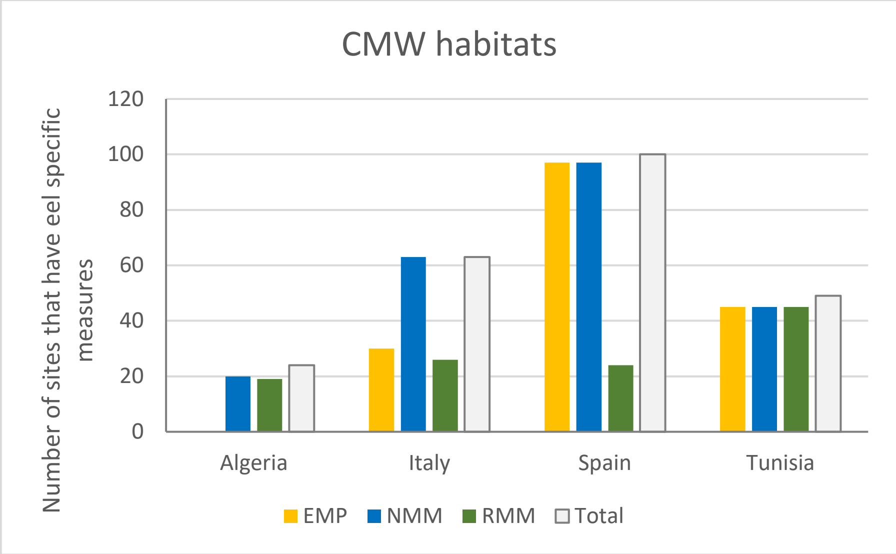

Figure 12.25. Number of sites in coastal marine water habitats that have specific eel measures by country

Notes: EMP = eel management plan, NMM = national management measures, RMM: regional management measures.

Table 12.25. European eel measures for commercial and recreational fisheries in coastal marine water habitats

Countries	*Regulation*	*Minimum landing size (cm)*	*Stage restriction*	*Mesh size restriction, mm*	*Gear restriction*	*Minimum 3-month closure*	*Banned sites*
Commercial fisheries							
Spain	EMP	10 (G); 35(S)	All	Yes	Yes	Yes	Yes
Tunisia	EMP	30	G	Yes	Yes	2 months	ND
Recreational fisheries							
Spain	EMP	35	All	Yes	Yes	ND	Yes

Notes: EMP = eel management plan, G = glass eel, Y = Yellow eel, ND = no data.

River and estuary habitats

A total of 497 sites were analysed as river and estuary habitats (Figure 12.5). Among the nine countries, seven had at least one type of measure for these sites. Algeria recorded eight and Tunisia recorded 53 eel sites in river and estuary habitats that are not fishery areas and not under any fisheries regulation (Figure 12.7). Egypt recorded two fishery eel river and estuary habitats in the Nile River, but without any eel-specific regulations. The EMP measures covered a wide range of size restrictions for commercial fisheries, similar to those in lagoons (Table 12.10).

As in the other habitats, the national measures were the most prominent type of measure (Figure 12.7). The measures on recreational fisheries are summarized and given in detail for some sites (Table 12AR4.1). In France, estuaries were under the marine water regulation (the same as for lagoons), and rivers were under a different regulation (freshwater). In French rivers, for both commercial and recreational eel fisheries, the duration of temporal restrictions was dependent on the category of the river (1 or 2). In addition to national level measures, there were local measures at the departmental level in rivers such as gear type and period that are not indicated in detail in Table 12AR4.1.

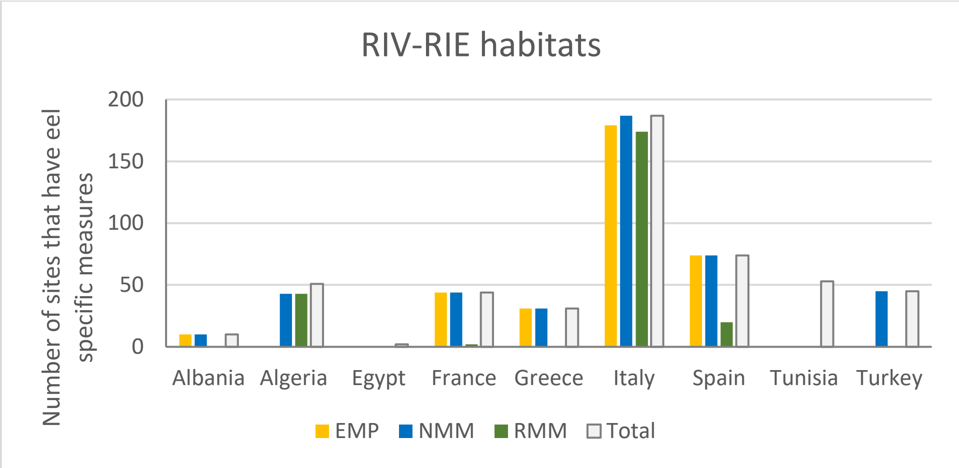

Figure 12.26. Number of river and estuary habitat sites that have specific eel measures by country

Notes: EMP = eel management plan, NMM = national management measures, RMM = regional management measures.

Table 12.26. European eel measures for commercial and recreational fisheries in river and river-estuary habitats

Notes: EMP = eel management plan, NMP = national management measures, RMM = regional management measures, G = glass eel, Y = Yellow eel, ND = no data.

Countries	***Regulation***	***Minimum eel size (cm)***	***Stage restriction***	***Mesh size restriction***	***Gear restriction***	***Minimum 3-month closure***	***Banned sites***
Commercial fisheries							
Albania	EMP, NMM, RMM	35	G	Yes	No	No	ND
Algeria	NMM, RMM	30	G	Yes	Yes	Yes	ND
France	EMP, NMM, RMM	12	All	Yes	Yes	Yes	ND
Greece	EMP, NMM	30	GY	Yes	Yes	Yes	ND
Italy	EMP, NMM, RMM	25, 28, 40	All	ND	Yes	Yes	Yes
Spain	EMP	10, 35, 38, 70	All	Yes	Yes	Yes	Yes
Türkiye	NMM	50	All	All	All	Yes	Yes
Recreational fisheries							
France	EMP, NMM	12	All	No	Yes	Yes	ND
Italy	EMP, NMM, RMM	25, 28, 40	All	Yes	Yes	Yes	Yes
Spain	EMP	35	All	Yes	Yes	ND	Yes
Türkiye	NMM	50	All	Yes	Yes	Yes	Yes

Albania has no fishery in river and estuary habitat sites. However, there were some regulations for these sites, as indicated in Table 12.4.

Less than ten percent of total catches of Algeria come from estuary habitat sites. In two estuaries, FYK are mainly used for the yellow and silver eel fishery. There are NMM and RMMs for MLS (30 cm), restrictions on glass eel fisheries, gear mesh size regulations (18 mm for *capechad* and 4 mm for *verveux*) and regulations on gear types (*capechade*, *trabaques*, *verveux* et *palangres*). There was a seven-month closure from October to May. No literature is available on the seasonality of silver eel migrations for Algeria, but when taking into consideration data from neighbouring countries, the closure time is compatible with the seasonality of silver eel migration.

River habitat sites are of very minor importance compared to total eel catches in France. The Rhône deltaïque and the Rhône aval are the most prominent among the seven yellow and silver eel river fishery sites. Eel management plans and NMMs regulate the eel fisheries mainly in terms of a 12 cm MLS together with some gear size and gear type restrictions. The three-month closure period was not reported due to its dependence on the category of the river and the department. There were also recreational fisheries in those rivers with the same regulations as for commercial fisheries.

River habitats are of minor importance for eel fisheries (less than one percent of total catch) in Greece as there is only one river (Evros) fished for silver eel using FYK. EMMs and NMMs regulate the eel fisheries at this site. Together with a closure period from April to June in EMP, there are three-month closures from September to November in NMM. In addition, there are life stage restrictions covering glass, yellow and silver eel together with gear mesh size (less than 20 mm for FYK) and gear restrictions (longlines, single stranded nets).

River habitats contribute 1.7 percent of total eel catches in Italy. Fences, NTS and FYK are the main gear types in 78 river and 20 estuary fishery habitat sites for yellow and silver eel catches. There are EMP, NMM and RMM regulations for these sites. In addition to life stage restrictions, MLS were reported as 25 cm, 28 cm and 40 cm in particular sites. There is a three-month closure period from January to March in the Veneto region together with an MLS of 40 cm. In addition, a six-month closure period from October to March was reported for the Friuli Venezia Giulia region without any size restriction, a three-month closure from 1 July–15 September to 31 August–15 October in the Lazio region (together with 25 cm MLS) and from August to October in the Toscana region without size restriction. Seven months from either January to June or March to September are closed in Sardegna region (28 cm MLS) and three months from January to March in the Emilia Romangna region by EMPs and NMMs. Apart from the fished sites, river and estuary habitats are closed for 12 months for all stages in Italy (Volano in Emilia Romagna, Adige and Brenta in Trentino Alto Adige, Dora Baltea in Piemonte and Valle d'Aosta, Po and Tanaro in Piemonte, Volturno in Campania).

There are no fished river habitat sites for eel in Spain and total catches from estuary habitats come from only one site (Marjal de Pego Oliva), fished by FYK, that contributes less than 1 percent to the total catch. In that site, EMP, NMM and RMM included the same regulations. The MLS is 70 cm, while no data exist on gear and mesh size restrictions. Closure periods are eight months (1 April to 30 November) for glass eel and five to six months (1 May to 30 September/31 October) for yellow and silver eel. There are limited data to understand the compatibility between silver eel migration seasonality and closure periods.

There are two river habitat sites (Acıkulak, Asi, Meriç and Tarsus) fished in Türkiye, contributing about 14 percent of the total Turkish catch by FYK. For two of these habitats (Acıkulak and Tarsus), only literature-based research data exist, as they are not real fisheries sites. Currently, only the Meriç and Asi rivers are the main river habitat sites in Türkiye, regulated by NMM (50 cm MLS and a three-month closure period from September to December), which is compatible with the seasonality of silver eel migration (Salman *et al.*, 2017). This regulation applies in a similar way also for recreational fisheries.

In addition, there were 32 more river and estuary habitat sites that are completely closed for commercial fisheries.

12.3.6. Restocking and release measures

Since the drastic decline of glass eel recruitment in the 1980s (some estimates reaching values of 1 percent of former values in 2000) many management measures have been employed for the protection and the recovery of the stock . Felix *et al.* (2020) believed that the decline of the population was not only the result of direct mortality caused mainly by glass eel fisheries but also of indirect mortality caused by factors such as habitat loss. According to Moriarty and Dekker (1997), the reduction of available habitat is responsible for creating unfavourable conditions including scarcity of food or shelter, parasite dissemination, but also spawning biomass reduction due to sex ratio changes (Costa *et al.*, 1993; Davey and Jellyman, 2005; Bevacqua *et al.*, 2011).

To reverse low natural immigration levels, restocking and release actions were undertaken as a way to increase recruitment and support recovery of the population (Moriarty and McCarthy, 1982; Andersson, Sandstrom and Hansen, 1991; Wickstrom, Westin and Clevestam, 1996; Pedersen, 1998; Simon *et al.*, 2012; Ovidio, Tarrago-Bes and Matondo, 2015; Rohtla *et al.*, 2020). Restocking and release actions incorporate the capture of naturally recruited eel of different stages and origins, and their release into fresh and brackish waters (Dekker and Beaulaton, 2016; Rohtla *et al.*, 2020).

Although restocking of glass eel has been favoured by many countries, many authors have raised questions regarding its benefit for the overall stock. Westin (2003), Sjoberg *et al.* (2009; 2016) and Marohn, Jakob and Hanel (2013) characterized it as controversial, mainly due to the uncertainty of its success. The authors questioned the transfer of glass eel from their catch origin to distant recipient sites, as it might increase their overall mortality.

Nevertheless, many countries have applied such measures either as part of their EMPs or as part of national and local regional management measures. Mediterranean countries have established release, restocking or assisted migration actions, in an effort to contribute to recovery of the species. According to ICES advice published in 2021, these actions are considered as a “conservation measure” in the EU regulation and are also included in many EMPs. However, ICES advised against continued fishing of glass eel for restocking purposes as the real impact of these actions on the stock are still unknown (ICES, 2021).

Project partner countries reported the release of eel of various life stages, either as glass eel, or after a period of quarantine, or after a period of some months of growth in aquaculture (on-grown glass eel), at the yellow eel or silver eel stage or at mixed life stages (glass eel and yellow eel) and (yellow eel and silver eel). These release actions are considered as separate from the assisted migration actions as they involve eel being moved between different water bodies, EMUs or between countries. On the other hand, assisted migration actions refer only to the displacement of individuals within the same water body in order to bypass obstacles (for example, dams or weirs) that prevent the upstream movement of glass eel or the downstream movement of silver eel.

Based on the information gathered with the questionnaires, data on the species life stage were provided but little is known about the number of eel used for restocking. Moreover, as the data were analysed it was identified that all the measures were applied to commercial fisheries and not to recreational fisheries, with the exception of Italy, who declared upstream assisted migration actions for both recreational and commercial fisheries. But again, no further data were provided on life stage, or the number of releases.

Some Mediterranean countries have established restocking actions as part of their EMPs or as part of their efforts to protect the species. However, there are also differences between regions inside the same country. For example, in Italy, where only two of nine regions indicated restocking or release actions (restocking ongrown glass eel). In Albania, restocking or release actions concerned the release of all life stages, while in Greece, glass eel restocking actions (10 percent of the imported glass eel for rearing) take place in freshwater systems.

The only countries providing data on the numbers of released eel were Albania (EMP and national law), Greece (EMP) and France (EMP). Greece has established measures to release 30 percent of the total catches of silver eel to the sea to increase the number of spawners and Albania has set the target at 20 percent of the mean landings over the last five years. In the French Mediterranean area, silver eel release actions take place in lagoon habitats in one EMU as a concerted action between fishers, the government and scientists.

12.3.7. Other measures

Conservation based measures are applied in protected areas such as those covered by Natura 2000, Ramsar or national parks. In Türkiye (Ramsar), Greece (Natura 2000), France (Ramsar and Natura 2000) and Algeria (marine protected areas) there are very comprehensive conservation-based measures for some special habitats. In Albania, there are closed seasons in four regions (Schkoder, Lezhe, Fier and Vlore). In France, in some specific areas, there are fishing bans related to polychlorinated biphenyl pollution.

All Mediterranean countries have indicated their conformity with the CITES regulation for traceability of the European eel trade and prohibitions in eel transportation to countries outside European Union.

12.4. DISCUSSION AND CONCLUSIONS

The collapse of the European eel population was attributed to a combination of both natural and anthropogenic actions, which affected both the eel population and its habitats, impacting not only one, but multiple, life stages of the species.

In 2007, the European Union issued Council Regulation (EC) No.1100/2007, advising all countries involved in the exploitation of eel by fisheries to establish a series of measures through EMPs with the goal of reducing anthropogenic mortalities and increasing the escapement of silver eel on their migration to the Sargasso Sea. Since 2010, the critical status of the stock has been recognized as well as the necessity for Mediterranean countries to participate in the European actions for the protection and recovery of European eel (Aalto *et al.*, 2016). In addition to eel specific management measures, the species management framework is affected also by many other laws (national and regional) and regulations and further influenced by international conventions as well as advisory and management bodies in the fields of nature conservation and fisheries.

However, the establishment of protective and management measures for the recovery of European eel, is a complicated issue due to the very peculiar life history of the species, its economic importance and the plethora of the habitats it inhabits during its life. In these terms, the measures employed by the countries could be categorized into those targeting the reduction of human induced mortality and the increase of spawner escapement and measures targeting the protection of habitats, or species other than eel, which could be of benefit to eel (for example, the EU water framework directive or the EU Habitat Directive).

Numerous measures have been employed by Mediterranean countries participating in the research programme towards the protection and recovery of the species. Wide variability was revealed in these measures and the targets these measures are setting (MLS, periods of closures). However, there were broad similarities in the measures employed by the participants, due to the implementation of regulations, such as the Council Regulation (EC) No. 1100/2007.

The complexity and diversity of the measures employed by the participant countries, at national or local, regional level is evident, leading to an even more complex situation, since one country could present a national EMP and more local or regional measures. But the presence of all these measures make the need to review their effectiveness and usefulness even more compelling towards identifying those with a real potential role in the achievement of the European eel stock recovery in the Mediterranean.

The majority of the actions outlined in EMPs, NMMs, and RMMs are implemented at the level of eel fishing sites. In addition, these included eel habitat sites, without active fishing data in some countries.

12.4.1. Fishery-related measures

Council Regulation (EC) No. 1100/2007 set targets of a reduction of anthropogenic mortalities and an increase in silver eel escapement to at least 40 percent (EC, 2007). To achieve these, the reduction in yellow eel and silver eel fishing effort, the facilitation of downstream migration of adults, the improvement of water quality, modifications to water management conducive to improved eel migration, the reduction of recreational fishing and assisted migration are prominent suggestions for sustainable eel fisheries (Bevacqua *et al.*, 2007).

The potential measures that cover the European eel can be analysed in various ways. The measures might address eel directly (size, life stage), or may target the protection of eel. This analysis describes the direct measures mitigating fisheries impacts on the eel grouping regulations into size restrictions, stage restrictions, gear restrictions, gear size restrictions and temporal restrictions (fishing seasons).

All countries, with or without an established EMP, have declared measures towards reducing fishing mortality by prohibiting specific fishing gear or allowing only fishing gear with specific characteristics, establishing MLS or restricting fishing on different life stages, as well as establishing fishery closure times and durations.

All participant countries have established an MLS, which was, however, found to be very variable (12 cm up to 70 cm), not only between countries but also within the countries. Mostly MLS appear to be larger than 30 cm and lower than 50 cm. The 50 cm MLS facilitates the escapement of male silver eel only and this restriction exists in Türkiye alone.

In addition to MLS, all countries, except Egypt, have life stage restrictions. While most countries do not allow glass eel fisheries, some countries (France, Spain, and Italy) are allowing them to continue operating, mainly based on EMPs and in accordance with the EU Regulation. Gear mesh sizes and gear types vary according to habitat and country. The gear mesh size and gear type as well as closure periods should be analysed together in terms of a multi-objective assessment as suggested by Bevacqua *et al.* (2007).

Closure periods should be compatible with silver eel migration seasonality in order to increase the escapement of spawners. Overlaps between silvering time and closure periods were found in some countries, but in others this was clearly not the case. However, a comprehensive overlap analysis could not be performed because of data limitations.

12.4.2. National measures on the migration of eel

Fisheries closures, either partial or total, have been established by countries in an effort to minimize fishing mortality and increase spawner escapement and therefore eventually recruitment. Both partial or total closures are applied to specific habitats where fisheries are present (freshwater/transitional/coastal) or to all of them or to a combination of them. A great variety was observed in the duration of closures (from 1.5 months to 12 months or total closure), the life stage targeted or habitat between the participant countries, or even between EMUs, as well as local regions or autonomous communities. Differences were also observed in the designation of the closure periods when partial closures were established.

12.4.3. Habitat-related restrictions

Except for Tunisia and Algeria, countries have specific habitat-related eel fisheries restrictions. In Greece, all habitats are under habitat restriction by the national laws for eel protection (Royal Decree 142/1972 A49 and Presidential Degree 235/1979 A79, Royal Decree 142/1971 A49). In Türkiye and Albania, all habitats for glass eel are under habitat-specific, eel fisheries prohibition by national laws for eel protection (Article 40 Regulations for eel in Türkiye and Management Plan for European Eel in Albania). In the French Mediterranean area, for two EMUs (Occitanie – PACA – Corsica regions), all habitats are under eel fisheries prohibitions for glass eel by national laws (Plan de gestion Anguille – volet local de l'unité de gestion Rhône Méditerranée et de l'unité Corse). In Spain, two regional orders and one local regional decree have been established for the protection of eel in specific habitats. More specific orders of 15 February 2019 and of 20 December 2019 established fisheries prohibitions, in terms of MLS and life stages, in lagoons (Mar Menor) and all continental waters of Murcia. The Regional Decree 209/2020, on the other hand, extended the prohibition of eel fisheries, in any of its phases, both in continental waters and marine waters for another 10 years. In Italy, eel fishing is prohibited by a national decree in all marine or coastal waters. In 11 local regions out of 20, eel fisheries are banned in all habitats (11 regions having closed all fisheries thus renouncing setting up a RMM, and nine maintaining fisheries in inland waters under regional management plans, these nine regions being designated as EMUs).

12.4.4 Stocking-related measures (restocking/releases)

A set of measures implemented by the countries, within the species distribution, concern restocking to enhance recruitment in specific sites, either to support local stocks or to increase spawner escapement. Mediterranean countries have established such actions as part of their EMPs or as part of their effort to protect the species. However, differences exist across different regions, within countries. For example, in Italy, where only two out of nine regions indicated restocking or release actions (restocking ongrown glass eel). In Albania, restocking or release actions concerned the release of all life stages, while in Greece, there are actions to restock glass eel (10 percent of the imported glass eel for rearing) in freshwater systems, and release 30 percent of the total catches of silver eel to the sea to increase the number of spawners. In the French Mediterranean area, silver eel release actions take place in lagoon habitats in one EMU as a concerted action between fishers, the government and scientists.

12.4.5. Conservation based measures: protected areas

Türkiye (Ramsar), Greece (Natura 2000), France (Ramsar and Natura 2000) and Algeria (marine protected areas) have very comprehensive conservation-based measures for some special habitats. In Albania, there are closed seasons in four regions (Schkoder, Lezhe, Fier and Vlore). In France, in a specific area, there is a fishing ban related to polychlorinated biphenyl pollution. In Greece, even though the lagoons are included in NATURA 2000 areas, there are no specific eel fisheries prohibitions, since the fishing cooperatives that manage the lagoons are using traditional passive fishing gears.

12.4.6. Convention on International Trade in Endangered Species of Wild Fauna and Flora

All Mediterranean Countries have indicated their conformation with the CITES regulation for traceability of European eel's trade and prohibitions of eel transportation to countries outside the European Union.

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Additional Results Part I – Measures for commercial and recreational eel fisheries in place in lakes (LAK) by country at the national and local (Eel Management Unit – EMU; Administrative region) levels

Table 12AR1.1

Measures by Eel Management Plan for commercial fisheries					
Countries	**Year of implementation**	**eel size restriction (min eel size to allow, cm)**	**eel stage restriction**	**gear size restriction, mm**	**gear restriction**
Albania	2019	35?	G	12	No
Greece	2009	30	GY	20	Fyke nets <20mm, longlines, single stranded nets
Italy	2011	ND	All YS G (only purpose of restocking)	ND	ND
Tunisia	2010	30	G	10 mm for square meshes 15 mm for triangular 40 mm for gillnets authorized in dams	ND
Measures by Eel Management Plan for recreational fisheries					
Italy	2011	ND	All YS G (only purpose of restocking)	ND	ND

National Measures for commercial fisheries					
Countries	Regulation	eel size restriction (min eel size to allow, cm)	eel stage restriction	gear size restriction, mm	gear restriction
Albania	Management Plan For European Ell *(Anguıllaanguılla)*	35	G	12	No
Algeria	Décretexécutif n°06-372 du 26 Ramadhan 1427 correspondant au **19 octobre 2006** Décretexécutif n°03-481 du 19 Chaoual 1424 correspondant au **13 décembre 2003** Décretexécutif n°04-86 du 26 Moharram 1425 correspondant au **18 mars 2004** Décretexécutif n°04-187 du 19 Joumada El Oula 1425 correspondant au **7 juillet 2004**	30	G	34, 18 mm for capechad 4 mm for verveux	Monofilaments filets à merlu, filets trémails, palangres, verveux et palangres

	Décretexécutif n°04-188 du 19 Joumada El Oula 1425 correspondant au **7 juillet 2004**				capechades et trabaques, Capechade, trabaques
Greece	1) Royal Decree 142/**1972** A49, 2) Presidential Degree 235/**1979** A79 3) Ministerial Degree 661/110826/**2019**	30	GYS	<20	Fyke nets <20mm longlines single stranded nets
Italy	MD n°403 25/07/**2019** OTHER NATIONAL LAWS: MD 12/01/2011 (FISHERY & TRADE OF G EEL)	NO ND	ALL	ND	ND ALL
Tunisia	law N° 94 – 13 dated on **31 january 1994** about fishing activity Decree of the minister of agriculture dated **28th of 550ydroelec 1995** concerning minimum landing size, minimum mesh size, eel fishery management in gharelmelhlagoon,…)	30	G	10 mm for square meshes 15 mm for triangular 40 mm for gillnets authorized in dams	ND
Turkey	**27 July 1973**-14607 RG -7/6719 “Su urunleri Tuzugu” Notification 5/1Regulating Commercial Fishing 2020/20	47 or 200 g 50	NP	NP	Fyke net longline harpoon pots, traps etc
National measures for recreational fisheries					
Algeria	loi n° 01-11 du 11 Rabie Ethani 1422 correspondant au 3 juillet 2001 relative à la pêche et à l’aquaculture, modifiée et complétée	Yes	No	No	No
Italy	MD n°403 25/07/2019	NO ND	ALL	ND	ND ALL
Turkey	**27 July 1973**-14607 RG -7/6719 Regulation **1982-1983**/14 circular Notification 5/2 Regulating Recreational Fishing-**2020/21**	70 (max 5 fish per fishermen per day) 50 (max 3 fish per fishermen per day)	NP	NP	Fyke net longlines trap

Regional measures for commercial eel fisheries					
Countries	**Regulation**	**eel size restriction (min landing size, cm)**	**eel stage restriction**	**gear size restriction, mm**	**gear restriction**
Algeria	Décretexécutif n° 05-184 du 9 Rabie Ethani 1426 correspondant au **18 mai 2005** ; Décretexécutif n°06-372 du 26 Ramadhan 1427 correspondant au **19 octobre**	30	G	18 mm for capechad and 4 mm for verveux	Capechade, trabaques, nasses,

	2006 ; Arrêté du 24 Rabie El Aouel 1432 correspondant au **27 février 2011** Décretexécutif n°03- 280 du 24 JoumadaEthania 1424 correspondant au **23 août 2003** ; Arrêtéinterministériel du 9 Ramadhan 1430 correspondant au **30 aout 2009**			34	verveux et palangres Monofilaments, filets à merlu, filets trémails, palangres capechades et trabaques
Italy	D.G.R. n. 76 **02/03/2012**	Max Size 25	YS	ND	ND
	DPGR n. 91/**2012** – art29, Reg regional n. 6/**2018**	40	ND	ND	ND
	DGR n870 del **5 luglio 2019** Closure of the European eel fishery in Tuscany.	NO	ALL	NO	ALL
	Document implementing the national plan for eel management	NO	ALL	NO	ALL
	RR 2/**2018** art. 2 * REGIONAL MEASURES FOR COMMERCIAL FISHERIES: The action is mentioned in the management plan but due to the presence of many barriers for hydroelectric purpose along the Tevere River it can't be implemented// OTHER NATIONAL LAWS: MD 12/01/2011 (FISHERY & TRADE OF G EEL)	NO	ALL	Max 6 Fyke Nets	ND
Tunisia	Recommendation GFCM/42/**2018**/1 on a multiannual management plan for European eel. (Anguilla anguilla L.) in the Mediterranean.	30	G	10 mm for square meshes, 15 mm for triangular 40 mm for gillnets authorized in dams	NP
Regional measures for recreational eel fisheries					
Italy	D.G.R. n. 76 **02/03/2012**	Max Sıze 25	YS	ND	ND
	DGR n870 del **5 luglio 2019** Closure of the European eel fishery in Tuscany.	NO	ALL	NO	ALL
	DPGR n. **91/2012** – art29, Reg regional n. **6/2018**	40	ND	ND	ND
	R.R. n. 2 **15/02/2011**;D.G.P. 374l 2/**12/2013**	40	ND	ND	ND
	RR **2/2018** art. 2 *** REGIONAL LAW FOR RECREATIONAL: MAX 1KG/ FISHERMAN// OTHER	NO	ALL	ND	ND

Additional Results Part II – Measures for commercial and recreational eel fisheries in place in lagoons (LGN) by country at the National and local (Eel Management Unit -EMU; Administrative region) levels

Table 12AR2.1

Countries	Year of implementation	eel size restriction (min eel size to allow, cm)	eel stage restriction	Gear mesh size restriction, mm	gear restriction
Measures in Eel Management Plan (EMP) for commercial fisheries					
Albania	2019	35	G	12	No gear restrictions
France	2010	All	All	All	All
		12	G :fihseryforbiden, Y and S : restrictions	no	Max 60 “verveux” or “nasse” per boat/day = Max of 20 capchades/boat/day
Greece	2009	30	GY	<20	Fyke nets <20mm
Italy	2011	ND	ALL SY G fishery for only restocking	ND	ND
Spain	2010	35	All	ND	ND
		70	All	ND	ND
		38	G	ND	ND
		10	Yes	Yes	Yes
		All	Yes	Yes	Yes
		10 cm (G); 35 cm (S)	Yes	Yes	Yes
		38	Yes	Yes	Yes
		12 cm (G)/ 25 cm (Y/S)	ND	Yes	Yes
		25	Yes	Yes	Yes
Tunisia	2010	30	G	10 mm for square meshes 15 mm for triangular	ND
Eel Management Plan (EMP) for recreational fisheries					
France	2010	12	G and S forbiddenY:restirction	no	Yes
Italy	2011	ND	ALL SY	ND	ND

		G fishery for only restocking			
Spain	2010	>35 cm (catch&release)	ND	ND	ND
		All	All	All	All
		NP	All	NP	NP

National Measures for commercial fisheries

Countries	Measures	eel size restriction (min eel size to allow, cm)	eel stage restriction	gear size restriction, mm	gear restriction
Algeria	Décretexécutif n°06-372 du 26 Ramadhan 1427 correspondant au 19 octobre 2006 Décretexécutif n°03-481 du 19 Chaoual 1424 correspondant au 13 décembre 2003 Décretexécutif n°04-86 du 26 Moharram 1425 correspondant au 18 mars 2004 Décretexécutif n°04-187 du 19 Joumada El Oula 1425 correspondant au 7 juillet 2004 Décretexécutif n°04-188 du 19 Joumada El Oula 1425 correspondant au 7 juillet 2004	30	G	34 / 16 and 25 mm for bordigues 18 mm for capechad and 4 mm for verveux	Bordigues, palangres, capéchades trémails, lignes à hameçon filets à merlu monofilaments trabaques verveux et palangres
France	Plan de gestion Anguille VOLET LOCAL DE L'UNITE DE GESTION RHONE MEDITERRANEE Arrêté national du 5 février 2016 relatif aux périodes de pêche de l'anguille européenne (Anguilla anguilla) aux stadesd'anguille jaune et d'anguille argentée	12	G:fishery forbidden, Y and S : restrictions	no	Max 60 "verveux" or "nasse" per boat /day. Max of 20 capchades/boat/day.
Greece	1) Royal Decree 142/1972 A49, 2) Presidential Degree 235/1979 A79 3) Ministerial Degree 661/110826/2019	30	GYS	<20	Fyke nets <20mm
Italy		No	All	ND	ND

	OTHER NATIONAL LAWS: MD 12/01/2011 (FISHERY & TRADE OF G EEL) MD n°403 25/07/2019	NP	All	NP	ALL
Spain		35	All	ND	ND
		38	G	ND	ND
		70	All	ND	ND
Tunisia	law N° 94 – 13 dated on 31 january 1994 about fishing activity Decree of the minister of agriculture dated 20th of September 1994 concerning fisheries management in dams Decree of the minister of agriculture dated 20th of september 1994 concerning fisheries management in dams	30	G	10 mm for square meshes 15 mm for triangular	
Turkey	**27 July 1973**-14607 RG -7/6719 "Su urunleri Tuzugu	47 or 200 g	NP	NP	NP
	5/1 Notification Regulating Commercial Fishing	50			
National measures for recreational fisheries					
Algeria	loi n° 01-11 du 11 Rabie Ethani 1422 correspondant au 3 juillet 2001 relative à la pêche et à l'aquaculture, modifiée et complétée	Yes	No	No	No
Italy	MD n°403 25/07/2019	NO ND	ALL	ND	ND ALL
France	Plan de gestion Anguille VOLET LOCAL DE L'UNITE DE GESTION RHONE MEDITERRANEE	NP	All	All	All
	Arrêté national du 5 février 2016 relatif aux périodes de pêche de l'anguilleeuropéenne (Anguilla anguilla) aux stadesd'anguille jaune et d'anguilleargentée	12	G and S: forbidden; Y:restriction	no	only lines with a max of 12 hooks in total

Turkey	**27 July 1973**-14607 RG -7/6719 Regulation	70	ND	ND	max 5 fish per fishermen per day
	1982-1983/14 circular	50			max 3 fish per fishermen per day
Regional Measures for Commercial Fisheries					
Country	**Measures**	**SizeR**	**SR**	**GSR**	**GR**
Algeria	Décre texécutif n°03-280 du 24 Joumada Ethania 1424 correspondant au 23 août 2003	30	G	34 / 16 and 25 mm for bordigues	Bordigues, palangres, filets à merlu, monofilaments, trémails, lignes à hameçon
	Décre texécutif n°06-372 du 26 Ramadhan 1427 correspondant au 19 octobre 2006			18 mm for capechad and 4 mm for verveux	Capechade, trabaques, nasses, verveux et palangres
France	Arrêté n°R93-2018-09-18-003 du 18 septembre 2018 portantcréationd'uneautorisation de pêche régionale pour la pêche professionnelle de l'anguilleen Méditerranée continentale Arrêté Corse n°R20-2020-03-31-001 rendantobligatoireunedélibération du Comitérégional des pêchesmaritimes et des élevagesmarins de Corse fixant la liste des titulaires de la licence régionale de pêche de l'anguilleen 2020	ND	YS	ND	Number of max gear per fisherman size and mesh size of net, restriction time size of the net, site restriction depending of the period
Italy	D.G.R. n. 76 02/03/2012	Max Size 25	YS	Max 6 Fyke nets	ND
	DPGR n. 91/2012 – art29, Reg regional n. 6/2018	40	ND		ND
	DGR n870 del 5 luglio 2019 Closure of the European eel fishery in Tuscany.	NO	ALL	NO	ALL
	MEASURES FOR FISHERY REDUCTION	Nr about specific size	ALL	Number about specific restriction	ND
	Dec Agriculture 2161 Dec. N. 41 30 Sept 2019	28	ND	ND	ND
	Region fishery office annual decrees. As for 2021, decree n. 974, 22 December 2020.	NO	ALL	ND	ND
		30	ND	ND	ND
Spain		35	All	ND	ND
		38	G	ND	ND
		70	All	ND	ND
Tunisia	Recommendation GFCM/42/2018/1 on a multiannual management plan for European eel. (Anguilla anguilla L.) in the Mediterranean.	30	G	10 mm for square meshes	ND
				15 mm for triangular	ND

Regional measures for recreational eel fisheries					
Italy	D.G.R. n. 76 02/03/2012	Max size 25	YS	ND	ND
	President decree n. 191/ Pres. 20 September 2012	ND	G	ND	ND
	DPGR n. 91/2012 – art29, Reg regional n. 6/2018	40	ND	ND	ND
	MEASURES FOR FISHERY REDUCTION	Nr About Specific Size	All	Nr About Specific Restrictions	ND
	Dec Agriculture 2161 Dec. N. 41 30 Sept 2019	28	ND	ND	ND
	DGR n870 del 5 luglio 2019 Closure of the European eel fishery in Tuscany.	NO	ALL	NO	ALL
Spain	Same as above	ND	ND	ND	ND
France	Same as above	ND	ND	ND	ND

Additional Results Part III – Specific eel measures for commercial and recreational fisheries in place in coastal marine waters (CMW) by country at the national and local (Eel Management Unit – EMU; Administrative region) levels

Table 12AR3.1

Eel Management Plan (EMP) for commercial fisheries					
Countries	**Year implemented**	**eel size restriction (min eel size to allow, cm)**	**eel stage restriction**	**gear mesh size restriction, mm**	**gear restriction**
Italy	2011	ND	SY; glass eel fishery permitted for the sole purpose of restocking ALL	ND	ND
Spain	2010	10 All	Yes	Yes	Yes
		ND	Yes	ND	ND
		>10 cm (G) / <35 cm (S)	Yes	Yes	Yes
		35	Yes	ND	ND
Tunisia	2010	30	G	10 mm for square meshes	ND
		30	G	15 mm for triangular	ND
Eel Management Plan (EMP) for recreational fisheries					
Spain	2010	35	ND	ND	ND
		All	All	All	All
		NP		NP	NP
Italy	2011	ND	All	ND	ND
		12	SY; glass eel fishery permitted for the sole purpose of restocking	no	only lines with a max of 12 hooks in total

National Measures for commercial fisheries					
Countries	**Measures**	**eel size restriction (min eel size to allow, cm)**	**eel stage restriction**	**gear mesh size restriction, mm**	**gear restriction**
Algeria	Décretexécutif n° 05-184 du 9 Rabie Ethani 1426 correspondant au 18 mai 2005 ; Décretexécutif n°06-372 du 26 Ramadhan 1427 correspondant au 19 octobre 2006 ; Décretexécutif n°03-481 du 19 Chaoual 1424 correspondant au 13 décembre 2003 ; Décretexécutif n°04-187 du 19 Joumada El Oula 1425 correspondant au 7 juillet **2004** ; Décretexécutif n°04-188 du 19 Joumada El Oula 1425 correspondant au 7 juillet 2004 ; Décretexécutif n°04-189 du 19 Joumada El Oula 1425 correspondant au 7 juillet 2004 ; Décretexécutif n°07-208	30	G	18 mm for capechad and 4 mm for verveux	Capechade, trabaques, verveux et palangres

	du 15 JoumadaEthania 1428 correspondant au 30 juin 2007 ; Arrêté du 24 Rabie El Aouel 1432 correspondant au 27 février **2011**				
Spain	??	ND 35	ND All	ND ND	ND ND
Italy	OTHER NATIONAL LAWS: MD 12/01/2011 (FISHERY & TRADE OF G EEL) , MD n° 403 25/07/2019 (BAN OF EEL MARINE FISHERY)//OTHER REGIONAL LAWS: DPGR n. 91/2012 – art 19, comma 4, Reg. Regional n. 6/2018 (BAN OF G EEL & ELVERS FISHERY) MD n°403 **25/07/2019**	ND No NP	ALL	ND NP	ALL ND ALL
Tunisia	law N° 94 – 13 dated on **31 january 1994** about fishing activity Decree of the minister of agriculture dated **28th of 559ydroelec 1995** concerning minimum landing size, minimum mesh size, eel fishery management in gharelmelh lagoon,…) Decree of the minister of agriculture dated **20th of 559ydroelec 1994** concerning fisheries management in dams	30	G	10 mm for square meshes, 15 mm for triangular	10 mm for square meshes, 15 mm for triangular
National Measures for commercial fisheries					
Italy	MD n°403 **25/07/2019**	No ND All	All	ND	ND All

Regional Measures for commercial fisheries

Countries	**Measures**	**eel size restriction (min eel size to allow, cm)**	**eel stage restriction**	**gear mesh size restriction, mm**	**gear restriction**
Algeria	Décretexécutif n° 05-184 du 9 Rabie Ethani 1426 correspondant au **18 mai 2005** ; Décretexécutif n°06-372 du 26 Ramadhan 1427 correspondant au **19 octobre 2006 ;** Arrêté du 24 Rabie El Aouel 1432 correspondant au **27 février 2011**	30 No	G No	18 mm for capechad and 4 mm for verveux No	Capechade, trabaques, nasses, verveux et palangres No
Spain	???	ND 35	ND	ND	ND

Italy	DPGR n. 91/2012 – art29, Reg regional n. 6/2018 DPGR n. 91/2012 – art29, Reg regional n. 6/2018	No ND	ALL		ALL
Tunisia	Recommendation **GFCM/42/2018/**1 on a multiannual management plan for European eel. (Anguilla 560ydroele L.) in the Mediterranean.	30	G	10 mm for square meshes, 15 mm for triangular	
Regional Measures for recreational fisheries					
Italy	DPGR n. 91/2012 – art29, Reg regional n. 6/2018 DPGR n. 91/2012 – art29, Reg regional n. 6/2018	No ND ALL	ALL	ND	ND ALL

Additional Results Part IV – Measures for commercial and recreational eel fisheries in place in rivers (RIV) and river estuaries (RIE) by country at the national and local (Eel Management Unit -EMU; Administrative region) levels

*For France, the measures exposed in this table concern only RIV (freshwater), the measures applied in RIE are the same that the one for LGN.

Table 12AR4.1

Eel Management Plan (EMP) for commercial fisheries					
Countries	**Year of implementation**	**eel size restriction (min eel size to allow, cm)**	**eel stage restriction**	**gear mesh size restriction, mm**	**gear restriction**
Albania	2019	35	G	12	No
France*	2010	12	G (prohibition), YS (restrictions)	no	Yes
Greece	2009	30	GY	<20	Fyke nets <20mm, longlines,single stranded nets
		30	G		
Italy	2011	ND	ALL	ND	ND
Spain	2010	70	Yes	ND	ND
		All	Yes	Yes	Yes
		ND	Yes	ND	ND
		10	Yes	Yes	Yes
Eel Management Plan (EMP) for recreational fisheries					
Spain	2010	35	ND	ND	ND
		All	All	All	All
Italy	2011	ND	ALL	ND	ND
		ND	SY; glass eel fishery permitted for the sole purpose of restocking	ND	ND
France	2010	NP	All	All	All
					Yes
		12	G and S :forbiddenS:restirction	No	
					Yes

National Measures for commercial fisheries					
Countries	**Measures**	**eel size restriction (min eel size to allow, cm)**	**eel stage restriction**	**gear size restriction, mm**	**gear restriction**
Albania		35	G	12	No

Algeria	Décretexécutif n°03-481 du 19 Chaoual 1424 correspondant au **13 décembre 2003** ; Décretexécutif n°04-187 du 19 Joumada El Oula 1425 correspondant au **7 juillet 2004** ; Décretexécutif n°04-188 du 19 Joumada El Oula 1425 correspondant au **7 juillet 2004** ; Décretexécutif n°04-189 du 19 Joumada El Oula 1425 correspondant au **7 juillet 2004** ; Décretexécutif n° 05-184 du 9 Rabie Ethani 1426 correspondant au **18 mai 2005** ; Décretexécutif n°06-372 du 26 Ramadhan 1427 correspondant au **19 octobre 2006** ; Décretexécutif n°07-208 du 15 JoumadaEthania 1428 correspondant au **30 juin 2007** ; Arrêté du 24 Rabie El Aouel 1432 correspondant au **27 février 2011**	30	G	18 mm for capechad and 4 mm for verveux	Capechade, trabaques, verveux et palangres
France*	**Les articles R. 436-65-5 du code de l'environnement et R. 922-50 du code rural et de la pêche maritime**	12	G(forbidden);YS(restriction) All	no	Yes """"
Greece	1) Royal Decree 142/**1972** A49, 2) Presidential Degree 235/**1979** A79 3) Ministerial Degree 661/110826/**2019**	30	GYS	<20	Fyke nets <20mm, longlines,single stranded nets
Italy	OTHER NATIONAL LAWS: MD 12/01/2011 (FISHERY & TRADE OF G EEL) MD n°403 **25/07/2019**	ND NP	ALL	ND NP	ALL
Spain	??	70 35	All	ND	ND
		35 38	All G	ND	ND
Turkey	**27 July 1973**-14607 RG -7/6719 "Su urunleri Tuzugu"	47 or 200 g	All	All	All
	Notification 5/1Regulating Commercial Fishing 2020/20	50	NP	NP	NP
National Measures for recreational fisheries					

Algeria	??	No	No	No	No
France	**Article R436-65-5 du code de l'environnementl'environnement**	12	G and S: forbidden Y: restriction All	no	Yes
Italy		No ND NP	ALL ALL ALL	ND ND NP	ND ALL ALL
Turkey	**27 July 1973**-14607 RG -7/6719 Regulation **1982-1983**/14circular Notification 5/2 Regulating Recreational Fishing-**2020/21**	70 70 (max 5 fish per fishermen per day) 250 g(max 3 fish per fishermen per day) 5070	All	NP	Fyke net, longline, harpoon, pots, traps etc

Regional Measures for commercial fisheries

Countries	Measure	eel size restriction (min eel size to allow, cm)	eel stage restriction	gear size restriction, mm	gear restriction
Albania		ND	ND	ND	ND
Algeria	Décretexécutif n° 05-184 du 9 Rabie Ethani 1426 correspondant au **18 mai 2005** ; Décretexécutif n°06-372 du 26 Ramadhan 1427 correspondant au **19 octobre 2006** ; Arrêté du 24 Rabie El Aouel 1432 correspondant au **27 février 2011**	30 No	G No	18 mm for capechad and 4 mm for verveux No	Capechade, trabaques, verveux et palangres No
France*	’’’	ND	ND	ND	ND
Italy	* REGIONAL MEASURES FOR COMMERCIAL FISHERIES: The action is mentioned in the management plan but due to the presence of many barriers for hydroelectric purpose along the Tevere River it can’t be implemented// OTHER NATIONAL LAWS: MD 12/01/2011 (FISHERY & TRADE OF G EEL) Décre texécutif n°03- 280 du 24 JoumadaEthania 1424 correspondant au **23 août 2003** ; Arrêtéinterministériel du 9 Ramadhan 1430	NO 28 Max size 25 40 ND	ALL ND YS ND ALL	ND NO ND ND Max 6 Fyke nets ND	ND ALL ND

	correspondant au **30 aout 2009**				
Spain		70	All		
Regional Measures for recreational fisheries					
Italy	***REGIONAL LAW: FROM APRIL TO SEPTEMBER A NUMBER OF 16 EELS/ MONTH/FISHERMAN ALLOWED // OTHER NATIONAL LAWS: MD 12/01/2011 (FISHERY & TRADE OF G EEL)// OTHER REGIONAL LAWS: President decree n. 191/ Pres.20 September 2012 (BAN OF G EEL FISHERY)	40	ND	ND	ND
		NO	ALL	ND	ND
		28	ND	ND	ND
		NO	ALL	NO	ALL
		Max size 25	YS	ND	ND
France	Depending on the river, special measures can be applied by fishermen federations, changing with years	12	G, S : forbidden; Y restrictions	ND	Yes, can in some place

CHAPTER 13. ESTABLISHING A COMMON BASIS FOR ASSESSING EEL STOCKS IN THE MEDITERRANEAN IN VIEW OF MANAGEMENT

ABSTRACT

A common basis for the assessment and the management of European eel across the Mediterranean Region was pursued with the data made available through the Research programme. Specific aims were to: define a solid and scientifically sound methodological approach and to determine an adequate spatial scales for eel stock assessment in the Mediterranean while also providing information on minimum requirements; identify common and suitable eel stock indicators; evaluate the eel stock in the Mediterranean area at the most accurate and most reliable level possible, based on the type and amount of data collected; and, test the effectiveness of different existing or potential management measures for the eel stock recovery and conservation. The assessment relied on the extensive data collected within the activities of other work packages (in particular WP1 and WP3) that gathered extensive and detailed data on eel habitats, local stock features, fisheries and management frameworks across the nine Mediterranean partner countries.

After a revision of existing eel stock assessment models, the Eel Stock Assessment Model (ESAM), an age- and sex-structured population dynamics model based on the early development of the DemCam model for French lagoons, was selected. This was due to its suitability for transitional waters (that is, lagoons and river deltas or estuaries) and the possibility of its application in both data-rich and data-poor conditions. Assessments were performed at site level for 122 locations for which information about fisheries (landings and effort, minimum eight years), biological data (size and age) and habitat (wetted area, sea connectivity and water temperature) were available (DATA RICH). Specific sites where historical (before 1990) or long time-series of landings from fishing barriers were available (SUPER SUBSET) were used to evaluate the range of the carrying capacity (kg/ha of potential settlers) and to estimate the potential biomass each site could produce in the absence of anthropogenic pressures. Results were extended to other sites that did not have data fulfilling minimum requirements (n=135, DATA POOR) and to a larger extent to all sites catalogued in WP3. Finally, the model was used to foresee the effects on eel potential spawning biomass at the country level, of some current or feasible management scenarios such as, different fishing closure periods at site or habitat level, minimum landing size for eels or gear restrictions. The results will facilitate discussions on the set of measures that could be applied in the different sites and habitats in the Mediterranean area to address declining eel stocks.

HIGHLIGHTS

Main outcomes

- A revision of existing and published stock assessment methods in Mediterranean region was presented.
- The identification of the optimal spatial scale (single site level) to apply a model approach in order to appraise alternative management measures for eel local stocks, was carried out.
- An extensive database was built, considering all data from other WPs that were checked and validated by scientific experts and National Focal Points from nine Partner Countries. Input data were complemented by available scientific literature.
- The ESAM (Eel Stock Assessment Model), an age-, sex- and stage-structured dynamic model that incorporates the main biological processes and anthropogenic pressures of eels at a single site scale, was selected to test collected data from more than 700 sites in different habitats and across nine Partner Countries in the Mediterranean.

- Different management scenarios were modelled to assess their effects in terms of landing biomass and silver eel escapement variations.

Main shortcomings

- Concerns remain on the representativeness of the assessment results, as the model strongly suffers from insufficient data. In general, the model generates figures for all eel habitat typologies, but it is very likely that the results are highly biased, due to insufficient and low-quality data. Therefore, the approach presented provides only provisional indications on stock status, while proposing a feasible methodology that, enriched with further site-specific data collection, could enable quantitative evaluation of management measures. Nevertheless, the comparison of different potential management measures, highlighting the most promising in terms of trade-offs between landings and escapement, may be of great interest for discussions on future management choices to be adopted for European eel stocks in the Mediterranean.

Recommendations

- Reliable and continuous data on fishing effort are crucial to correctly calibrate the model and obtain precise results.
- Historic commercial eel fishery catch and effort data should be retrieved (at least back to 1985) as they are extremely important for the ESAM model approach to be able to reliably estimate carrying capacity for each site.
- The establishment of glass eel monitoring across the Mediterranean will allow for the use of ad-hoc recruitment time series improving model output reliability

13.1. INTRODUCTION

13.1.1. The use of models for fishery management

Mathematical models provide effective tools to analyse fishery dynamics and identify trade-offs between conservation and management goals (Quinn, 2003). Unfortunately, developing reliable models requires specific training in mathematics or computer science and the availability of good quality, long-term datasets. Data availability is particularly critical for small-scale, data-poor fisheries lacking the financial and institutional capacity typical of more lucrative industrial fisheries.

The essentially local nature of eel populations means that responsibility for the attainment of management and conservation objectives set by international regulations largely resides with national governments, with individual river basins as the primary management units. Local measures, that should produce equitable and consistent results across river basins and countries, need specific analytical tools able to provide a cost-effective and consistent approach to conservation of this widespread species.

However, it is highly unlikely that the status of a local stock can be assessed in all waters in the Mediterranean region where eels are found. In this framework, pragmatic approaches and the use of models to describe the population dynamics are the basic element for the designation of site-specific management and conservation plans. Eel population models can identify critical components of species life history and its responses to different environmental forces (De Leo *et al.*, 2009). The modelling of complex eel life cycles for different habitats (including lagoons, estuaries, rivers, streams and lakes) is extremely difficult, and for this reason, various modelling approaches adjusted to the features of each environment have been proposed (Dekker, 2000a, Dekker, 2000b; Feunteun *et al.*, 2000; Aprahamian *et al.*, 2007; De Leo *et al.*, 2009; Oeberst and Fladung, 2012; McCarthy *et al.*, 2014; Schiavina *et al.*, 2015; Bevacqua *et al.*, 2019).

At the local or regional scale, eel stock monitoring series and information on anthropogenic impacts are often lacking. In these situations, models can complement, although not completely substitute for, an analytical assessment of the stock. With a general knowledge of eel biology, strengthened with available data, a model may yield an initial assessment of the status of the stock in relation to sustainability targets. To provide advice on sustainable management, knowledge is required of the pressures that anthropogenic activities generate on the stock, whether these conflict with the sustainability targets set in the recovery plan, whether pragmatic reference points for local management can be derived and which quantitative effect the management options available for remedial action will have.

Despite these improvements, some concerns remain about the representativeness of the assessment results, as the model strongly suffers from insufficient data. The calculation model generally generates figures for all eel habitat typologies, but it is very likely that the results are highly biased, due to insufficient and low-quality data. Therefore, the approach presented here provides only provisional indications on stock status, but proposes a feasible methodology that, enriched with further data collection on specific information that is lacking in each site, could enable a quantitative evaluation of management measures. However, this analysis shows how the model can be used for the assessment of different management measures and the comparison of results in relative terms.

13.1.2. Eel stock assessment models: a brief review

Most common fish population models have been developed for species with well-defined population structures. To take this into account, models estimating the population dynamics of eel are often trying to cover wide geographical scales and are therefore largely dependent on input data compiled from literature sources (Aprahamian *et al.*, 2007; Åström and Dekker, 2007; Lambert and Rochard, 2007). In the absence of system-specific, input data, it is often necessary to convert and generalise vital population characteristics to a larger scale and simplify the model assumptions (Aprahamian *et al.*, 2007; Åström and Dekker, 2007).

Earlier approaches to eel stock modelling (for example, Rossi, 1979 and Sparre, 1979) were based on classical fishery modelling by using cohort models or age-structured models and provided first insights into certain eel populations but lacked the inclusion of some key characteristics of eel population dynamics. A major step towards developing a realistic model was made during the SLIME (Study Leading to Informed Management of Eels) project (Dekker et al. 2006). Six different models were reviewed and tested, using datasets of ten case studies at river basin level from all over Europe to derive reference points for sustainability and to model the potential effect of legal and technical measures aimed at stock recovery. Generally, previous modelling approaches can be categorised as stage-specific models (for example, GEMAC in SLIME), cohort models (Sparre, 1979, Rossi, 1979, Gatto and Rossi, 1979), input-output models (Vøllestad and Jonsson, 1998), size- and age-structured models (for example, De Leo and Gatto, 1995; Dekker, 1996; Greco *et al*., 2003; Åström and Wickström, 2004; DemCam in SLIME), models enabling an analysis of spatially distributed populations (Lambert and Rochard, 2007) and global models (Dekker, 2000; Åström and Dekker, 2006; Bevacqua *et al*., 2015).

The focus and the modelling methods differ, with respect to the main purpose of the model, the availability of data and the accuracy needed. Most of the models consider eel stocks of a single water body, while some of them take the spatial dynamics explicitly into account. The exceptions to this are global models developed with the aim of assessing the entire European eel stock (Dekker, 2000; Åström and Dekker, 2006; Bevacqua *et al*., 2015) as they provide an estimate of the time scale of recovery of recruitment and give information about the scale of restrictions needed to pursue the route to stock recovery.

The main difference between global and local modelling approaches is the representation of the eel life cycle. Global models could benefit from implementing the full life cycle, generating each eel cohort on the basis of each spawner cohort abundance, while local models only focus on the inland and coastal phase of the life cycle thus depending on external inputs for the recruitment time series to estimate the spawner biomass leaving the area. It is apparent how the global model could be self-consistent in the population dynamics of the species. However, the spatial extent (an area of more than 50 000 km^2 from the Sargasso Sea to Europe and the Mediterranean) and the scale of the characteristics of the process (including river basins and lagoons) require a level of complexity and a completeness of data availability that is solved with approximations. On the other hand, local models could benefit from site-specific data on the habitat and the biological characteristics and are more suitable for representing local behaviour and management scenarios, but always rely on input recruitment time-series, which are very often lacking, especially at the single site level.

Recently developed models include several aspects of eel dynamics, namely recruitment, body growth, sexual development, density-dependent settlement (that is, carrying capacity), natural and fishing mortality, adult metamorphosis, migration and simulation of a variety of effects (not just fishing). Most models are built to enable the testing of management options by modelling different scenarios and also to reconstruct former or "pristine" conditions. There are also simplistic models, which are flexible (for example, SWAM in SLIME). Different models for estimating the escapement of silver eel were tested and applied during the EU project "Pilot projects to estimate potential and actual escapement of silver eel" (POSE, Walker *et al.,* 2011) which used different basic data for estimations.

Despite their accuracy in reproducing observed data, they have been used mainly for research purposes, as their complexity prevents application outside academic circles. On the other hand, general-purpose software packages (for example, those developed by Pauly, Christensen and Walters, 2000; Kell *et al.*, 2007; Lembo *et al.*, 2009) are not structured to grasp the complexity of eel demography nor to guide users to properly define the functions describing the relevant processes and set up model parameters accordingly.

Recently, the use of modelling approaches has become more frequent in Mediterranean contexts in order to quantify the escapement rate of silver eels (Bevacqua *et al.*, 2009; Walker *et al.*, 2011; Schiavina *et al.*, 2015). However, such methods, should be validated with field studies, allowing a general estimation of future migrating spawners even in "data poor" situations.

In the Mediterranean area, very few studies have been published aimed at setting up tools to quantify stock parameters. Both recent and older papers, based mainly on research at the local level (single catchment or lagoon), estimated population size using mark-recapture approaches (LaBar, Casal and Delgado, 1987 in Spain; Amilhat *et al.*, 2008 and Charrier *et al.*, 2012 in France; Rossi *et al.*, 1988 in Italy; Derouche, Aoun and Kraiem, 2014, in Tunisia). An overview of existing and previously used stock assessment methods in the Mediterranean region were produced during the early phase of this research programme (Table 13.1). In general, few studies were found, especially in recent years and most were targeted at local eel stocks in lagoons. Indeed, they reported case studies providing methods and results that would be difficult to transfer to other contexts and habitats. Moreover, none went beyond an estimation of current silver eel escapement and did not foresee an assessment of alternative management scenarios.

The assessment of local stocks and impacts of anthropogenic factors is a complex issue for eel, given the considerable diversity in environmental, biological, and fishery-related factors, as well as the large spatial coverage, differences between the monitoring schemes and the availability of data found across the nine Mediterranean country partners. The ultimate aim of this WP was to provide, through the most suitable and reliable modelling approach, a common methodological path for the assessment of Mediterranean local eel stocks. Additionally, it would make scientific and technical contributions towards discussions on the effectiveness of different possible coordinated approaches for eel conservation and eel management measures for the implementation of Eel Management Plans in Mediterranean countries.

Table 13.1. Overview of the published and previously used stock assessment methods in Mediterranean region

Country	Eel STOCK assessment	Spatial level	Eel Stage	Approach used	RESULTS		Periodicity	Year of assessment	Reference value		Scientific published references	Data accessibility
	Has an eel stock assessment ever been carried out in your country?	*where it has been carried out?*	*1) standing stock (yellow eel) assessment 2) escapement assessment (silver eel) 3) both*	*1) Electrofishing 2) Fyke netting 3) Mark– recapture 4) Model approach*	*data*	*1) assessed biomass in tons/yr or kg/ha 2) assessed density in ind/m2*	*1) single attempt 2) yearly 3) etc.*	*ex. 2018*	*Has a pre-eel stock decline biomass value been defined?*	***HOW?*** *1) historical silver eel catches 2) back-calculated by a model? 3) scientific literature*	*ex. AB & CD (2019)*	*YES / NO / upon formal request*
Albania	Y	Country	silver eel	model approach	69	tons/yr	single attempt	2000-2012	Y	scientific literature (ICES, 2011)	Aalto et al. 2016	Yes
Algeria	Y	Country	silver eel	model approach	1	tons/yr	single attempt	2000-2012	Y	scientific literature (ICES, 2011)	Aalto et al. 2016	Yes
Bosnia and Herzegovina												
Croatia												
Cyprus												
Egypt	Y	Country	silver eel	model approach	1367	tons/yr	single attempt	2000-2012	Y	scientific literature (ICES, 2011)	Aalto et al. 2016	Yes
France	Y	Country	silver eel	model approach	84	tons/yr	single attempt	2000-2012	Y	scientific literature (ICES, 2011)	Aalto et al. 2016	Yes
	Y	Bages-Sigean lagoon	silver eel	mark-recapture	30	kg/ha	single attempt	2007	Y	historical landings	Amilhat et al. 2008	Yes
	Y	Camargue lagoon	silver eel	model approach	14	ton/yr	single attempt	2007	N	na	Bevacqua et al. 2007	Yes
	Y	Or lagoon	silver eel	mark-recapture	13,2	kg/ha	single attempt	2009	N	na	Charrier et al 2012	Yes
	Y	Prevost lagoon	silver eel	model approach	0,5	kg/ha	single attempt	2014	Y	modelling fishing effort = 0	Schiavina et al. 2015	Yes
	Y	Camargue lagoon	silver eel	model approach	7,8	kg/ha	single attempt	2014	Y	modelling fishing effort = 0	Schiavina et al. 2015	Yes
Greece	Y	Country	silver eel	model approach	205	tons/yr	single attempt	2000-2012	Y	scientific literature (ICES, 2011)	Aalto et al. 2016	Yes
Israel												
Italy	Y	Country	silver eel	model approach	913	tons/yr	single attempt	2000-2012	Y	scientific literature (ICES, 2011)	Aalto et al. 2016	Yes
	Y	Comacchio Lagoon	silver eel	model approach	0,45	kg/ha	single attempt	2011-12	N	na	Aschonitis et al., 2017	Yes
	Y	Comacchio Lagoon	silver eel	mark-recapture	19,32	kg/ha	single attempt	1963-73	Y	historical landings	Rossi 1979	Yes
	Y	Comacchio Lagoon	silver eel	model approach	6,15	kg/ha	single attempt	1989	Y	historical landings	De Leo & Gatto 1995	Yes
	Y	Porto Pino lagoon	both	model approach	19	kg/ha	single attempt	1979-81	N	na	Rossi & Cannas 1984	Yes
Lebanon												
LIbYa	Y	Country	silver eel	model approach	23	tons/yr	single attempt	2000-2012	Y	scientific literature (ICES, 2011)	Aalto et al. 2016	Yes
Malta												
Monaco												
Montenegro	Y	Country	silver eel	model approach	11	tons/yr	single attempt	2000-2012	Y	scientific literature (ICES, 2011)	Aalto et al. 2016	Yes
Morocco (MED)	Y	Country	silver eel	model approach	81	tons/yr	single attempt	2000-2012	Y	scientific literature (ICES, 2011)	Aalto et al. 2016	Yes
Slovenia	Y	Country	silver eel	model approach	0	tons/yr	single attempt	2000-2012	Y	scientific literature (ICES, 2011)	Aalto et al. 2016	Yes
Spain	Y	Country	silver eel	model approach	204	tons/yr	single attempt	2000-2012	Y	scientific literature (ICES, 2011)	Aalto et al. 2016	Yes
Syrian Arab Republic												
Tunisia	Y	Country	silver eel	model approach	492	tons/yr	single attempt	2000-2012	Y	scientific literature (ICES, 2011)	Aalto et al. 2016	Yes
	Y	Ichkeul Lake	silver eel	mark-recapture	23,55	kg/ha	single attempt	2013-14	Y	historical landings	Derouiche et al., 2016	
Turkey	Y	Country	silver eel	model approach	328	tons/yr	single attempt	2000-2012	Y	scientific literature (ICES, 2011)	Aalto et al. 2016	Yes

13.2. MATERIAL AND METHODS

13.2.1 The ESAM model

Overview and assumptions

The ESAM (Eel Stock Assessment Model) is an age-, sex- and stage-structured dynamic model that incorporates the main biological processes and anthropogenic pressures of eels at a single site scale.

The strength of this model is the possibility to embed a set of default parameters to run simulations in all data availability situations, from data-rich cases to data-poor, producing outputs of time-series for landings and silver eel escapement. ESAM was selected for use because it is flexible and easily adapted to data-poor case studies, and it was developed specifically for lagoons that represent highly productive habitats for eel in the Mediterranean area.

The ESAM model builds on early work on eel demography and management by De Leo and Gatto (1995; 1996; 2001) for the Comacchio lagoons (Italy), on subsequent developments by Bevacqua *et al.* (2007) for the Camargue lagoons and on a generalization at the European scale by Andrello *et al.* (2011) followed by a further improvement by Schiavina *et al.* (2015) for eel stock assessment.

The approach was reviewed and positively evaluated in the ICES working group SGIPEE and the POSE project (Walker *et al*., 2011) that underlined its reliability for the assessment of the eel stock and catches in spatially implicit environments such as lagoons, lower water systems or uniform stretches of rivers.

In a general formulation, ESAM can be used to describe the demography of different eel stocks, provided that sufficient data are available for parameter calibration. The model covers the whole continental phase of the life cycle of European eel, from recruitment at the glass eel stage up to the escapement of migrating silver eels. It defines the eel stock and the harvest structured by age, length, sex and maturation stage (yellow or silver) on an annual basis. The most important improvement implemented during this work was the use of seasonality for recruitment, silvering and fishing effort, to account for monthly closures and their different effects on both yellow and silver eel catches. In fact, the model is based on annual iterations, but it also considers interannual events with specific seasonality, such as recruitment, silvering and fishing pressure that can be adapted to the different conditions and provide more accurate results when assessing management measures (for example, specific monthly closures). By considering all parameters as constant since the latest input year, the model is able to run forecast scenarios imposing different management measures.

ESAM requires data on historic and current wetted areas, temperature, connection with the sea (both for recruitment and escapement), silver eel characteristics (length, age or more detailed von Bertalanffy parameters to set the body growth model), sex ratio (set to 0.5 when information is missing), morphometric relationships, stocking abundances, exploitation characteristics (of all stages; glass eels, yellow eels, silver eels and migrating silver eels), seasonality of recruitment, silvering and exploitation, and observed time-series of catches. For many of these data, default values (literature averages for the European population) were proposed and used in data-poor case studies.

Body growth curves were described by the model proposed by Melià *et al*. (2014), which derives von Bertalanffy parameters from migrating silver eel characteristics. The probability of reaching sexual maturity and natural mortality were estimated with the model proposed by Bevacqua *et al*. (2006; 2011) with parameters adapted accordingly to growth curves (Andrello *et al*., 2011).

Fishing mortality rate (F) was computed for fisheries using both nets and hooks. It was calculated as the result of effort, the selectivity of the nets or hooks used (depending on the length and the mesh or hook size of the gears) and catchability (Bevacqua *et al*., 2009), specifically calibrated for each site, eel stage and gear typology (that is, nets or hooks). The model also considered fishing barriers that, when active, capture all silver eels along the escapement way. All fishing mortalities and captures in barriers were modulated by the seasonality of fishing activities (for example, barriers capture all escapement only in the declared working months). Calibrations were carried out by minimizing the sum of square errors between predicted and observed catches in each class (yellow, silver and silver from fishing barriers). When available observed landings data were disaggregated by stage and gears, the model compared annual landings, predicted and observed, separately. In cases where these data were provided as aggregated biomass, the model compared an aggregation of predicted landing biomass with observed values.

The model allowed consideration of other anthropogenic mortality, such as silver eel mortality during the downstream migration, by considering the number of dams with hydroelectric turbines and the likelihood of their survival at each facility (ς = 0.682, ICES, 2011), cormorant impacts (when available data on cormorant populations were available) and habitat loss mortality.

Moreover, the model made it possible to concatenate several sites within the same river basin, letting the escapement of silver eels flow from the upper site to the sea and considering the added mortality from the fishery in the intermediate sites (for example, upper river escapement goes into the estuary and is subject to the fishing pressure at this site before being considered escapement to the sea).

On the basis of historical landings (before 1990, when available) or fishing barriers landings, the model estimated the carrying capacity of the site, that corresponded to the settlement potential, that is the maximum number of glass eels that can settle in a site (Bevacqua *et al.*, 2007). Using a generalization of the recruitment index for 'Elsewhere Europe' (that is, a decreasing exponential function calibrated on ICES time-series) provided by ICES (2021), the recruitment time-series was reconstructed for each site under the assumption of a saturation of the settlement potential before the 1980s and a minimum recruitment level in 2010. Following the ICES (2021) analysis, the recruitment increased until 2016 and was considered as constant since (also during the forecast scenarios). With this series and considering the available wetted areas, the model simulated the system to obtain an estimate of the annual escapement of silver eels and forecast possible scenarios.

The limits of the application of this model were largely related to the lack of specific data for each site. The generalization process for a particular site may lead to overestimates or underestimates of the biomass of spawners. In particular, the value of recruitment, both pristine and actual, and the possible density effects in the settlement process had a strong influence on model predictions and the lack of specific data for the estimation of this parameter made the assessments less reliable. Therefore, the outputs of forecast management scenarios were provided as relative variations with respect to baseline scenario outputs of escapement and landings.

Recruitment

Following ICES (2021), the annual recruitment R was considered 100 percent of the historical recruitment R_0 until 1975, followed by an exponential drop to the 2010 level. The calibration of the exponential curve on the 'Elsewhere Europe' recruitment index gave the following function between 1975 and 2010:

$$R_{year} = R_0 \exp\left(-2.7539(year - 1979.42)\right). \quad (1)$$

From 2011, the recruitment showed a tiny restoration (modelled following the exponential function backwards) until 2016, the year that showed the beginning of a plateau (modelled with stable recruitment, also imposed throughout the forecast scenarios).

Settlement

The juvenile settlement density *S* was an increasing and saturating function of the annual recruitment density *R*, based on Bevacqua *et al.* (2007):

$$S = \frac{R}{1 + R/K} \qquad (2)$$

where *K* is the maximum settlement potential (that is, the asymptotic value of the settlement function, here also called carrying capacity). This value was calibrated for all sites having at least five years of landings before 1990, or using fishing barriers (as they are considered to capture all the escapement during the working season).

13.2.2. Spatial scale of assessment and input data

The ESAM model was used at site level taking into account the habitat typologies (lakes = LAK, lagoons = LGN, rivers = RIV and river estuaries = RIE) identified in WP3. Each RIV is connected to the RIE, but lacks information on the presence of dams and connections to LAK sites.

The data used to feed the model were extrapolated using the databases set up in other WPs and are reported in Table 13.2.

Table 13.2. ESAM model data input table. Information has been gathered at single site level and for each year

<table>
<tr><td rowspan="6">SITE DESCRIPTION</td><td rowspan="6">LGN, RIV, RIE, LAK</td><td>Country</td></tr>
<tr><td>Site name</td></tr>
<tr><td>Habitat typology</td></tr>
<tr><td>Pristine surface (ha)</td></tr>
<tr><td>Current surface (ha)</td></tr>
<tr><td>Average water temperature (°C)</td></tr>
<tr><td rowspan="3">NATURAL MORTALITY - CORMORANTS</td><td>Number of birds in the local colony</td><td>Cormorant abundance</td></tr>
<tr><td>Usually 120 days (Buttu et al., 2013; Volponi and Verza, 2008)</td><td>Wintering days</td></tr>
<tr><td>If unknown use 422 g/day (Feltham and Davies, 1996)</td><td>Average daily food intake (g/day)</td></tr>
</table>

	If unknown use ***0.5 percent.*** *Average value of Buttu et al., 2013; Carpentier et al., 2009; Fonteneau et al., 2009; Privileggi, 2003; Volponi and Callegarini, 1997; Suter, 1997; Cherubini, 1996*	**Eel percentage in cormorant diet**
		Yellow eels removed by wintering cormorants (kg)
LOCAL STOCK BIOLOGICAL DATA		**Average length of silver males (mm)**
		Average age of silver males (yr)
		Average length of silver females (mm)
		Average age of silver females (yr)
		Oldest silver eel found or maximum age (yr)
	$W = \mathbf{a} * L^B$ *Morphometric relationship from cm to g. If unknown set* ***a=0.000834*** *(Bevacqua et al., 2011)*	**Morphometric coefficient (g/cm)**
	$W = a * L^B$ *Morphometric relationship from cm to g. If unknown set* ***b=3.17*** *(Bevacqua et al., 2011)*	**Morphometric exponenet**
	If unknown use 1:1 Sex ratio: ***50 percent***	**Males fraction**
CONNECTION FROM-TO **Factors affecting fraction entering and fraction leaving**	*Percentage of glass surviving from marine fishery First entry will be used for all previous years 100* ***percent*** *no glass eel fishery*	**Glass eel fishery survival**
	0-1 Possibility to recruit in this strata this year	**Recruitability**
	month of recruitment peak	**Recruitment season**
	2008 was the year with minimum recruitment (ICES, 2014). If unknown set it equal to ***10 percent***	**Minimum level of recruitment with respect to 1980s**
	0-Absence 1-Presence	**Fishing barriers presence**

	0 ***percent*** *For completely closed barriers 100% if no migration barrier is present* ***(Not hydropower or fishing barrier)***	**Percentage of release from migration barriers**
	month of silvering peak	**Silvering peak month**
	Do not consider turbines along emissary for lake strata as it will be accounted in river strata. If you consider more than one river or lake per stratus weight this number by the area	**Number of turbines along migration route**
	Percentage of turbines with eel pass	**Presence of eel pass**
	Survival of ***91 percent*** *with turbines equipped with eel pass;* ***68 percent*** *without (ICES, 2011)*	**Hydropower survival**
RESTOCKING		**Glass eels stocked (kg)**
		Bootlaces stocked (kg)
		Average length of bootlaces stocked (mm)
	If unknown set it equal to ***76 percent*** *(Simon and Dorner, 2013)*	**Restocking survival**
FISHERY - EXPLOITATION	*(nets/day*day of fishing)*	**Per capita fishing effort**
		Fishermen abundance
	*(E = e*N or set 1 for a year and proportions among years)*	**Fishing effort**
	knot-to-knot mesh size if unknown use ***12mm***	**Net mesh size (mm)**
		Nets season
		Per capita hooks fishing effort
		Fishermen with hooks abundance
		Hooks fishing effort
		Hook size (mm)
	months (1-12)	**Hooks season**
		Barrier effort
	months (1-12)	**Barrier season**

		Minimum length allowed (cm)
FISHERY - OBSERVED CATCHES	*if data is missing leave* ***-1***	**Yellow eel catches observed (kg)**
	if data is missing leave ***-1***	**Silver eel catches observed (no barrier) (kg)**
		Nets yellow and silver eel catches observed (kg)
	if data is missing leave ***-1***	**Hooks yellow eel catches observed (kg)**
	if data is missing leave ***-1***	**Hooks silver eel catches observed (no barrier) (kg)**
		Hooks yellow and silver eel catches observed (kg)
	if data is missing leave ***-1***	**Silver eel catches from barrier observed (kg)**
		Total catches observed (kg)
STOCK MANAGEMENT	*months (1-12)*	**Season closure yellow eels**
	months (1-12)	**Season closure silver eels**

The huge amount of work carried out for other databases was the starting point for site selection for modelling. In order to organize and process the data, all sites were categorized into three groups with different levels of information: DATA-RICH, DATA-POOR, NO DATA sites.

Moreover a “super subset” was selected to estimate carrying capacity

The minimum requirements for a DATA-RICH site were:

- Assessed wetted area;
- yearly landing and effort data with high reliability scores (see Chapters 9 and 10 for details);
- at least eight years of landings data (even non-consecutive);
- reported mean annual water temperatures; and,
- eel biological features (at least from a nearby site in the same country and habitat typology).

Minimum requirements for a DATA-POOR sites were:

- Assessed wetted area;
- yearly landing and effort data with high reliability score (see Chapters 9 and 10 for details); quantitative landings, “quant-land”; qualitative effort, “qual-effort”; or quantitative landings and effort, “quant - land&effort”;
- at least one year of landings data;
- if unreported, mean annual water temperature was derived from a nearby site of the same latitude and habitat typology; and,
- eel biological features (at least from a nearby site of the same country and habitat typology).

Sites included in the habitat database but without the available information to be classed as DATA-RICH or DATA-POOR sites were classified as NO DATA sites.

13.2.3. Input characteristics for the ESAM database

In total, nine Mediterranean countries were covered, with 3 883 annual eel catch datapoints from 181 DATA-RICH+POOR sites (Figure 13.1) while NO DATA sites amounted to 558. Among DATA-RICH sites, Mediterranean coastal lagoons were the most frequently represented habitat in terms of wetted area (509 377 ha, n = 102) followed by lakes (69 765 ha, n = 16) and river estuaries (27 306, n = 11). DATA-POOR sites included 52 sites equally distributed between LGN and LAK (54 189 ha, n = 25 and n = 25, 23 508 ha, respectively) and covered a total wetted area of 377 241 ha.

In terms of numbers, most sites belonged to the NO DATA group. However, in terms of wetted area, data-poor and data-rich sites represented more than 60 percent of the whole dataset showing that the dataset used in this work was reliable and consistent.

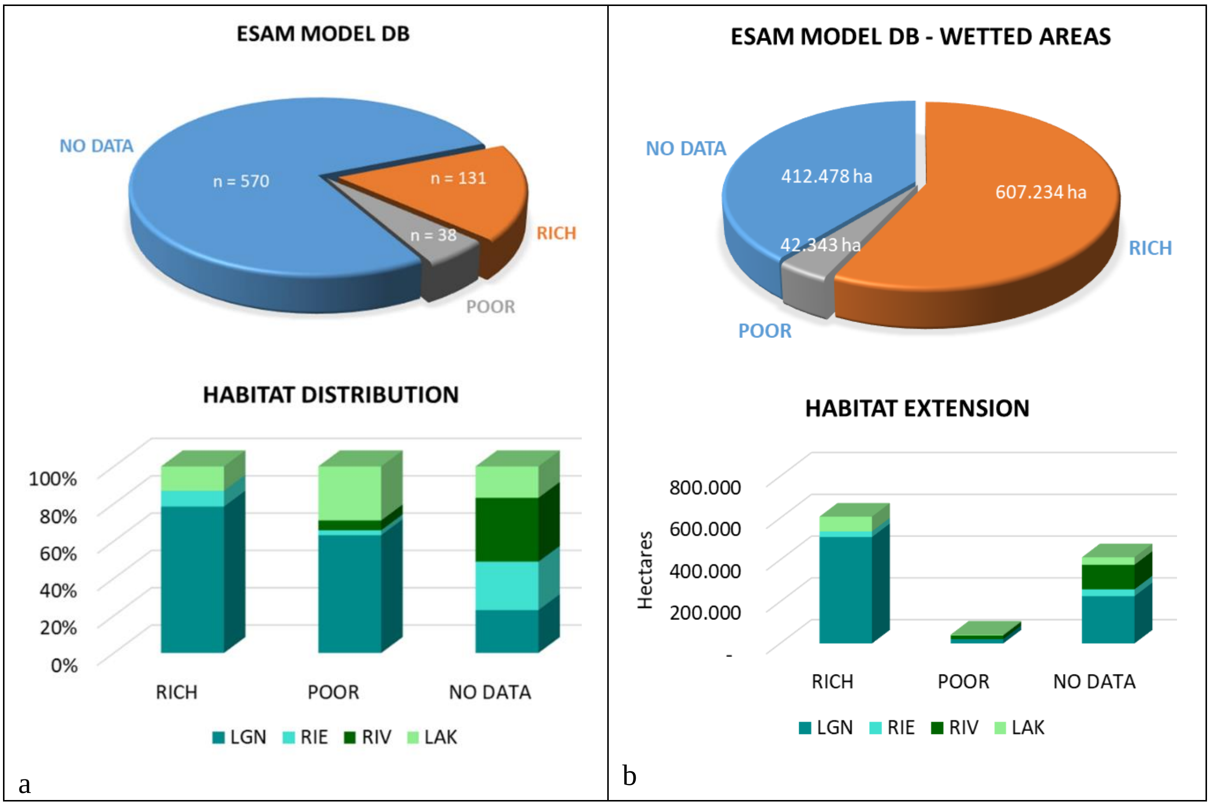


Figure 13.1. ESAM database composition by data richness, habitat (lakes = LAK, lagoons = LGN, rivers = RIV and river estuaries = RIE) and by (a) number and proportion (percent) of sites and (b) wetted area (hectares).

13.3. RESULTS

13.3.1 Calibration and carrying capacity estimation

The calibration results, based on one site as an example for each country involved in the project, showed how the model could or could not, reproduce specific landings data (Figure 13.2; points: observed data collected by WP3, lines: the model output). In general, when the model did not fit the points, problems were mainly due to the deficiency or absence of effort data (for example, in the case of Mellah lagoon effort was considered constant, since there was no information, Figure 13.2b)

In Bardawil Lagoon (Figure 13.2c) where the fishery was not present before 1998 then the model was able to go through the collected data, even if the inter-annual variability was not represented. This was given by our assumption on recruitment as no data on local variability were available. Effort variability was key, but was rarely available. Moreover, inter-annual variation in catches was partly due to effects not contemplated by the model (such as wind, water currents or rain).

In Greece, the model performance was better (Figure 13.2d), due to the fact that most sites were managed with fishing barriers only, the simplest capture sub-model. For example, the model followed silver eel catches at Mazome Lagoon barriers very well, with a slight delay in the landings increase seen in recent years.

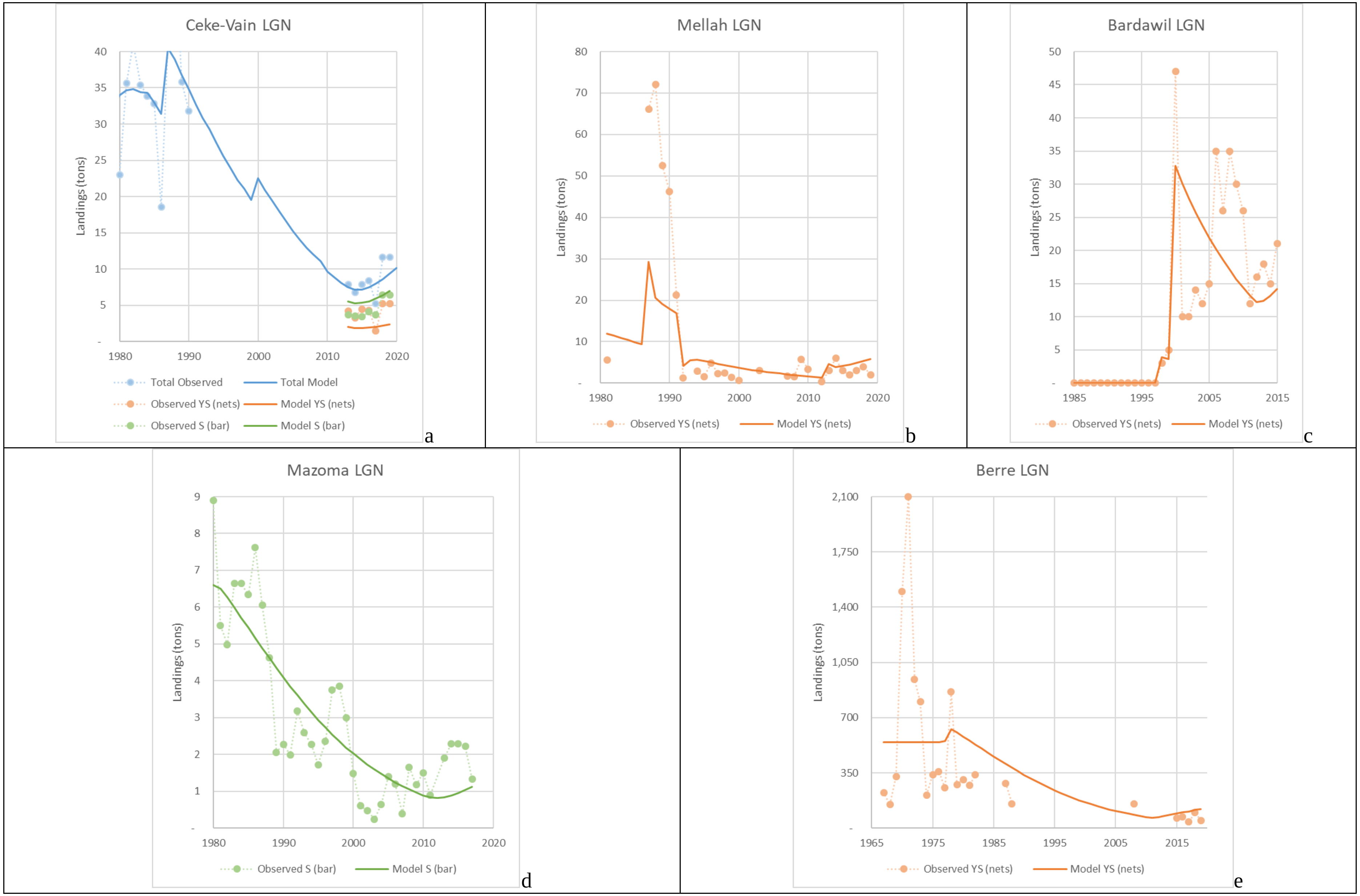
For Italy, model calibration performance is shown for Orbetello Lagoon, the most detailed and longest time-series of fishery data available (Figure 13.2f).

In the Ebro estuary in Spain, and in Ichkeul in Tunisia, the model was applied to calibrate landings also in non-lagoon habitats, such rivers and lakes. In Ichkeul Lake there was high variability of landings data during the time-series and the model did not perform efficiently (Figure 13.2g). This could be due to several reasons such as the lack of effort data, or the fact the eels were not a target of the fishery, or to lack of past data that did not allow fine-tuning of carrying capacity at this site. In Turkey the calibration results are shown for Enez Lagoon (Figure 13.2i).

In order to underline that effort data are very important input parameters for the model to understand and reproduce eel dynamics, more so than landings data, Figure 13.2j reports the model behaviour in the Po estuary in Italy. Even if the time-series for landings was short compared with other sites tested, having reliable effort data allowed the model to follow inter-annual variations in yellow eel catches correctly.

Considering the performance of the modelling approach, when sufficient fishery landings and effort data were available, the model was able to reproduce observed trends in commercial catches. This is important, especially in sites managed with fishing barriers where most of the escapement is trapped, because it confirms the validity of the main assumptions at the basis of the ESAM model, that is, the use of a recruitment trend index (calculated by last ICES Advice) and the hypothesis about glass eel settlement saturation pre-1980s in Mediterranean sites.

However, quantification of the actual recruitment level at a more local scale (for each site or at least country or area) is critical to determine the magnitude of model outputs such as spawner escapement and landings. Considering these assumptions, rather than using this approach to make accurate estimations (in absolute terms, such as eel tonnage), the relative performance of a selection of management alternatives were calculated in terms of percentage increase or decrease of eel landings and escaping silver eels with respect to a baseline situation.


Ceke-Vain LGN
Landings (tons)
Total Observed
Total Model
Observed YS (nets)
Model YS (nets)
Observed S (bar)
Model S (bar)
a
Mellah LGN
Landings (tons)
Observed YS (nets)
Model YS (nets)
b
Bardawil LGN
Landings (tons)
Observed YS (nets)
Model YS (nets)
c
Mazoma LGN
Landings (tons)
Observed S (bar)
Model S (bar)
d
Berre LGN
Landings (tons)
Observed YS (nets)
Model YS (nets)
e

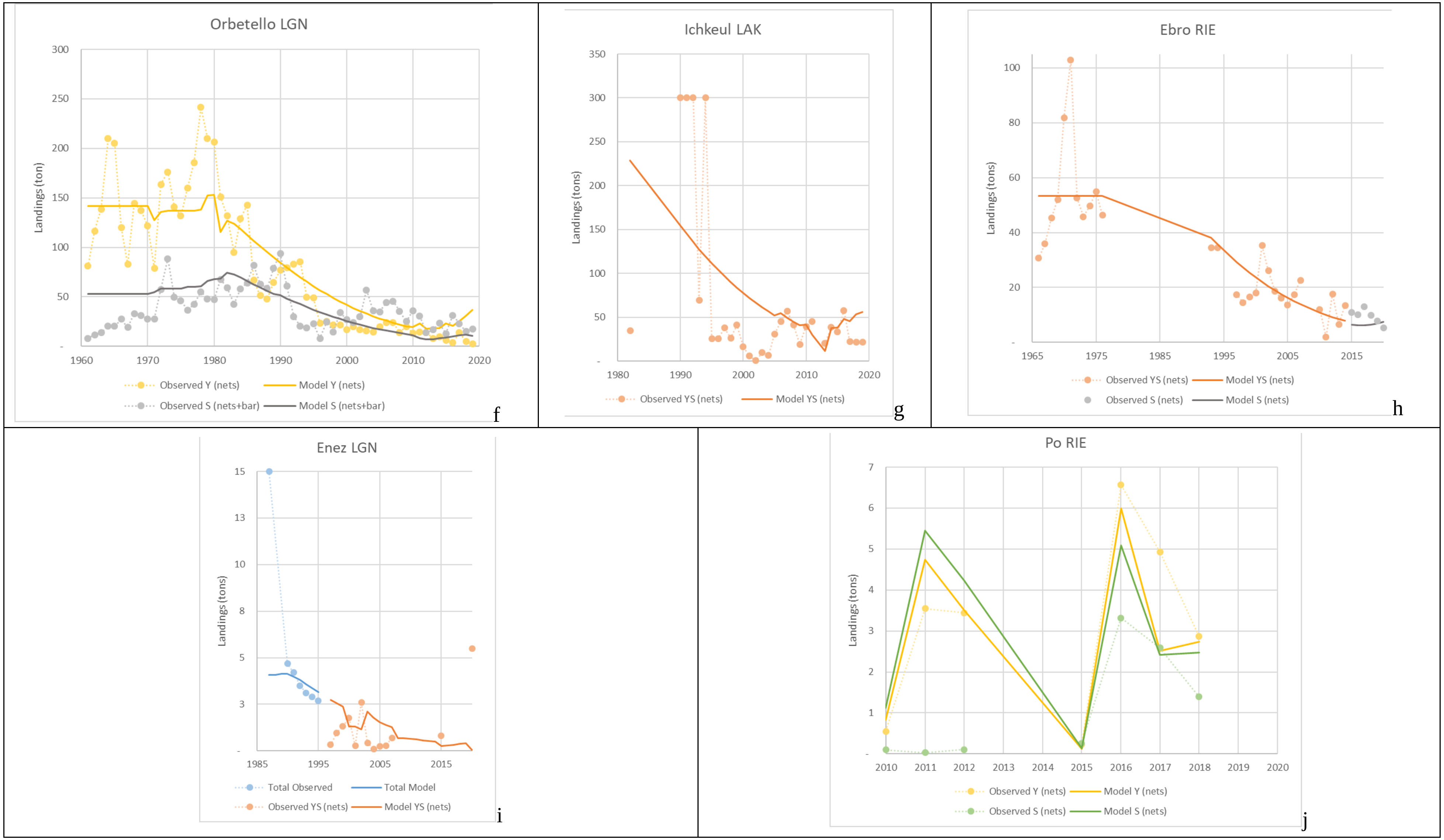


Figure 13.2. Model calibration examples in the nine countries involved in the project (a-j). Dots are observed landings data, lines show model landings estimations. (lakes = LAK, lagoons = LGN, rivers = RIV and river estuaries = RIE; Y = yellow eel, S = silver eel, YS = mixed yellow and silver eel)

13.3.2 Management Scenarios

The management scenarios tested by the ESAM model took into account some fundamental *a priori* choices:

- The projections were foreseen for the year 2030, thus considering the evolution of model results after seven years of implementation, for all possible management frameworks, in each simulation.
- Outcomes were expressed in terms of relative change (percent): increase or decrease, respectively of landings and escapement with respect to a baseline.
- The baseline scenario was referred to the situation in 2030 if the current measures in each site and country (as collected in WP1) remained in place as they are.

The management scenarios considered are listed below:

A. Maintenance of current measures – baseline.
B. No fishery temporal closures (without the three- month closures requested by Recommendation GFCM/42/2018/1 and EU Reg. 2019/124).
C. Abolition of current minimum landing size (where present).
D. Full fishery closure.
E. Reduction by half of fishing effort at fixed barriers.
F. Reduction by half of fishing effort of all nets.
G. Reduction by half of fishing effort of all other gears (that is, hooks).
H. Reduction by half of ALL fishing effort.
I. River connectivity restoration (both upstream and downstream).
J. Restocking in all sites (with 1 g/ha).
K. Full fishery closure in protected sites (RAMSAR, Nature2000, etc.).

These are examples of management scenarios that were conceived to evaluate their respective suitability to allow for an increased or decreased escapement and a correspondent decrease or increase in fishery landings.

Results for all scenarios are described below along with the percentage increase or decrease at site level (nine locations where model calibration had been tested) and at country level. To obtain these estimations, results assessed in data-RICH and data-POOR sites, were extended to all other sites of the nine countries involved in the project and included in the WP3 database.

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Table 13.3. Results at site and global level of management scenario B "No fishery temporal closures" (np = not pertinent, increase in landings or escapement in green, decrease in landings or escapement in red).

SITE LEVEL

SITE	LANDINGS	SILVER EEL ESCAPEMENT
Ceke-Vain	+25%	-59%
Mellah	+107%	-48%
Bardawil	np	np
Berre	-3%	-7%
Mazoma	+0%	+0%
Orbetello	+6%	-94%
Ebro	+4%	-1%
Ichkeul	+0%	+0%
Enez	+90%	-1%

GLOBAL LEVEL

	LAGOONS		LAKES		RIVERS	
COUNTRY	LANDINGS	SILVER EEL ESCAPEMENT	LANDINGS	SILVER EELS ESCAPEMENT	LANDINGS	SILVER EEL ESCAPEMENT
Albania	+25%	-55%	+25%	-52%	+33%	-19%
Algeria	+107%	-48%	+125%	-40%	+115%	-79%
Egypt	+0%	+0%	np	np	+0%	+0%
France	-2%	-8%	np	np	+0%	+0%
Greece	+8%	-19%	+60%	-11%	-0%	+0%
Italy	+18%	-26%	+25%	-1%	+11%	-4%
Spain	+43%	-22%	np	np	+4%	-1%
Tunisia	+0%	+0%	+4%	-3%	+124%	-79%
Turkey	+19%	-9%	+60%	-10%	+9%	-18%
TOTAL	+3%	-7%	+35%	-10%	+19%	-3%

B. No fishery temporal closures

The evaluation of the effectiveness of the consecutive three-month closure (requested by both Recommendation GFCM/42/2018/1 and EU Reg. 2019/124) showed how, without this measure, in all sites and countries, eel landings would increase and escapement decline. Egypt has yet to implement monthly closures and the effects of this measure were not evident.

France was a peculiar case where the model depicted an overexploitation of the species before this monthly closure was imposed. Therefore, when going back to the unmanaged baseline scenario, both landings and escapement biomass decreased.

Table 13.4. Results at site and global level of management scenario C “Abolition of current minimum landing size” (np = not pertinent, increase in landings or escapement in green, decrease in landings or escapement in red).

SITE LEVEL

SITE	LANDINGS	SILVER EEL ESCAPEMENT
Ceke-Vain	+7%	-48%
Mellah	-0%	-0%
Bardawil	np	np
Berre	np	np
Mazoma	+0%	-0%
Orbetello	np	np
Ebro	+2%	-1%
Ichkeul	-0%	-0%
Enez	+20%	-0%

GLOBAL LEVEL

	LAGOONS		LAKES		RIVERS	
COUNTRY	LANDINGS	SILVER EEL ESCAPEMENT	LANDINGS	SILVER EELS ESCAPEMENT	LANDINGS	SILVER EEL ESCAPEMENT
Albania	+9%	-59%	+25%	-87%	+3%	-3%
Algeria	-0%	-0%	+0%	-0%	-2%	-0%
Egypt	+0%	+0%	np	np	+0%	+0%
France	+0%	+0%	np	np	+0%	-0%
Greece	+0%	-0%	+32%	-5%	+0%	-0%
Italy	-0%	-7%	+0%	-0%	+6%	-3%
Spain	+0%	-0%	np	np	+2%	-1%
Tunisia	+0%	-1%	-5%	-0%	-2%	-0%
Turkey	+28%	-10%	+32%	-5%	+2%	-2%
TOTAL	+0%	-2%	+11%	-4%	+1%	-0%

C. Abolition of current minimum landing size

In this scenario the abolition of the minimum landing size, a measure implemented in most of partner countries, did not particularly affect landings, nor escapement. It should be noted that in Albania and Turkey, where the minimum landing size is very high (30 cm and 50 cm respectively), effects in terms of reduced landings and increased silver eel escapement were more evident.

Table 13.5. Results at site and global level of management scenario D "Full fishery closure" (np = not pertinent, increase in landings or escapement in green, decrease in landings or escapement in red).

SITE LEVEL

SITE	LANDINGS	SILVER EEL ESCAPEMENT
Ceke-Vain	-100%	+701%
Mellah	-100%	+26%
Bardawil	-100%	+5%
Berre	-100%	+2890%
Mazoma	-100%	+215%
Orbetello	-100%	+1626%
Ebro	-100%	+44%
Ichkeul	-100%	+149%
Enez	-100%	+1%

GLOBAL LEVEL

	LAGOONS		LAKES		RIVERS	
COUNTRY	LANDINGS	SILVER EEL ESCAPEMENT	LANDINGS	SILVER EELS ESCAPEMENT	LANDINGS	SILVER EEL ESCAPEMENT
Albania	-100%	+607%	-100%	+467%	-100%	+91%
Algeria	-100%	+26%	-100%	+19%	-100%	+66%
Egypt	-100%	+260%	*np*	*np*	-100%	+5%
France	-100%	+680%	*np*	*np*	-100%	+14%
Greece	-100%	+232%	-100%	+13%	-100%	+14%
Italy	-100%	+151%	-100%	+49%	-100%	+39%
Spain	-100%	+60%	*np*	*np*	-100%	+44%
Tunisia	-100%	+150%	-100%	+102%	-100%	+62%
Turkey	-100%	+29%	-100%	+12%	-100%	+66%
TOTAL	-100%	+209%	-100%	+35%	-100%	+12%

D. Full fishery closure

This scenario tested an extreme situation that was suggested by ICES in its last 2021 advice ("target: zero catches of eel at all life stages in all habitats").

In this test, landings were reduced to zero and the effects on silver eel escapement were the highest among tested scenarios. This scenario could be considered as the potential silver eel escapement with estimated current recruitment.

Table 13.6. Results at site and global level of management scenario E “Reduction by half of fishing efforts at fixed barriers” (np = not pertinent, increase in landings or escapement in green, decrease in landings or escapement in red).

SITE LEVEL

SITE	LANDINGS	SILVER EEL ESCAPEMENT
Ceke-Vain	-37%	+263%
Mellah	np	np
Bardawil	np	np
Berre	np	np
Mazoma	-50%	+108%
Orbetello	-1%	+18%
Ebro	np	np
Ichkeul	np	np
Enez	np	np

GLOBAL LEVEL

	LAGOONS		LAKES		RIVERS	
COUNTRY	LANDINGS	SILVER EEL ESCAPEMENT	LANDINGS	SILVER EELS ESCAPEMENT	LANDINGS	SILVER EEL ESCAPEMENT
Albania	-31%	+192%	-14%	+78%	np	np
Algeria	np	np	np	np	np	np
Egypt	-33%	+97%	np	np	np	np
France	np	np	np	np	np	np
Greece	-39%	+90%	-3%	+1%	np	np
Italy	-19%	+28%	np	np	np	np
Spain	-1%	+1%	np	np	np	np
Tunisia	np	np	np	np	np	np
Turkey	-12%	+4%	-3%	+1%	np	np
TOTAL	-17%	+39%	-3%	+1%	np	np

E. Reduction by half of fishing efforts at fixed barriers

This scenario belonged to different effort reduction forecasts for the main eel fishing gears used in Mediterranean countries.

For barriers, halving effort was pertinent and beneficial only in those sites where a permanent trap was present at the sea channels of coastal lagoons and coastal lakes that was able to catch most migrating silver eels. Rivers are not involved by this measure. A reduction of effort for this gear typology can be obtained, reducing the operating time by half, from four months per year to two months per year. The level of escapement increase was higher in sites where fixed barriers were the only gear typology used (for example, Greece), and lower where barriers were coupled with other gears that contributed to diversify fishing effort on European eel. This measure had a great impact in terms of biomass since it affected only migrant silver eels with huge body biomass (females).

Table 13.7. Results at site and global level of management scenario F "Reduction by half of fishing effort of all nets" (np = not pertinent, increase in landings or escapement in green, decrease in landings or escapement in red).

SITE LEVEL

SITE	LANDINGS	SILVER EEL ESCAPEMENT
Ceke-Vain	-1%	+6%
Mellah	-37%	+11%
Bardawil	-49%	+2%
Berre	+1%	+129%
Mazoma	*np*	*np*
Orbetello	-0%	+54%
Ebro	-44%	+19%
Ichkeul	-37%	+57%
Enez	-50%	+1%

GLOBAL LEVEL

	LAGOONS		LAKES		RIVERS	
COUNTRY	LANDINGS	SILVER EEL ESCAPEMENT	LANDINGS	SILVER EELS ESCAPEMENT	LANDINGS	SILVER EEL ESCAPEMENT
Albania	-2%	+6%	-4%	+5%	-24%	+23%
Algeria	-37%	+11%	-38%	+8%	-1%	+7%
Egypt	-3%	+5%	*np*	*np*	-49%	+3%
France	-2%	+58%	*np*	*np*	-43%	+6%
Greece	-1%	+2%	-27%	+3%	-43%	+6%
Italy	-7%	+13%	-31%	+4%	-27%	+11%
Spain	-35%	+21%	*np*	*np*	-44%	+19%
Tunisia	-24%	+38%	-24%	+24%	-1%	+6%
Turkey	-16%	+4%	-27%	+2%	-15%	+10%
TOTAL	-8%	+20%	-24%	+5%	-34%	+4%

F. Reduction by half of fishing effort of all nets

In this scenario the fishing effort of all nets (including fyke nets, *capechades*, fences) was reduced by half. A reduction of effort for this gear typology can be obtained by reducing by half the number of fishers, the number of nets or the number of fishing days in a site. The effect depended on how important the effort level in that site or country was.

Since nets are the most widely used gears in the Mediterranean area, the effects on landings and escapement were evident in all sites and countries. Moreover, the effect on silver eel escapement was relatively higher in most exploited sites (where fishing effort was highest, that is in lagoons more than in lakes and rivers.

Table 13.8. Results at site and global level of management scenario G "Reduction by half of fishing effort of all other gears (that is, hooks)" (np = not pertinent, increase in landings or escapement in green, decrease in landings or escapement in red).

SITE LEVEL

SITE	LANDINGS	SILVER EEL ESCAPEMENT
Ceke-Vain	*np*	*np*
Mellah	*np*	*np*
Bardawil	*np*	*np*
Berre	*np*	*np*
Mazoma	*np*	*np*
Orbetello	*np*	*np*
Ebro	*np*	*np*
Ichkeul	*np*	*np*
Enez	*np*	*np*

GLOBAL LEVEL

	LAGOONS		LAKES		RIVERS	
COUNTRY	LANDINGS	SILVER EEL ESCAPEMENT	LANDINGS	SILVER EELS ESCAPEMENT	LANDINGS	SILVER EEL ESCAPEMENT
Albania	*np*	*np*	-1%	+1%	*np*	*np*
Algeria	*np*	*np*	+0%	+0%	*np*	*np*
Egypt	*np*	*np*	*np*	*np*	*np*	*np*
France	+0%	+0%	*np*	*np*	*np*	*np*
Greece	*np*	*np*	*np*	*np*	*np*	*np*
Italy	+0%	+0%	+3%	+0%	-0%	+0%
Spain	*np*	*np*	*np*	*np*	*np*	*np*
Tunisia	*np*	*np*	+0%	+0%	*np*	*np*
Turkey	*np*	*np*	+0%	+0%	*np*	*np*
TOTAL	+0%	+0%	+1%	+0%	-0%	+0%

G. Reduction by half of fishing effort of all other gears (that is, hooks)

This commercial fishery gear typology was used in very few sites across the Mediterranean area. A reduction of effort for this gear typology can be obtained reducing by half the number of fishers, the number of hooks or the operative fishing days in a site. The effect of a reduction in effort was also negligible in the few sites where long-lines with hooks were used.

Table 13.9. Results at site and global level of Management scenario H "Reduction by half of ALL fishing effort" (np = not pertinent, increase in landings or escapement in green, decrease in landings or escapement in red).

SITE LEVEL

SITE	LANDINGS	SILVER EEL ESCAPEMENT
Ceke-Vain	-43%	+305%
Mellah	-37%	+11%
Bardawil	-49%	+2%
Berre	+1%	+129%
Mazoma	-50%	+108%
Orbetello	-3%	+94%
Ebro	-44%	+19%
Ichkeul	-37%	+57%
Enez	-50%	+1%

GLOBAL LEVEL

	LAGOONS		LAKES		RIVERS	
COUNTRY	LANDINGS	SILVER EEL ESCAPEMENT	LANDINGS	SILVER EELS ESCAPEMENT	LANDINGS	SILVER EEL ESCAPEMENT
Albania	-38%	+229%	-26%	+122%	-19%	+16%
Algeria	-37%	+11%	-38%	+8%	-1%	+7%
Egypt	-35%	+102%	*np*	*np*	-49%	+3%
France	-3%	+58%	*np*	*np*	-43%	+6%
Greece	-41%	+95%	-33%	+4%	-43%	+6%
Italy	-26%	+42%	-27%	+4%	-28%	+11%
Spain	-37%	+22%	*np*	*np*	-44%	+19%
Tunisia	-24%	+38%	-24%	+24%	-1%	+6%
Turkey	-29%	+9%	-33%	+3%	-15%	+10%
TOTAL	-26%	+60%	-29%	+7%	-34%	+4%

H. Reduction by half of ALL fishing effort

In this scenario all fishing methods were considered (barriers, nets and hooks). All countries were similarly affected, both with a consistent decrease in landings and likewise with an increase in silver eel escapement. Results varied, depending on the level of total fishing effort in place in different sites, habitats and countries.

Table 13.10. Results at site and global level of management scenario I "River connectivity restoration" (np = not pertinent, increase in landings or escapement in green, decrease in landings or escapement in red).

SITE LEVEL

SITE	LANDINGS	SILVER EEL ESCAPEMENT
Ceke-Vain	np	np
Mellah	np	np
Bardawil	np	np
Berre	np	np
Mazoma	np	np
Orbetello	np	np
Ebro	+5%	+6%
Ichkeul	np	np
Enez	np	np

GLOBAL LEVEL

	LAGOONS		LAKES		RIVERS	
COUNTRY	LANDINGS	SILVER EEL ESCAPEMENT	LANDINGS	SILVER EELS ESCAPEMENT	LANDINGS	SILVER EEL ESCAPEMENT
Albania	np	np	np	np	+0%	+0%
Algeria	np	np	np	np	+0%	+8%
Egypt	np	np	np	np	+0%	+0%
France	np	np	np	np	+0%	+0%
Greece	np	np	np	np	+0%	+0%
Italy	np	np	np	np	+3%	+5%
Spain	np	np	np	np	+5%	+6%
Tunisia	np	np	np	np	+0%	+8%
Turkey	np	np	np	np	+0%	+0%
TOTAL	np	np	np	np	+1%	+1%

I. River connectivity restoration (both upstream and downstream)

This scenario was purely theoretical, and only relevant to river habitats. It considered the colonizable and productive area for eels as, not only lower stretches, but also river areas above the first unpassable dam. To carry out this simulation 229 675 ha of additional river surface were considered (an increase of about 54 percent of the currently available wetted area).

Since there were no fishery landing series in the uppermost part of rivers, the carrying capacity applied by the ESAM model to these river stretches was derived from scientific literature (3.2 kg/ha/yr of silver eels; Moriarty and Dekker, 1997).

In a speculative condition where river connectivity is completely restored (that is, all river habitats are suitable for eels without obstacles such as dams, and turbines) in the entire Mediterranean area, the increase in terms of silver eel biomass contribution by such habitats was scarce if compared with other scenarios. These results can be explained by the low eel density and carrying capacity generally showed in the uppermost reaches of rivers, along with low water temperatures. These characteristics resulted in lower silver eel production and growth rate with respect to other habitat typologies.

Table 13.11. Results at site and global level of Management scenario J "Restocking in all MED sites" (np = not pertinent, increase in landings or escapement in green, decrease in landings or escapement in red).

SITE LEVEL

SITE	LANDINGS	SILVER EEL ESCAPEMENT
Ceke-Vain	+0%	+0%
Mellah	+1%	+1%
Bardawil	+0%	+0%
Berre	+1%	+1%
Mazoma	+6%	+6%
Orbetello	+0%	+0%
Ebro	+6%	+7%
Ichkeul	+0%	+0%
Enez	+0%	+0%

GLOBAL LEVEL

	LAGOONS		LAKES		RIVERS	
COUNTRY	LANDINGS	SILVER EEL ESCAPEMENT	LANDINGS	SILVER EELS ESCAPEMENT	LANDINGS	SILVER EEL ESCAPEMENT
Albania	+1%	+0%	+1%	+1%	+3%	+7%
Algeria	+2%	+1%	+1%	+1%	+4%	+5%
Egypt	+0%	+0%	*np*	*np*	+0%	+0%
France	+1%	+1%	*np*	*np*	+5%	+5%
Greece	+8%	+7%	+0%	+0%	+5%	+5%
Italy	+2%	+2%	+2%	+0%	+2%	+3%
Spain	+2%	+3%	*np*	*np*	+6%	+7%
Tunisia	+0%	+0%	+2%	+2%	+4%	+4%
Turkey	+1%	+1%	+0%	+0%	+3%	+2%
TOTAL	+1%	+1%	+1%	+0%	+2%	+1%

J. Restocking in all MED sites

This particular scenario was developed only to show the maximum effects of restocking in Mediterranean habitats. It should be considered as theoretical because it relies on the hypothesis that all glass eels available would be used only for restocking. To run this scenario, restocking density was estimated considering the average amount of glass eel official landings in the Mediterranean area in the last five years (catches of ~1 tonne/yr). This quantity was used to equally stock all Mediterranean sites (1 061 730 ha of wetted area). Simulation results showed that in 2030, both landings and escapement would increase, even if at low levels. The most evident effects of simulated restocking were evident where stocking density (1 g/ha of glass eels) was closer to the actual recruitment estimated by the model for that site or country.

However, restocking practices entail both economic and biological consequences that go beyond numerical estimation as restocking success is rarely scientifically monitored and the real contribution of silver eels from restocked glass eels is uncertain.

Table 13.12. Results at site and global level of Management scenario K "Full fishery closure in protected sites" (np = not pertinent, increase in landings or escapement in green, decrease in landings or escapement in red).

SITE LEVEL

SITE	LANDINGS	SILVER EEL ESCAPEMENT
Ceke-Vain	-100%	+701%
Mellah	-100%	+26%
Bardawil	-100%	+5%
Berre	*np*	*np*
Mazoma	*np*	*np*
Orbetello	-100%	+1626%
Ebro	*np*	*np*
Ichkeul	-100%	+149%
Enez	-100%	+1%

GLOBAL LEVEL

	LAGOONS (74%)		LAKES (78%)		RIVERS (53%)	
COUNTRY	LANDINGS	SILVER EEL ESCAPEMENT	LANDINGS	SILVER EELS ESCAPEMENT	LANDINGS	SILVER EEL ESCAPEMENT
Albania	-85%	+131%	-100%	+407%	-13%	+12%
Algeria	-99%	+26%	-100%	+19%	-67%	+44%
Egypt	-34%	+64%	*np*	*np*	+0%	+0%
France	-65%	+496%	*np*	*np*	+0%	+0%
Greece	-65%	+149%	-100%	+13%	-97%	+13%
Italy	-90%	+136%	-90%	+4%	-76%	+29%
Spain	-100%	+60%	*np*	*np*	-93%	+12%
Tunisia	-97%	+146%	-44%	+44%	+0%	+0%
Turkey	-73%	+23%	-95%	+12%	-87%	+2%
TOTAL	-63%	+127%	-87%	+18%	-39%	+3%

K. Full fishery closure in protected sites

This scenario was purely theoretical. It envisaged a full eel fishery closure, applied only in specific sites, and selected among those that fell within protected areas such as RAMSAR sites, Nature 2000 network sites and national or regional parks. In the Mediterranean region among 629 sites registered, 268 are classified as protected sites (about 42 percent). The highest number are lagoons followed by lakes and rivers. For this reason, the criteria to select FRAs should be based on further caveats, and this scenario was foreseen as a way to exemplify the possibility of applying fishery closures on a site, as well as estimate how site-level closures could affect silver eel escapement.

Comparison of scenarios

The estimated effects of different management scenarios in terms of landing biomass and silver eel escapement are summarised in Table 13.13 by merging the three habitats for each hypothesis.

The best performance was obtained by total and protected site closures. Legal restriction of commercial eel fisheries seemed to be one of the measures showing instant short-term improvement of escapement numbers, but concurrently would give rise to great public controversy. The reduction of effort by half of different gears showed variable and interesting results. A reduction of all fishing effort obtained a higher increase in escapement and a higher reduction in landings, followed by halving effort at fixed barriers and of all nets. Negligible effects were produced by halving the effort of hooks.

This outcome was particularly important towards gaining an overall idea of the order of magnitude of effects on eel landings and silver eel escapement biomass produced by different management choices. Showing which management measures are deemed most promising in terms of trade-offs between landings and escapement could be of great interest for discussion among managers and stakeholders.

Table 13.13. Summarised results of management scenarios B to K on landings and silver eel escapement (increase in landings or escapement in green, decrease in landings or escapement in red).

<table>
<tr><th></th><th colspan="2">2030 SCENARIOS</th><th>LANDINGS</th><th>SILVER EEL ESCAPEMENT</th></tr>
<tr><td rowspan="10">2030 Maintenance of current measures
-
BASELINE</td><td>D</td><td>FULL FISHERY CLOSURE</td><td>-100,0%</td><td>+109,7%</td></tr>
<tr><td>K</td><td>FULL FISHERY CLOSURE IN PROTECTED SITES
(RAMSAR, Regional parks, etc.)</td><td>-65,5%</td><td>+64,3%</td></tr>
<tr><td>H</td><td>REDUCTION BY HALF OF ALL FISHING EFFORT</td><td>-25,9%</td><td>+31,4%</td></tr>
<tr><td>E</td><td>REDUCTION BY HALF OF FISHING EFFORTS AT BARRIERS</td><td>-15,5%</td><td>+19,2%</td></tr>
<tr><td>F</td><td>REDUCTION BY HALF OF FISHING EFFORTS OF ALL NETS</td><td>-10,2%</td><td>+11,8%</td></tr>
<tr><td>J</td><td>RESTOCKING IN ALL SITES (1g/ha)</td><td>+0,3%</td><td>+3,2%</td></tr>
<tr><td>G</td><td>REDUCTION BY HALF OF FISHING EFFORTS OF OTHER GEARS (hooks)</td><td>+0,0%</td><td>+0,0%</td></tr>
<tr><td>I</td><td>RIVER CONNECTIVITY RESTORATION
(both upstream and downstream)</td><td>+0,0%</td><td>+0,4%</td></tr>
<tr><td>C</td><td>ABOLITION OF CURRENT MINIMUM LANDING SIZE
(where present)</td><td>+0,7%</td><td>-1,5%</td></tr>
<tr><td>B</td><td>NO TIME CLOSURES
(without 3 months requested by GFCM/42/2018/1 & EU Reg. 2019/124)</td><td>+4,1%</td><td>-5,7%</td></tr>
</table>

13.4. DISCUSSION AND CONCLUSIONS

The main aim of this analysis was the definition of a solid and scientifically sound methodological approach for the assessment and management of European eel across the Mediterranean region, highlighting the best spatial scales and the minimum requirements to conduct the analysis. The approach provided a methodology to evaluate the eel stock in the Mediterranean and to test the effectiveness of different existing or potential new management measures for eel stock recovery and conservation.

The analyses benefited from the extensive data collection and validation work made in the other WPs of the project that involved all nine countries. In total, 739 Mediterranean sites were covered and although only 23 percent (DATA-RICH + POOR sites) presented detailed information about the eel fishery and the environment, in terms of wetted area, this group represented more than 61 percent of the total number of registered sites. Considering that sites with no data on fisheries, aside from extensions in hectares, were supposedly free from any legal fishery exploitation, the results presented should be considered highly representative. Notwithstanding this, the results obtained by the ESAM model-based approach do not constitute an assessment of Mediterranean local eel stocks but an appraisal of alternative hypothetical management measures in order to understand their effects on both eel landings and silver eel escapement, in different habitats and across partner countries in the Mediterranean. Therefore, outcomes concerning the different management scenarios considered were expressed in terms of relative change (percent), to anticipated landings and escapement with respect to a baseline scenario carried forward to 2030 (that is the baseline referred to the situation in 2030 assuming that the current management measures actually in place in each site and country continue as at present).

The results can be discussed in different ways for different countries. For countries that have implemented data collection on several aspects linked to eel (fisheries data, environmental characteristics, management measures) and their local stocks since several years, this evaluation may provide a first indication on both methodological aspects that can be improved and act as a starting point for future work.

For example, the collection of reliable and continuous data on fishing effort, in terms of number of fishers, gears used or operating days (seasonality), has a direct effect on population dynamics and is fundamental to correctly calibrating the model in order to obtain precise results. Nevertheless, countries that have been included in the evaluation process under the obligations of EU Regulation 1100/2007 provided a more structured dataset, but even in this case the data on fishery effort were scarce and must be improved.

Another aspect that deserves to be emphasized is the need to retrieve (at single site level) historical eel commercial fishery catches and of course effort data, if available, at least to 1985. To achieve this aim, even old documents reporting the order of magnitude of fished eel biomass could be useful. In fact these data are crucial for the ESAM model approach to estimate a reliable carrying capacity for each site as it requires an ecological reference point that corresponds to the settlement potential in terms of the maximum number of glass eels that can settle in a site. Due to different boundary conditions and the diversity of local climatic conditions, the heterogeneous morphology, hydrology and geochemistry of Mediterranean sites has to be added, and each lagoon, river, or lake should be regarded as a case in itself. This situation emphasises the need to collect data of different types at the single site level in order to implement reliable stock assessments and to evaluate how specific management measures could affect single eel local stocks in different ways.

Lastly, better estimates of glass eel recruitment are needed as the very few and short time-series (both fishery-dependent and fishery-independent) available from Mediterranean sites (compared to Atlantic sites), meant that the ESAM model based the recruitment index time-series on the ICES evaluation. Although the results obtained relative to the recruitment analysis in the present project appear to be consistent with the ICES index, great benefits in reliability would be obtained by the availability of data from glass eel monitoring in at least different areas of the Mediterranean.

Concerning the behaviour of the ESAM model in different habitat typologies, transitional waters (coastal lagoons, river estuaries or deltas) were better calibrated than freshwater sites (uppermost parts of the rivers and lakes). This is due to the fact that there was even less available information on eel fisheries in these habitats. For freshwater sites, a complementary approach might be envisaged for future development of eel stock evaluation, such as different assessment methods that take into consideration alternative data inputs (for example, eel density estimation by electrofishing), dependent on the habitat type and data availability, also in the Mediterranean area.

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CHAPTER 14. ANALYSIS OF EEL MONITORING IN THE MEDITERRANEAN

ABSTRACT

The aim of this chapter is to present all types of monitoring for eel in the Mediterranean region including glass eel recruitment, silver eel escapement and yellow eel stocks. The location of monitoring programmes and their characteristics helped to identify relevant key sites and methods that could be selected for long-term monitoring of each eel stage in the future as part of a coordinated network to evaluate the status of Mediterranean eel stocks on a long-term basis. Monitoring was considered as any study that took place in the same site, with the same standardized protocol, over a number of years. It included long-term series with at least ten years of data collection, following WGEEL criteria, but also short-lived research lasting one year or more. Questionnaires were provided to the nine partner countries to collect data, followed by a data quality check procedure before analysing the data. Only scientific monitoring was used and presented, with few exceptions.

HIGHLIGHTS

Scientific

- Most of the monitoring was located in northern Mediterranean countries and particularly EU countries. An important data gap was observed in the southern and eastern parts of the Mediterranean region.
- There was a general lack of long-term monitoring programmes with only two sites for glass eel recruitment, five sites for silver eel escapement and ten sites for yellow eel stocks. They covered only lagoon habitats for recruitment and escapement monitoring, and both lagoon and river habitats for yellow stock monitoring.
- Future monitoring is planned in Algeria and Türkiye in all habitat types (lagoon, river, lake), which could help to reduce data gaps at the Mediterranean level.
- Glass eel recruitment monitoring included 42 surveys with records between 1993 and 2021. The 19 on-going glass eel monitoring surveys take place only in the northern Mediterranean, EU countries, including France (four), Italy (13) and Spain (two). They are mostly located in rivers (ten) and lagoons (six). There is no glass eel monitoring in lakes. Only three long-term monitoring surveys were recorded, two in Vaccarès lagoon and one in Arles à Fos channel, all in France. The most commonly used method was fyke nets.
- Silver eel escapement monitoring was based around 28 surveys with records between 2010 and 2021. The 22 ongoing monitoring surveys took place only in the northern Mediterranean in Albania (10), France (1) and Italy (11). The surveys were mostly located in lagoons (18) but also in three rivers (in Italy) and one lake (in Albania). Only five long term monitoring surveys were recorded and they concerned only lagoon habitats, all five in Sardinia (Italy). The methods used were mostly fixed barriers and fyke nets.
- Yellow eel stock monitoring consisted of 35 surveys with records between 1993 and 2021. The 25 ongoing monitoring surveys took place only in the northern Mediterranean, in EU countries: including France (five), Greece (one), Italy (15) and Spain (four). The monitoring surveys were mostly located in lagoons (15) and rivers (ten). Ten long term monitoring surveys were recorded (five in France and five in Italy), and they concerned lagoon (seven) and river (three) habitats. There was no monitoring recorded in lakes. The methods used were diverse, principally fyke nets (nine lagoons and five rivers), fish pass traps (one river), enclosures (two lagoons) and electrofishing (three rivers). The widespread national electrofishing networks present in France since 1981, involving around 300 sites in the Mediterranean Region, was considered separately.
- Calich, Fogliano and Orbetello lagoons and Po and Tevere rivers (Italy) are the only sites where all stages were monitored simultaneously.
- Only one lake (Shkodra in Albania) is monitored at the present time. Egypt is the only country where no monitoring surveys were recorded. Information is missing from other Mediterranean

countries not participating to the GFCM European eel research programme, but from the literature, only Croatia and Cyprus seem to have monitoring programmes.

- Methodologies to collect data were not homogenous at the country level nor at the Mediterranean level, consequently monitoring results were difficult to compare.
- A large variety of methodologies including gear type, gear characteristics, sampling frequencies and survey periods were observed. A more in-depth analysis is required to ensure the scientific quality of the data collected and evaluate their potential use to determine Mediterranean indicators for recruitment, escapement, and yellow eel stocks on a long-term basis.
- Considering the variety of habitats in the Mediterranean Region, at least one monitoring programme per eel stage should be set up to represent each main type of habitat, in each part of the Mediterranean (north, south and east).
- Determination of key sites and common methodologies is complex and depends on many variables. However, proposals are discussed in this chapter. Considering the difficulties of setting up long-term monitoring, it is important to maintain long-term monitoring programmes that are already in place, continue ongoing monitoring where the methodology and results are satisfactory and start new monitoring programmes taking into account the highlighted gaps and proposals from the data providers. Whenever possible, monitoring of the three eel life stages should take place at the same site to better understand the population dynamics.

Management

- Four countries reported scientific monitoring under the DCF EU MAP framework: France (one monitoring programme, only for glass eels), Greece (one yellow eel stock monitoring programme), Italy (nine monitoring programmes, for all three stages) and Spain (two monitoring programmes for glass eels and four for yellow eels). Considering that DCF Regulation obliges EU member states to collect data on glass eel recruitment, silver eel escapement and yellow eel stocks, and that EU can provide financial support for this data collection programme, EU countries should evaluate the opportunity to start new monitoring programmes or maintain existing programmes through this framework.
- Monitoring from the southern and the eastern Mediterranean needs to be encouraged. The DCRF could be, in the same way as the DCF, a tool to promote long-term monitoring for non-EU countries in these regions.
- Since the EMPs were implemented, long time-series based on commercial fisheries have been impacted. This highlights the importance of maintaining and setting up new scientific monitoring programmes. Scientific monitoring surveys are often based on fisheries methodologies, and carried on with the essential knowledge and contribution of professional fishers but framed by a scientific protocol.
- Efforts should be maintained to include all Mediterranean countries in the annual joint EIFAAC/ICES/GFCM WGEEL to gather and enhance data from existing monitoring programmes but also to promote interactions with scientists from the entire eel distribution area to discuss and share advice on eel monitoring.
- The recent workshop on the future of eel advice (WKFEA) (ICES, 2021b) proposed a roadmap that targets the improvement of data that should be part of the stock analysis. This includes time-series for yellow and silver eels as well as biological parameters, reinforcing the need to maintain existing programmes and set up new monitoring programmes with consistent data collection and reporting in the Mediterranean region.

14.1. INTRODUCTION

Monitoring is defined by Goldsmith (2012) as “intermittent (regular or irregular) surveillance carried out in order to ascertain the extent of compliance with a predetermined standard or the degree of deviation from an expected norm” with surveillance being an “extended programme of surveys, undertaken in order to provide a time-series, to ascertain the variability and/or range of states or values which might be encountered over time”. Any static measures (for example, the size of an animal) but also dynamic processes (for example, growth, recruitment or production) can be employed for monitoring. Monitoring is mostly used by ecologists to detect incipient change and is also used to assess the effectiveness of legislation. Long-term monitoring programmes are repeated sampling over a long time period.

Standard definitions on what represents a long time period do not exist in the literature. However, within the joint EIFAAC/ICES/GFCM Working group on eel (WGEEL), only time-series more than ten years long are integrated in the trend analysis to produce the recruitment index. The analysis is based on long time-series for glass and yellow eel recruitment derived from fishery-dependent and independent surveys. However, only four glass eel time-series from the Mediterranean region of the 77 selected time-series across the geographic range of European eel are currently included in the WGEEL analysis (ICES, 2021a). Three are fishery-dependent, two from Spain and one from Italy, and one is fishery-independent, from France. Time-series of abundance of yellow and silver eels were explored for the first time by the WGEEL in 2020 but the analysis is more complex because these abundances are the results of both the general status of the population and local conditions including environmental conditions, anthropogenic pressures, life-history traits and management practices (ICES 2020a). From the 92 yellow eel and 41 silver eel time-series analysed, only two were from the Mediterranean, one for yellow eel (Lake Vistonida, fishery-independent monitoring in Greece) and one for silver eel (Albufera lagoon commercial catches in Spain, with unknown fishing effort) (ICES 2020a). Due to concern about the effect of management measures on commercial glass eel fisheries, since 2008 the WGEEL has highlighted the importance of fishery-independent monitoring programmes and recommended that member states protect long-term time-series and set up additional programmes. Monitoring is essential to follow stock trends, quantitatively and qualitatively. Some monitoring became compulsory, such as the request by the European Commission (Commission Delegated Decision (EU) 2019/910) for Member States to collect annual data on eels in at least one river basin by EMU on glass eel abundance, yellow eel stocks and silver eel escapement abundance, weight and sex ratios.

Meanwhile, at the Mediterranean level, the GFCM adopted Recommendation GFCM/42/2018/1 in 2018 to sustain the eel stock in this area. The GFCM eel research programme is part of these recommendations and one of its objectives is to review all the eel monitoring activities in the Mediterranean region in order to identify needs, as well as opportunities, to organise an efficient network in the future in terms of habitat type, geographical coverage, eel life stages monitored and methods.

This chapter aims to present and describe eel monitoring in the Mediterranean region, by performing a census of the current monitoring activities and frameworks for eel, mapping eel monitoring sites (including those for recruitment, yellow eel and silver eel), reviewing the methods for eel monitoring (including sampling design, life stage identification and aging) and proposing key sites and common methods that could be used for long-term monitoring.

Monitoring based on commercial fisheries was not taken into account as these programmes were analysed and discussed in Chapters 5 and 10. However, an exception was made for escapement monitoring based on fixed barrier fisheries in Albania, as it provides relatively good estimations of escapement in a region where there are no other silver eel escapement monitoring surveys. Fishery-independent monitoring can use similar gears to fisheries or other types of gears, but with a survey design based on scientific data collection.

14.2. MATERIALS AND METHODS

14.2.1 Data collection

Two kinds of templates were used to collect all available information on eel monitoring; databases (Excel format) and questionnaires (Word format) to be completed by data providers.

The database (see Supplementary Material on the Methodology Parts I and II), included:

- Three information sheets with the names and email addresses of the data processors, the official codes to use for countries, EMUs, habitats and missing data.
- Eight monitoring sheets, one per type of monitoring: commercial landings, recreational landings, recruitment, escapement, yellow eel stocks, trade, eel contamination and other monitoring programmes. For each type of monitoring, the same kind of information was requested including the site (country, region, EMU, site name, latitude and longitude WGS84 of the site and habitat type), the method used (gears, description of the method and frequency), the administrative aspects of the data collection (organisation in charge, framework, owner and access, data format, access contacts, use and end users), the data itself (variables available, time periods of records, and missing periods). This information was collected for the monitoring in place but also to a lesser extent, for past and future monitoring. Questions were adapted to the type of monitoring.

This structure aimed to be as exhaustive as possible, in order to have a detailed understanding of the protocols, data collection and monitoring management in place in each country. Each data provider was asked to complete the WP2 databases with specific information for its country.

Questionnaires were divided into sections for glass eels, yellow eels and silver eels. For each life stage, tables gathered information on sampling methods, life stage identification and age reading methods with the aim of having an overview of the advantages and limits of each method, linked to the habitat where they were used in each partner country. Similarly to WP2 databases, WP2 questionnaires were completed by each data provider with country-specific information.

Before starting data analysis, quality check procedures were conducted on the databases and the questionnaires. This step consisted of a data accuracy and reliability check in collaboration with all partners. In particular, misunderstandings of the information requested, empty cells, habitat attributions, codes and spelling errors were checked and corrected.

14.2.2 Data analysis

This chapter focused on monitoring glass eel recruitment, yellow eel stocks and silver eel escapement while other types of monitoring are discussed in other chapters. Databases were aggregated to have all the country information in the same table.

To present monitoring data, each category of monitoring was defined as follows:

- **Monitoring** is a study that takes place in the same site, with the same standardised protocol during a certain number of years. It could concern long-term studies, but also short-term research (more than one year). Studies that lasted one year but were still ongoing were considered as monitoring when planned to be carried on the following year. In this chapter, monitoring based on fisheries data was not included as it was already analysed in Chapter 5 on recruitment. However, an exception was made for escapement monitoring based on fisheries data-series from fixed barriers. They were considered as monitoring when the site and the method were consistent over time.
- **Long-term monitoring** is monitoring in place for ten years minimum.
- **Past monitoring** is monitoring that was done in the past and was stopped.
- **Present monitoring** is monitoring that is still ongoing.

- **Future monitoring** is monitoring planned for the future that had not started yet.
- **Monitoring attempt** was a short time study that lasted only one year or less. This indicates potential sites and methods that could be used in the future.

In order to take the potential attractiveness of the entire habitat into account and not only the habitat covered by the monitoring station, more detailed habitat codes were used for estuarine or transitional waters as follows:

- **RIE_lgn** for transitional waters linked to a lagoon (such as a tidal channel),
- **RIE_riv** for transitional waters linked to a river (usually estuary),
- **RIE_chan** for transitional waters linked to a channel (can be irrigation or drainage channel)
- **RIE_mar** for transitional waters linked to marshland

When reporting the type of habitat monitored, for more visibility, RIE_lgn and RIE_mar were integrated into the lagoon habitat category (LGN) while RIE_riv, and RIE_can were integrated into the river habitat category (RIV).

All maps were made using the software *QGIS* (2021) with the ESRI Ocean base map.

14.3 RESULTS

14.3.1 Glass eel recruitment monitoring

General overview of glass eel recruitment monitoring

A diverse range of glass eel monitoring activities were reported in terms of site (habitat type), time period covered, methods, organisms involved and management frameworks. Although some were compulsory under special frameworks at local, national or EU level (including, DCF EU MAP, EU EMP), only a few ongoing monitoring activities were identified. They were all based in EU countries, especially in Italy, where 68 percent of the current monitoring activities were being carried out. Only four long-term monitoring surveys (more than ten years of records) were identified, one in the past and three ongoing, all in France. Overviews of the monitoring surveys are presented in Figure 14.1 and Figure 14.2.

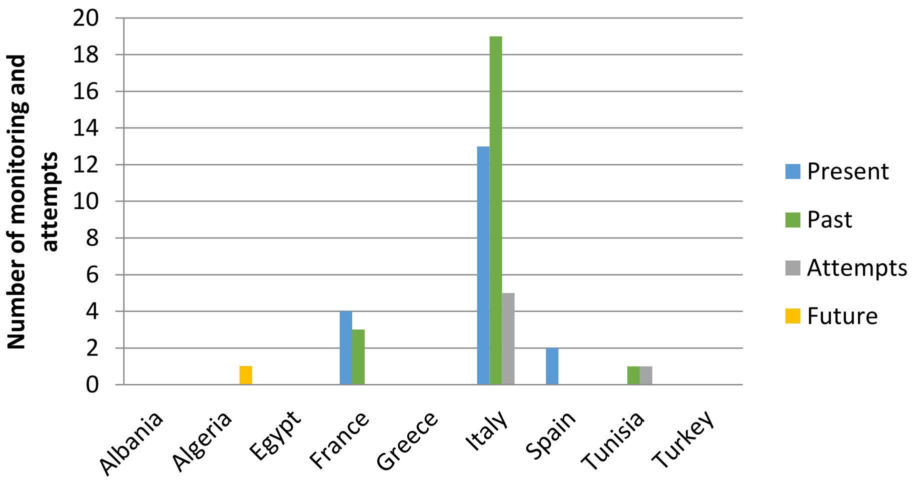

Figure 14.1. Reported number of glass eel recruitment monitoring activities (past, present, future) and monitoring attempts made in the Mediterranean region for the nine countries involved in the GFCM project.

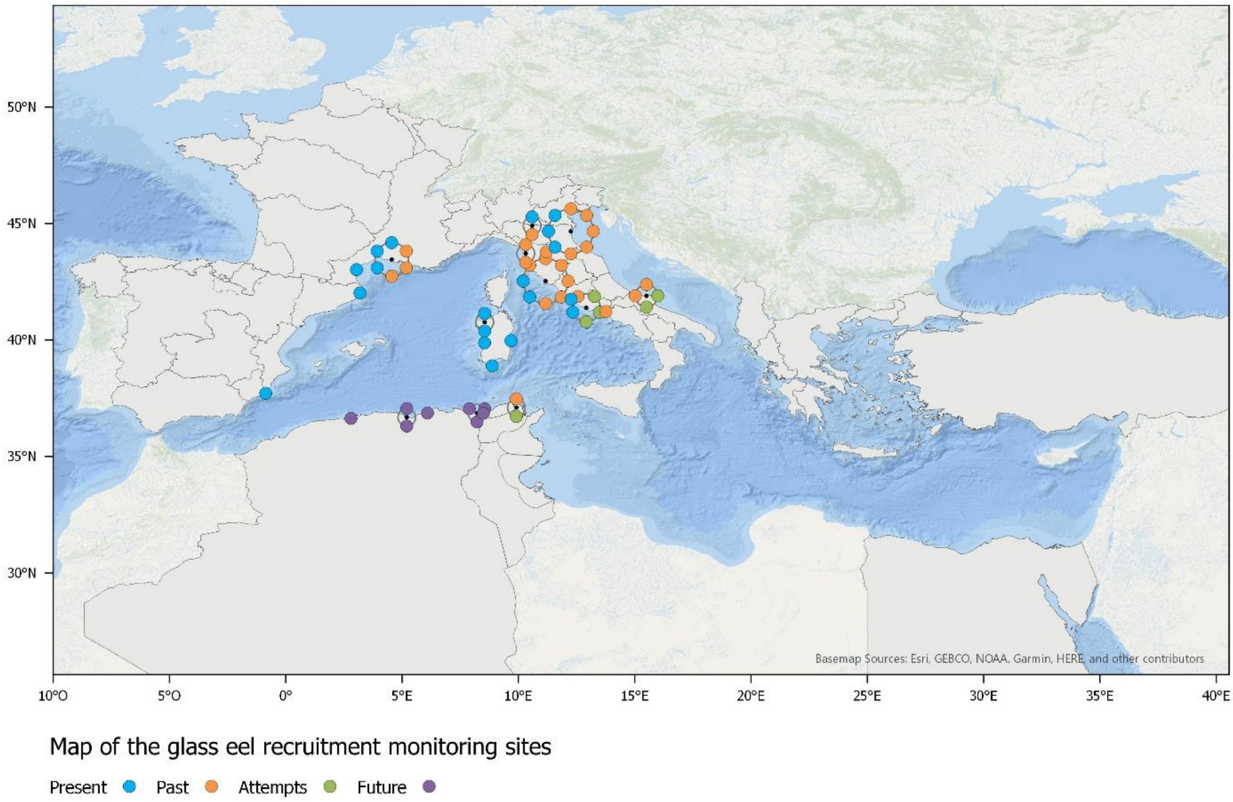

Figure 14.2. Maps of the countries reporting glass eel recruitment monitoring (past, present and future) and monitoring attempts in the Mediterranean region for the nine countries involved in the research programme.

Among the nine partner countries, only France, Italy, and Spain are currently monitoring glass eel recruitment with a total of 19 monitoring programmes (Table 14.1, Figure 14.1 and Figure 14.2). In total 42 monitoring programmes were recorded (past and present) and six monitoring attempts. Past monitoring programmes were carried out mostly in Italy (19 programme), but also in in France (three programmes) and Tunisia (one programme) (Table 14.2, Figure 14.1 and Figure 14.2). Italy was the country with the largest surface area of coverage as monitoring programmes were spread across the entire territory, including the island of Sardinia (Figure 14.2). Monitoring attempts were made in Italy (in five lagoons) and Tunisia (in one lagoon) (Table 14.3). The Tunisian attempt was carried out for a Ph.D. thesis but without enough success to be developed into a long-term monitoring programme. Algeria is planning to start at least one recruitment monitoring programme in high-potential sites (two lakes, one lagoon and five rivers) in the coming years (Table 14.4, Figure 14.1 and Figure 14.2).

Table 14.27. Summary of the present ongoing glass eel recruitment monitoring programmes in the nine countries participating in the GFCM eel project. (Site name: (s) indicates sites in the island of Sardinia. Habitat: LGN = lagoon, RIE = river estuary, RIV = river)

Country	Site name	Type of habitat	Start year	Length of programme	Method	Framework
France	Vaccarès, Capelière	1 LGN	1993	29 years	Fyke nets (Capéchades)	
	Vaccarès, Fourcade	1 RIE_lgn	2004	18 years	Active trap (fish pass trap)	PLAGEPOMI EMP EU-MAP
	BagesSigean	1 RIE_lgn	2018	4 years	Passive traps (Flottang)	PLAGEPOMI EMP

	Canal d'Arles à Fos	1 RIE_chan	2007	15 years	Active trap (fish pass trap)	
Italy	Orbetello	1 RIE_lgn	2019	2 seasons	Fyke nets	Pilot study DCF- EU-MAP
	Po di Goro	1 RIE_riv	2019	2 seasons	Fyke nets	Pilot study - DCF-EU-MAP
	Po di Volano	1 RIE_riv	2019	2 seasons	Fyke nets	Pilot study - DCF-EU-MAP
	Lamone	1 RIE_riv	2021	1 season	Fyke nets	FEAMP project
	Tevere	1 RIE_riv	2013	7 seasons	Fyke nets	Regional EMP (EU Eel Regulation)
	Marta	1 RIE_riv	2013	7 seasons	Fyke nets	Regional EMP (EU Eel Regulation)
	Pramaera (s), Coghinas (s) Pesaria (s), Chia (s)	4 RIE_riv	2017	4 seasons	Fyke nets	Regional EMP (EU Eel Regulation)
	Po	1 RIV	2021	1 season	Fyke nets	
	Fogliano	1 RIE_lgn	2013	7 seasons	Fyke nets	Regional EMP (EU Eel Regulation)
	Calich (s)	1 LGN	2017	4 seasons	Fyke nets	Regional EMP (EU Eel Regulation)
Spain	Mar Menor	1 LGN	2013	9 years	Fyke net type (monot)	EU-MAP
	Ter	1 RIE_riv	2014	8 years	Fyke net type (Busso)	EU-MAP

Table 14.28. Summary of the past glass eel recruitment monitoring programmes in the nine countries participating in the GFCM eel project. (*: In a channel linking Ichkeul and Bizerte lagoons,. Habitat: LGN = lagoon, RIE = river estuary, RIV = river)

Country	Site name	Type of habitat	First year	Last year	Length of programme	Method	Framework
France	Vaccarès Mornès	1 LGN	1993	1997	5 years	Fyke nets (capéchade)	
	Imperiaux Malagroy	1 LGN	1994	2014	21 years	Fyke nets (capéchade)	
	Camargue salines	1 RIE_mar	2016	2021	6 years	Fyke nets (verveux capéchade)	
Italy	Garigliano	1 RIE_riv	2017	2019	2 seasons	Fyke nets	Pilot study DCF-EU-MAP Should be resumed in 2022-2026 EU-MAP
	Reno	1 RIE_riv	2011	2013	2 seasons	Fyke nets	Regional EMP (EU Eel Regulation)
	Po di Volano Lamone	2 RIE_riv	2013	2015	3 seasons	Fyke nets	Regional EMP (EU Eel Regulation)
	Burlamacca, Arno, Scolmator, Albegna, Bruna, Ombrone, San Leopoldo	7 RIE_riv	2009	2011	2 seasons	Fyke nets	Regional EMP (EU Eel Regulation)
	Po	1 RIV	2013	2015	3 seasons	Fyke nets	Regional EMP (EU Eel Regulation)
	Lesina Acquarotta	1 RIE_lgn	2017	2019	2 seasons	Fyke nets	Pilot study DCF-EU-MAP Should be resumed in 2022-2026 EU-MAP
	Monaci	1 RIE_lgn	2001	2004	2 seasons	Fish pass trap	
	Orbetello	1 LGN	2009 2013	2011 2015	3 years 3 years	Fyke nets	Regional EMP (EU Eel Regulation)
	Comacchio	1 LGN	2011	2013	2 seasons	Fyke nets	Regional EMP (EU Eel Regulation)

	Valle Fattibello	1 LGN	2011	2013	2 seasons	Fyke nets	Regional EMP (EU Eel Regulation)
	Lesina	1 LGN	2001	2003	3 seasons	Fyke nets	
Tunisia	Ichkeul*	1 LGN	2004	2007	4 years	Traps	

Table 14.29. Summary of glass eel recruitment monitoring attempts in the nine countries participating in the GFCM eel project. (LGN = lagoon)

Country	Site name	Type of habitat	First year	Last year	Length of monitoring programme	Method	Framework
Italy	Varano, Lesina	2 LGN	2013	2014	1 season	Fyke nets	EMP (regional implementation) EU eel regulation
	Monaci, Caprolace	2 LGN	1999	2000	1 season	Fyke nets	
	Fogliano	1 RIE_lgn	1999	2000	1 season	Fyke nets	
Tunisia	Kalaat Al Andalous	1 RIE_lgn	2007	2007	1 season	Scoop net	

Table 14.30. Summary of the future glass eel recruitment monitoring and potential sites in the nine countries participating in the GFCM eel project. (ND: not determined yet, Habitat: LAK = lake, LGN = lagoon, RIE = river estuary)

Country	Site name	Type of habitat	First year	Last year	Method	Framework
Algeria	Tonga	1 Lak	2022	2025	ND	
	Oubiera	1 Lak	2022	2025	ND	
	Mellah	1 LGN	2022	2025	ND	
	Mafragh, El Kebir, Agerioun, Soummam, Mazafran	5 RIE_riv,	2022	2025	ND	

Habitat type and area covered by glass eel recruitment monitoring

Recruitment monitoring programmes (past and present) and monitoring attempts were recorded for two habitat types, lagoons (seven ongoing, 11 in the past and six attempts) and rivers (12 ongoing and 12 in the past) (Figure 14.3, Figure 14.4 and Figure 14.5). For these two habitats, transitional waters were also monitored: nine tidal channels for the lagoons and 21 estuaries for the rivers (Table 14.1, Table 14.2 and Table 14.3). No lake was monitored.

All the ongoing monitoring was done by European Union countries in the northern part of the Mediterranean (Figure 14.7, Additional Results Part I) while there was an obvious lack of monitoring in the eastern and southern Mediterranean. France was monitoring glass eel recruitment in two lagoons (Vaccarès and Bages-Sigean) and one channel (Canal d'Arles à Fos) (Figure 14.3, Figure 14.6 and Figure 14.7). Italy had the most monitoring, located in ten rivers (Po di Goro, Po di Volano, Po, Lamone, Tevere, Marta, Pramaera, Coghinas, Pesaria, Chia) and three lagoons (Orbetello, Fogliano and Calich). Spain was monitoring one river (Ter) and one lagoon (Mar Menor) (Figure 14.6 and Figure 14.7). Results need to be evaluated on a comparative basis, but preliminary observations confirm that not all sites give good results and that sampling schemes must take into account the hydro-morphological features of the sites and local environmental conditions.

In the past, Italy carried out 19 monitoring programmes in five lagoons (Lesina, Orbetello, Comacchio, Valle Fattibello and Monaci) and 12 rivers (Garigliano, Reno, Po, Po di Volano, Lamone, Burlamacca, Arno, Scolmatore, Albegna, Bruna, Ombrone and San Leopoldo) (Figure 14.4). The southeastern Mediterranean had only one monitoring programme, by Tunisia, at Ichkeul lake that is considered as a lagoon (Figure 14.4 and 8). The real name of the Ichkeul ecosystem is a “garaet”; a waterbody linked to a lagoon (Bizerte) by a wadi (Tinja).

Monitoring attempts were made in Italy in five lagoons, Varano, Lesina, Fogliano, Monaci and Caprolace, and Tunisia in one lagoon, Kalaat Al Andalous (Figure 14.5 and Figure 14.9).

Algeria plans to implement glass eel recruitment monitoring (Figure 14.10) in eight potential sites; five rivers (Mafragh, El Kebir, Agerioun, Soummam and Mazafran), one lagoon (Mellah) and two lakes (Tonga and Oubiera) while Albania, Egypt, Greece and Türkiye have never monitored glass eel recruitment.

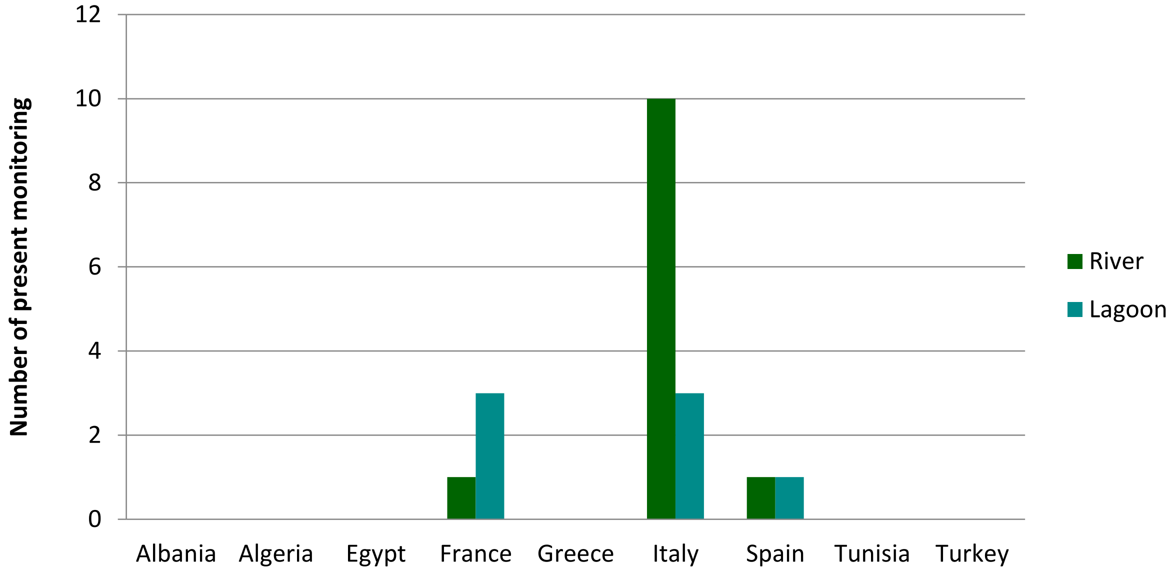

Figure 14.3. Number of present glass eel recruitment monitoring programmes in GFCM partner countries by habitat type.

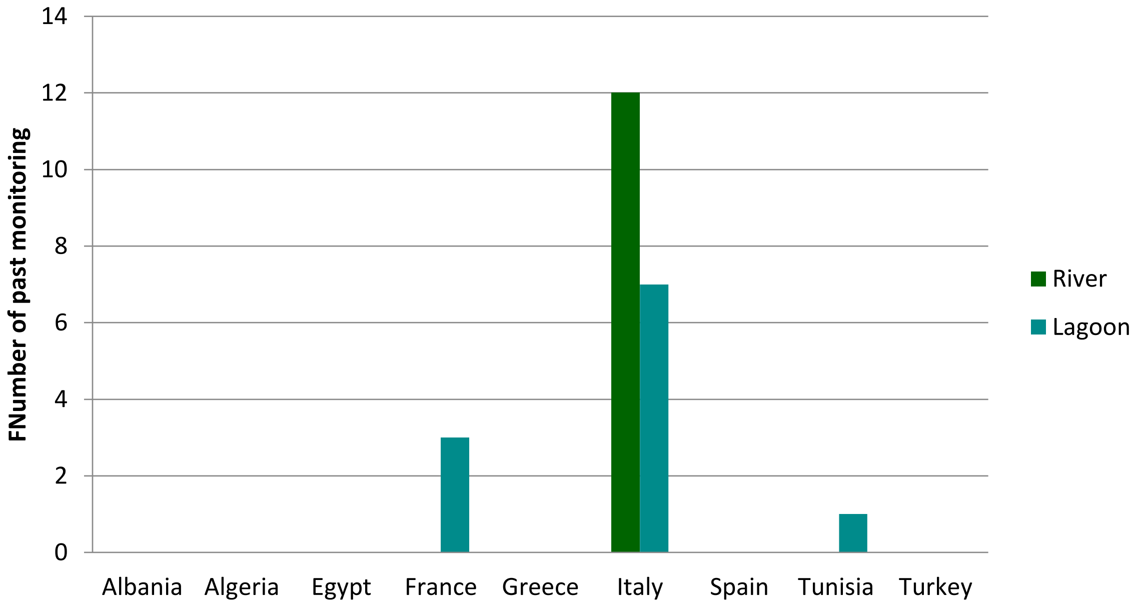

Figure 14.4. Number of past glass eel recruitment monitoring programmes in GFCM partner countries by habitat type.

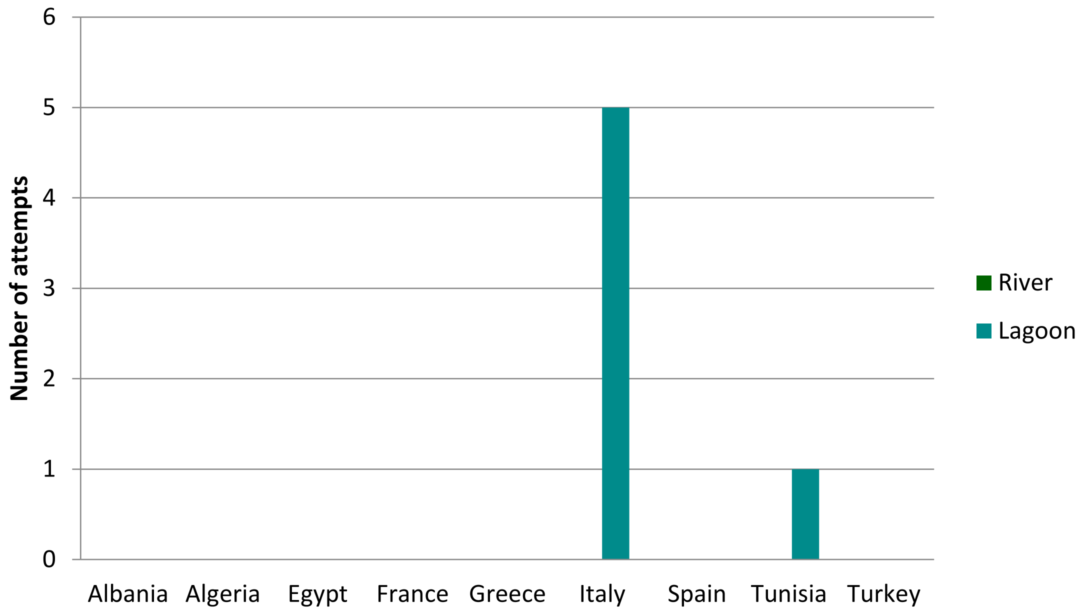

Figure 14.5. Number of glass eel recruitment monitoring attempts in GFCM partner countries by habitat type.

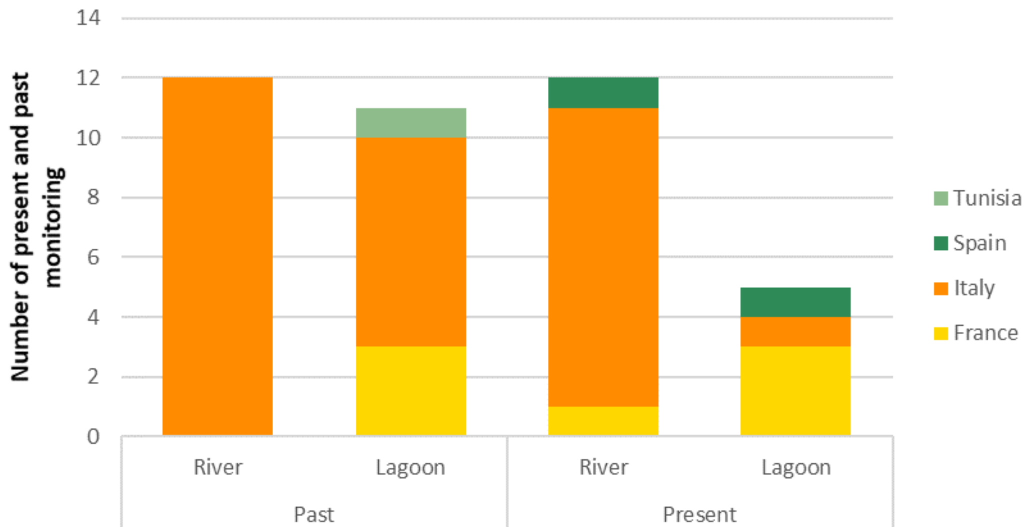

Figure 14.6. Number of present and past glass eel recruitment monitoring programmes by habitat type and by country

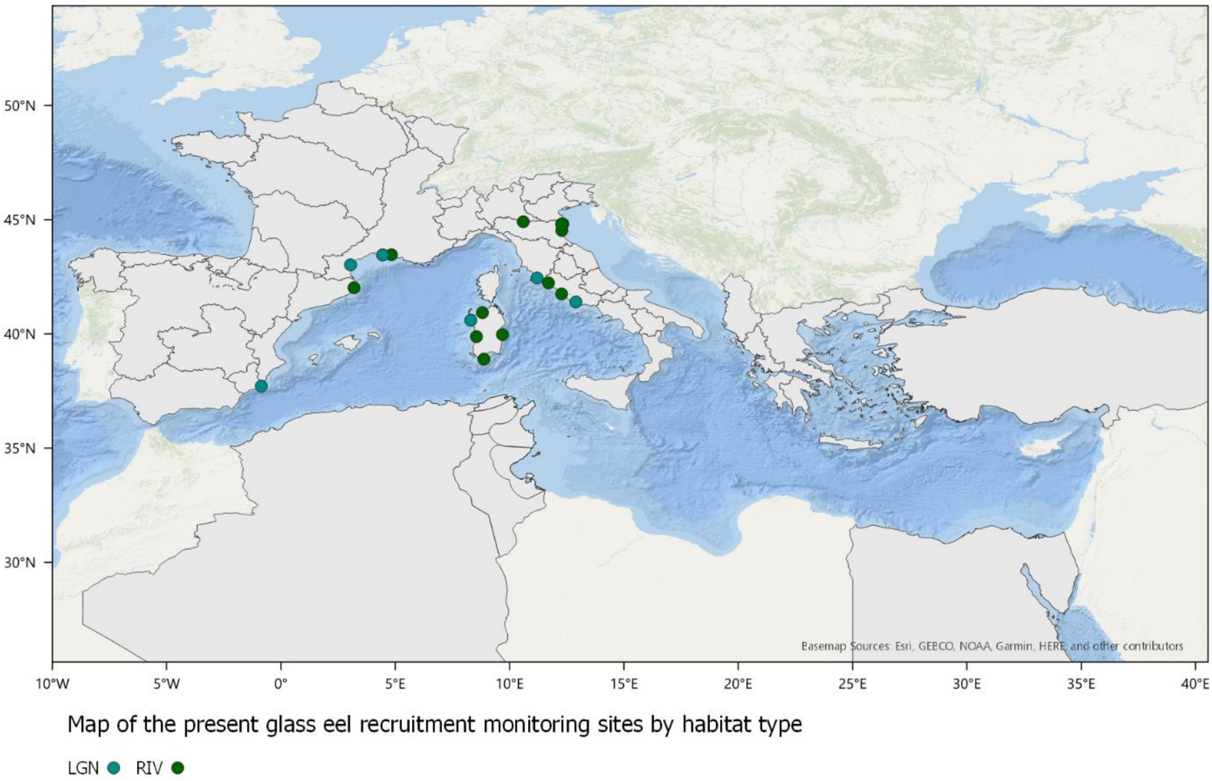

Figure 14.7. Location of present glass eel recruitment monitoring sites by habitat type (LGN = lagoon, RIV = river) in the Mediterranean. Countries participating in the GFCM eel research project are highlighted in light grey.

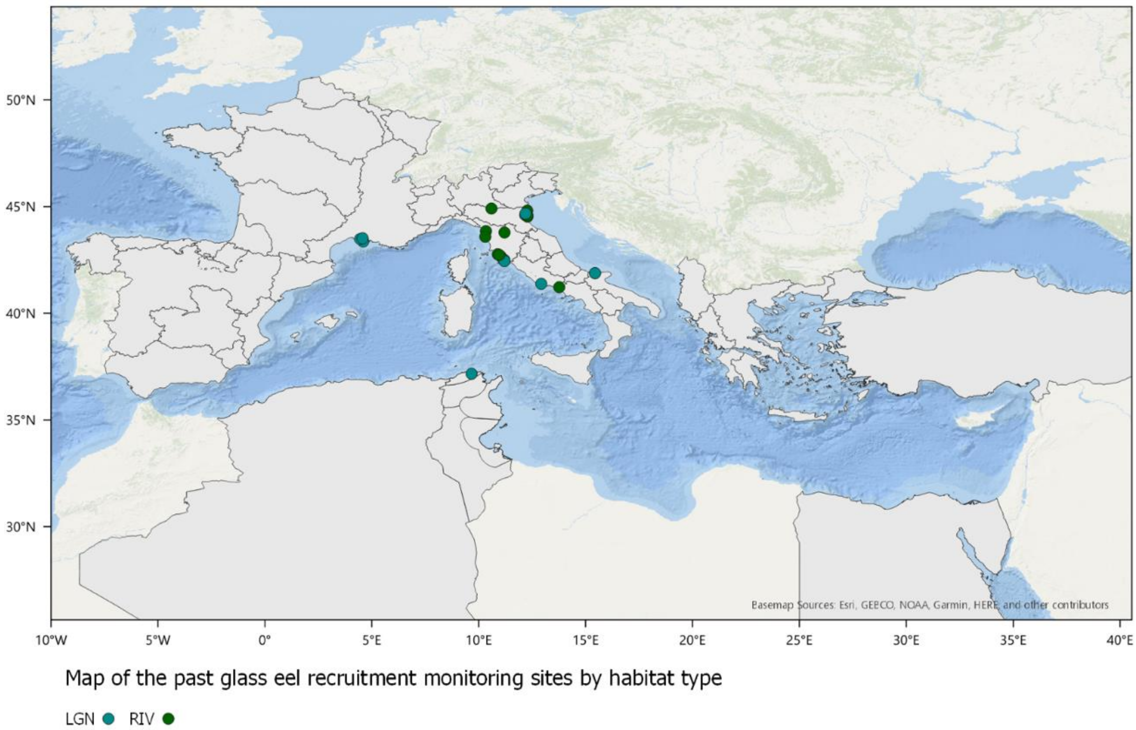

Figure 14.8. Location of past glass eel recruitment monitoring sites by habitat type (LGN = lagoon, RIV = river) in the Mediterranean. Countries participating in the GFCM eel research project are highlighted in light grey.

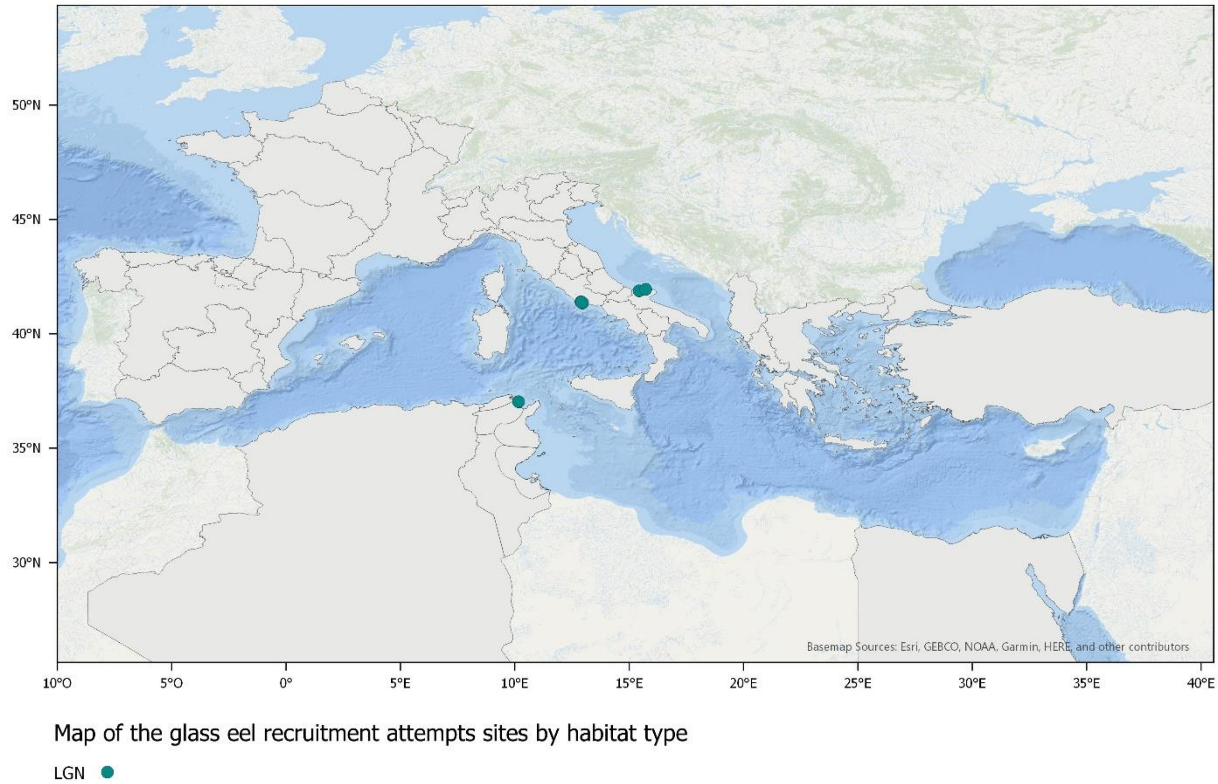

Figure 14.9. Location of glass eel recruitment monitoring attempts sites by habitat type (LGN = lagoon) in the Mediterranean. Countries participating in the GFCM eel research project are highlighted in light grey.

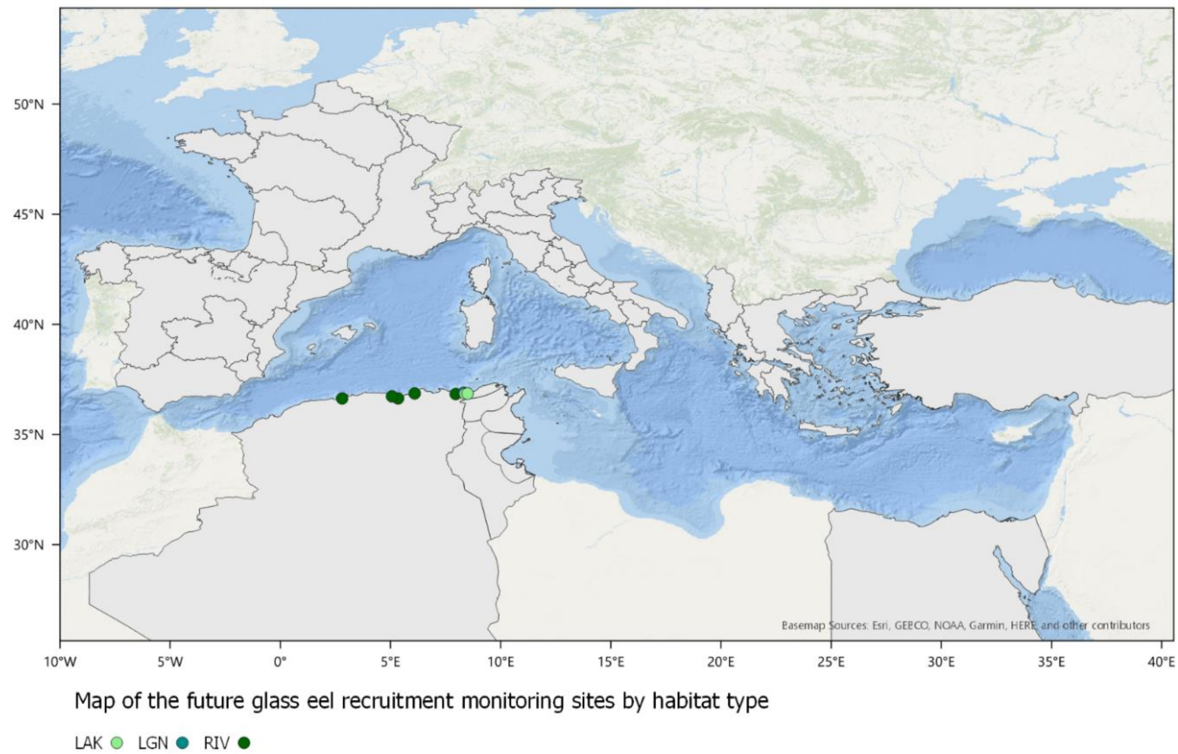

Figure 14.10. Location of future glass eel recruitment monitoring sites by habitat type (LAK = lake, LGN = lagoon, RIV = river) in the Mediterranean. Countries participating in the GFCM eel research project are highlighted in light grey.

Time coverage of glass eel recruitment monitoring

The time period for ongoing monitoring programmes varied from one to 29 years. The shortest time period started in 2021 in Lamone and Po rivers (Italy) and the longest started in 1993 in Vaccarès lagoon (France). Half of the recorded ongoing monitoring programmes were in the range of three years to seven years long. The only fishery independent time-series from the Mediterranean included in the WGEEL stock analysis was from Vaccarès lagoon that started in 2004 and now has 18 years of data.

Long-term monitoring (defined arbitrarily as time-series having more than ten years of data) were only found in France as follows (Table 14.5):

- Two ongoing time series in Vaccarès lagoon with 18 years and 29 years of data were collected in Grau de la Fourcade (fish-pass) and Capelière (fyke nets) stations, respectively.
- One ongoing time-series in the downstream part of a channel at the canal d'Arles à Fos (fish-pass), on a dam created to stop salt-water intrusion had 15 years of data. However, in 2014, a drastic decline in the number of captured eels was observed, probably linked to dredging activities and no glass eels were recorded in 2017. Since then, the number of glass eels trapped has trended upwards from 468 in 2018, to 317 in 2019 and 30 714 in 2020). According to Grand port de Marseille (in charge of the fish-pass), the decline was probably linked to the lack of freshwater (no attraction). Investigations need to be made before deciding if this site can be used as a reliable monitoring site.
- One past 20 year monitoring programme in Impériaux lagoon using fyke nets at the Malagroy station started in 1993 but had to stop in 2014 due to lack of funds and the low number of glass eels trapped. The site depth was perhaps too low and too far from the principal recruitment route.

The other current monitoring programmes (one in France, 13 in Italy and two in Spain) have been in place from one to nine years (Table 14.5). In Spain, a scientific monitoring programme at Mar Menor lagoon (nine years) is almost long-term but apparently did not work very well because of the low abundance of glass eels. Another one in the Ter river with more consistent data, started four years ago. In Italy, three series are almost in the category of long-term monitoring. Programmes at Fogliano lagoon and Tevere and Marta rivers, all started seven years ago (Table 14.6).

Past monitoring programmes were recorded in France, Italy and Tunisia (Table 14.5 and Table 14.6). The period recorded ranged from three to six years (except for the 21-year monitoring programme at Imperiaux lagoon). These short monitoring programmes were scientific projects that were funded for short periods, usually three years. In Italy, even if these monitoring programmes are not ongoing, a lot of methods have been tested and time-series have been reviewed in order to implement new monitoring programmes in the future for the DCF EU-MAP that will start in 2022. In Tunisia, monitoring was carried out from 2004 to 2007 at Ichkeul lake (a lagoon) for a PhD thesis (Hizem, 2014).

Short monitoring attempts, for one year or one season were carried out in Italy and Tunisia (Table 14.7 and 12).

Algeria is planning future monitoring programmes starting in 2022 for a duration of at least three years, but the sites have not been defined yet.

Table 14.5. Time coverage for glass eel recruitment monitoring in France, Spain and Tunisia for long-term, ongoing monitoring programmes (black hatched), current monitoring programmes (black), past monitoring programmes (light grey) and monitoring attempts (dark grey). "ICES" indicates time series used in the WGEEL (Habitat: LGN = lagoon, RIE = river estuary

Country	Habitat	Site name	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
France	LGN	Vacarès Capelière																													
	RIE_lgn	Vaccarès Fourcade												ICES																	
	RIE_lgn	Bages Sigean lagoon																													
	RIE_can	Canal Arles à Fos																													
	LGN	Vaccarès Mornès																													
		Impériaux Malagroy																													
	RIE_mar	Camargue salines																													
Spain	LGN_riv	Mar Menor																													
	RIE_riv	Ter river																													
Tunisia	LGN	Ichkeul																													
	RIE	Kalaat Al Andalous																													

Table 14.6. Time coverage for glass eel recruitment monitoring in Italy for current monitoring programmes (black), past monitoring programmes (light grey) and monitoring attempts (dark grey). *indicates sites in the island of Sardinia. (Habitat: RIV = river, RIE = estuary, LGN = lagoon)

Country	Habitat	Site name	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Italie	RIE_riv	Po di Goro																							
		Po di Volano																							
		Lamone																							
		Tevere																							
		Marta																							
		Pramaera*																							
		Coghinas*																							
		Pesaria*																							
		Chia*																							
		Garigliano																							
		Reno																							
		Burlamacca																							
		Arno																							
		Scolmatore																							
		Albegna																							
		Bruna																							
		Ombrone																							
		San Leopoldo																							
	RIV	Po																							
	RIE_lgn	Fogliano																							
		Lesina Acquarotta																							
		Orbetello																							
		Monaci																							
	LGN	Calich*																							
		Orbetello																							
		Comacchio																							
		Valle Fattibelo																							
		Lesina																							
		Coprolace																							
		Varano																							
		Monaci																							

Methods used for glass eel recruitment monitoring

General overview

Four methods are used to monitor glass eel recruitment; fyke nets, traps, scoop nets and fish-pass traps. The most commonly used method is fyke nets and related gears. Details on the number of monitoring programmes using each method and used in each habitat type are recorded in Table 14.8 for on-going monitoring programmes and in Table 14.7 for past monitoring programmes and monitoring attempts. In ongoing monitoring programmes (Table 14.8, Figure 14.11 and Figure 14.12), fyke nets were used in France, Italy and Spain at total of 16 sites (five lagoons and 11 rivers), passive traps were used in France on one lagoon and active fish pass traps were used in France at two sites (one lagoon site and one river site). Regarding past monitoring programmes and monitoring attempts (Table 14.7, Figure 14.11 and Figure 14.13), fyke nets were used in two countries (France and Italy) over 23 sites (11 lagoons, 12 rivers), while an active fish-pass trap was used in one country (Italy) in one lagoon site and scoop nets were used in one country (Tunisia) in one lagoon site. The duration of monitoring activities and the frequency of capture were different between methods and sites (Table 14.9 and Table 14.10).

Table 14.7. Methods used for the past monitoring and monitoring attempts of glass eel recruitment by habitat type in partner countries.

Methods	Countries using the method	Number of river sites monitored	Number of lagoon sites monitored	Number of lake sites monitored	Total number of sites monitored
"Fyke net" type	France, Italy	12	11		23
Fish pass trap	Italy		1		1
Scoop net	Tunisia		1		1
Passive trap	Tunisia		1		1
Total		***12***	***14***	***0***	***26***

Table 14.8. Methods used for ongoing monitoring of glass eel recruitment by habitat type in partner countries.

Methods	Countries using the method	Number of river sites monitored	Number of lagoon sites monitored	Number of lake sites monitored	Total number of sites monitored
"Fyke net" type	France, Italy, Spain	11	5		16
Fish pass trap	France	1	1		2
Passive trap	France		1		1
Total		***12***	***7***	***0***	***19***

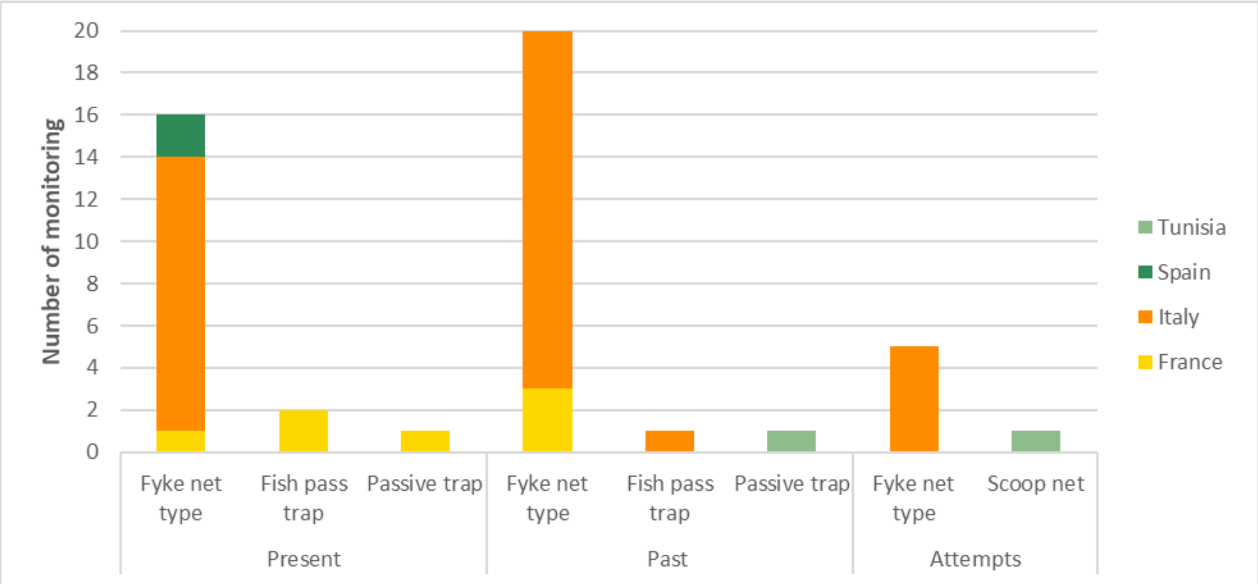

Figure 14.11. Type of gears used by country for current and past monitoring and monitoring attempts for glass eel recruitment.

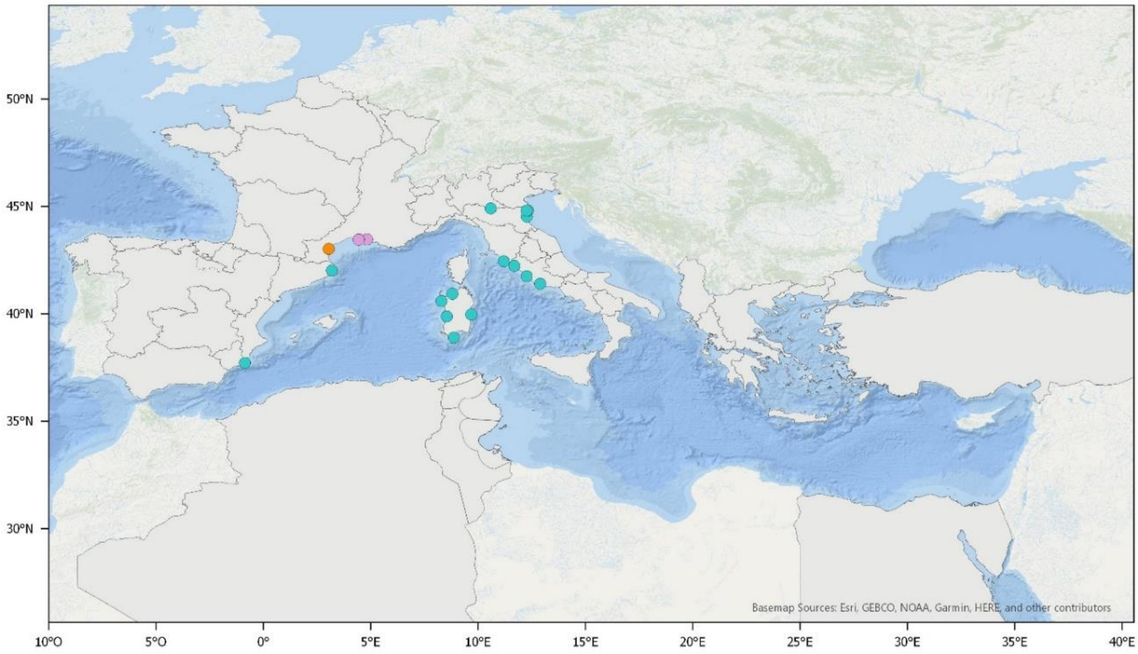

Figure 14.12. Location of present glass eel recruitment monitoring methods used in the Mediterranean. Countries participating in the GFCM eel research project are highlighted in light grey.

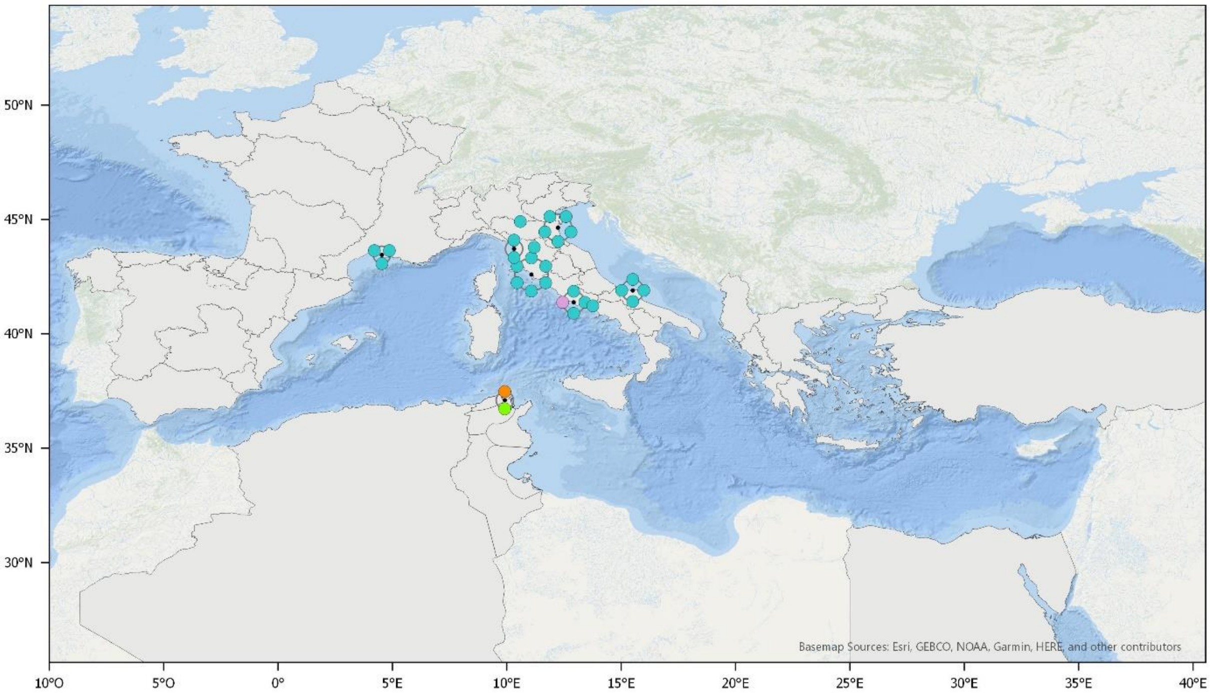

Figure 14.13. Location of past glass eel recruitment monitoring and monitoring attempts by method used in the Mediterranean. Countries participating in the GFCM eel research project are highlighted in light grey.

Table 14.9. Frequency of monitoring and season monitored (except for "fyke net" method) of the present and past glass eel recruitment monitoring and attempts. (Months monitored: light grey cells show the possible extension of the monitored season depending on the year, dotted cells show missing data. Total days = total number of days monitored in a year. Nb Gear = number of gears used for each monitoring or attempt. Mesh size: in mm. Habitat: River = RIV, lagoon = LGN. NC = not collected, NP = not pertinent.)

Method	Months monitored (Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug)	Frequency	Total days	Nb gear	Mesh size	Site	Habitat	Country
Fish pass trap		1 or 2 times/week	360	1	NP	Canal d'Arles à Fos	RIV	France
		2 to 5 times/week	210	1	NP	Vaccarès	LGN	France
		Daily	105 and 75	1	NP	Monaci	LGN	Italy
Scoop net		NC	NC	NC	NC	Kalaat Al Andalous	LGN	Tunisia
Trap		NC	NC	NC	10 and 25	Ichkeul	LGN	Tunisia
		Daily	180	5 to 16	NP	Bages Sigean	LGN	France

Table 14.10. Frequency of monitoring and season monitored for the "fyke net" type method for the present and past glass eel recruitment monitoring and attempts. (Months monitored: hatched cells show the possible extension of the monitored season depending on the year. Total Days = total number of days monitored in a year. Nb Gear = number of gears used in the study. "5V, 1C": five verveux and 1 capéchade. Mesh size: in mm. NC = not collected.)

Months monitored (Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug)	Nb Month	Frequency	Total days	Nb Gear	Mesh size	Site	Habitat	Country
	12	1 week consecutive/month	84	1 to 3	NC	Chia	RIV	Italy
				NC	NC	Calich	LGN	Italy
				NC	NC	Coghinas	RIV	Italy
				NC	NC	Pesaria	RIV	Italy
				NC	NC	Pramaera	RIV	Italy
	4	3 days/week/month	48	2	NC	Comacchio	LGN	Italy
						Reno	RIV	Italy
						Valle Fattibello	LGN	Italy
		3 time/week , 1 week/month	12	5V, 1C	1.5	Camargue salines	LGN	France
				NC	1.5	Vaccarès Mornès	LGN	France
	8	4 days consecutive/month	32	NC	1	Impériaux Malagroy	LGN	France
			32	1 to 3	1	Vaccarès Capelière	LGN	France
	2	3 days consecutive/month	6	2	NC	Po di Goro	LGN	France
						Po di Volano	LGN	France
	3	2 or 3 days/month	9	NC	NC	Lamone	RIV	Italy
						Po	RIV	Italy
		2 days/week/month	24	NC	NC	Lamone	RIV	Italy
						Po	RIV	Italy
						Po di Volano	RIV	Italy
	2	1 week consecutive/month	53	2	NC	Orbetello	LGN	Italy
	5	1 week consecutive/month	35	2	NC	Fogliano	LGN	Italy
						Marta	RIV	Italy
						Tiber	RIV	Italy
		Daily	150	3	NC	Orbetello	LGN	Italy
				NC		Albegna	RIV	Italy
						Arno	RIV	Italy
						Bruna	RIV	Italy
						Burlamacca	RIV	Italy
						Ombrone	RIV	Italy
						Orbetello	LGN	Italy
						San Leopoldo	RIV	Italy
						Scolmatore	RIV	Italy
		New moon nights	5	2 to 4		Mar Menor	LGN	Spain
	3	5 days/month (daily catch)	15	2	2	Lesina Acquarotta	LGN	Italy
		6 times consecutive/month	18	2	NC	Garigliano	RIV	Italy
	6	1 day/month (new moon)	6	3	1	Tevere	RIV	Spain
		Daily	180	4	NC	Lesina	LGN	Italy
						Varano	LGN	Italy
				NC	NC	Caprolace	LGN	Italy
						Fogliano	LGN	Italy
						Lesina	LGN	Italy
						Monaci	LGN	Italy

<u>Fyke net</u>

"Fyke net" is used here as the general term to describe passive traps that are submerged, usually in shallow waters. This type of gear includes funnel-shaped gears with bottlenecks that lead to a closed terminal chamber or receptacle. Their dimensions, shapes, mesh sizes, materials and numbers of chambers vary between countries, regions and sites. For glass eel monitoring the common criteria is a small mesh size from one mm to two mm. France, Italy and Spain have used this kind of trap to monitor glass eel recruitment. Fyke nets have different local names and specific details according to the country

(Table 14.11, Figure 14.14). These gears are also used by the professional fishers, except in France where the glass eel fishery is prohibited.

Table 14.11. Different fyke net types used to monitor glass eel recruitment.

Local name and country	**Habitat**	**Characteristics**
Verveux ***in*** France (Figure16A) ***Bertovello*** in Italy (Figure16C)	Lagoon, river	Conical nylon net mounted on plastic rings with two or three bottlenecks. A funnel-shaped net placed such that fish can enter in but not leave the trap. Two net wings guide fish to the entrance of the in net.
Capechade in France (Figure16B)	Lagoon	Three *verveux* are arranged to form an arrow at the extremity of a barrier net fixed to the bottom.
Monot in Spain (Figure16D)	Lagoon	Rectangular trap made of netting, with an entrance of four cm maximum width.
Bussó in Spain (Figure16E)	River	Fishing gear shaped as a polyhedron, made of wood or iron and artificial fibre or iron mesh. The base of the gear has a funnel pointing inwards through which the glass eels enter.

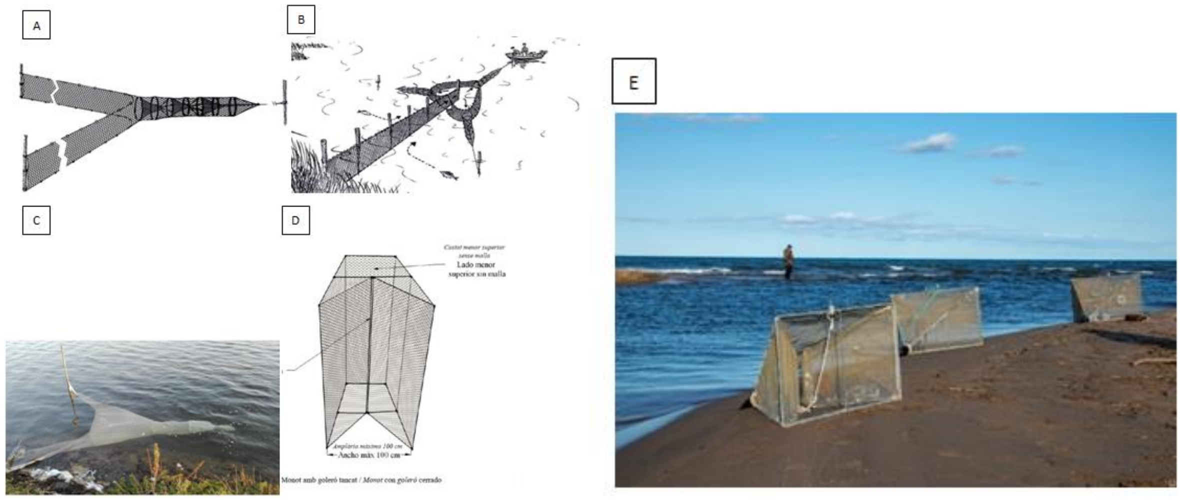

Figure 14.14. Fyke net types used for glass eels recruitment monitoring. A= Verveux (France) (Luneau, Mertens and Trancart, 2003), B=Capéchades (France) (Luneau, Mertens and Trancart,, 2003), C= Bertovello (Italy) (©Chiara Leone), D=Monot (Spain), E=Busso (Spain) (©Lluis Zamora).

Advantages and limitations to the use of fyke nets and similar types for recruitment monitoring are summarised in Table 14.12.

Table 14.12. Advantages and limitations to the use of fyke nets for glass eel recruitment monitoring.

Advantages	**Limitations**
• Collaboration with professional fishers is possible through sharing of materials or advice about the best place and time period to install traps • Data can be compared with fisheries data	• Can be difficult to handle and install (depend on the habitat type and characteristics) • Not suitable for deep water and strong currents

• Once they are installed, glass eel collection can be done by either fishers or scientists or both (depending on local facilities)	• Need maintenance including cleaning and repairs as clogging can impact the results • Results will depend on the site, the time and the frequency of collection • Difficult to transport and store

<u>Passive traps</u>

Passive traps create an artificial habitat that glass eels use as a shelter and can be used in both deep and shallow waters. In the Mediterranean, two kinds of passive traps were recorded: *flottangs* and plastic traps. *Flottangs* (Plate 1, A, B, C, D) are used in France in the channel of Bages Sigean lagoon. They are made from ten, piled squares of geotextile. A PVC-covered foam plate improves the buoyancy of the trap and the darkness of the shelter during the day. Five to 16 traps are set up between October and March and glass eels are collected every day for 180 days per year. This method requires intensive and regular collection as it is not trapping the eels but just providing them with a shelter that they can leave when they want. They also are substrate dependant and may be less attractive where the substrate underneath the trap provides more interesting shelter for the glass eels (Bages-Sigean study, pers. com). Plastic traps are used in Tunisia at Ichkeul lake (Plate 1, E). They consist of rectangles, 50 cm to 60 cm in length and 20 cm diameter. Square mesh material of 10 mm or 25 mm mesh surrounds the traps that are filled with pondweed (such as potamogéton) to attract glass eels (Hizem, 2014).

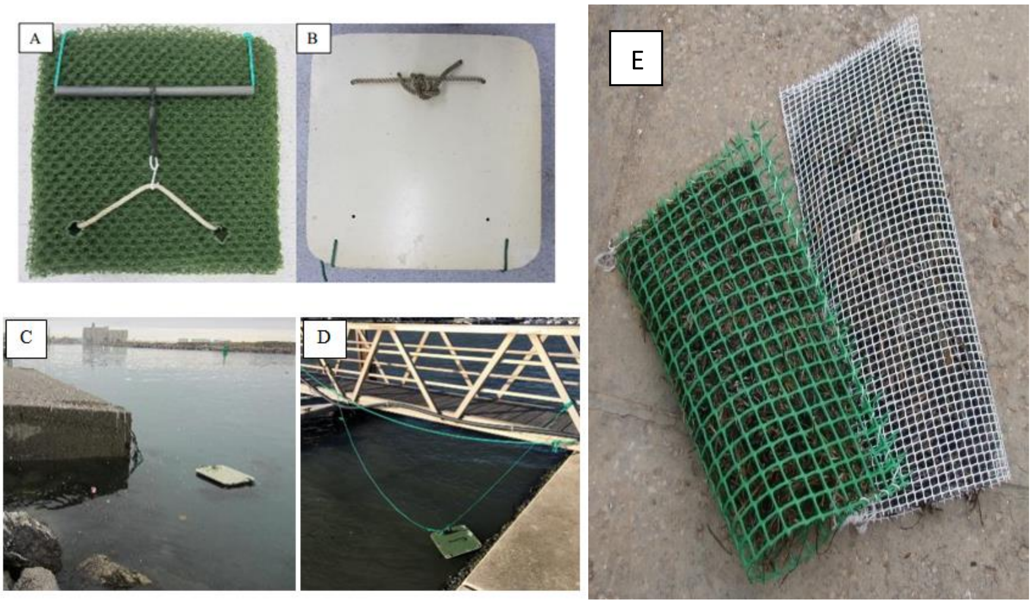

Plate 14.1. Passive traps. A, B, C, D= flottangs used in Bages-Sigean lagoon. A = View from below: piled squares of geotextiles that are submerged. B = Top view: floating part. C = Example of a flottang attached from the harbour shore. D = Example of a flottang attached to a pontoon (© CEFREM UPVD). E = Plastic traps used at Ichkeul lake (Hizem, 2014).

Advantages and limitations to the use of passive traps for recruitment monitoring are shown in Table 14.13.

Table 14.13. Advantages and limitations to the use of passive traps for glass eel recruitment monitoring.

Advantages	Limitations
• Low cost • Easy to build and install • Low maintenance and robust; once they are installed, traps can be used throughout the recruitment season • Selective for glass eels • Easy to transport	• High frequency of data collection is needed; daily is best as eels are free to escape the refuge • Low capture efficiency but this depends on the site • Substrate dependant • They can easily be stolen

Active traps

Active traps use the climbing behaviour of eels to trap individuals. The general principle is to link a climbing ramp with running water to a container, so once individuals reach the top of the ramp they get caught in the tray. They are often built as fish passes and could be built into obstacles such as dams (Drouineau *et al.*, 2014), or in river banks (Watz *et al.*, 2017) or in the middle of waterbodies (Watz *et al.*, 2017). The efficiency of this type of fish trap depends on many factors including ramp height, slope and substrates (Baran and Basilico, 2012, Lagarde *et al.*, 2021a). Active traps could be built by stakeholders or by companies such as *Fish Pass* that sell prototypes that could be installed and maintained, as has been done in France and Italy. The principle is to take advantage of the obstacle to install the trap (Plate 2C). During the recruitment period, glass eels arrive from downstream, and crawl in the gutter irrigated by fresh water to climb and avoid the obstacle. After the ramp, they are captured in a container (Plate 2 A,B) where they can be counted and weighed.

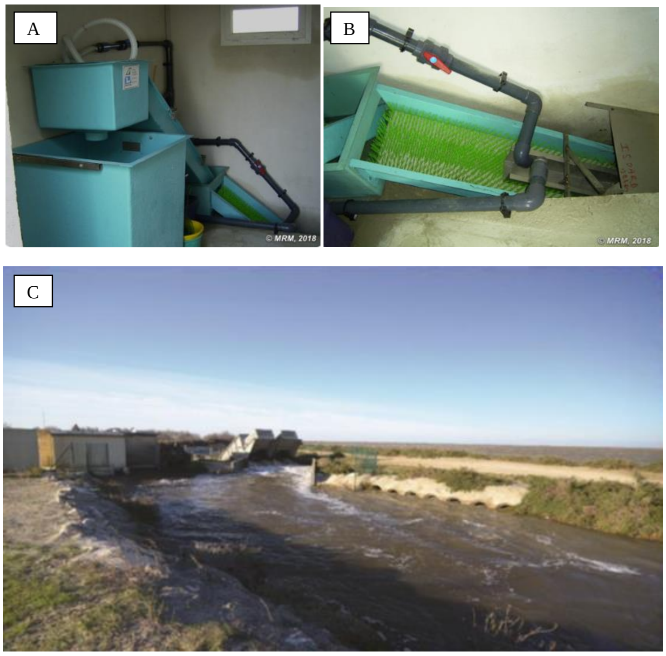

Plate 14.2. Fish pass. A, B, C= Active trap used in France at Vaccarès lagoon. A) Eel container. B) Entrance way of the ramp. C) Drainage station where the fish-pass is installed (©MRM 2010).

Advantages and limitations to use the use of fish passes for recruitment monitoring are shown in Table 14.14.

Table 14.14. Advantages and limitations to the use of MRM active traps for glass eel recruitment monitoring.

Advantages	Limits
• Once the fish pass has been installed, a long-term routine can be established (for example, the Vaccarès fish pass was installed 14 years ago) • It does not need to be checked every day, except if a CPUE per day is needed • One person can manage the data collection, except during the recruitment peak when two persons are needed • There are specialised companies (such as FishPass) that can install these fish passes and provide after sales services and product updates.	• They need maintenance at least once a year to clean the pump, the ramp and eventually to replace defective components • The initial cost is high and extra purchases are needed (for example, a stainless steel frame with manual winch, pumps, electrical panel). The total initial cost for a fish pass is around Euro 14 000 (Euro 7 400 for the fish pass and extra material could be around Euro 6 000) • The site needs electricity • The fish pass needs to be protected and installed in a safe place to avoid vandalism • It needs a freshwater supply to create attraction, either from a pumping system or by gravity if the site configuration allows it

<u>Scoop nets</u>

Scoop nets catch eels when they swim, often against the current. This gear was used in Tunisia with nets of one mm mesh (Plate 3). The efficiency depends on the hydroclimatic parameters of the site being monitored, for example water currents, as well as the data collector, the scoop net size and mesh size. The advantages and limitations of this method are presented in Table 14.15.

Plate 14.3. Scoop net (http://pngimg.com)

Table 14.15. Advantages and limitations for the use of scoop nets for glass eel recruitment monitoring.

Advantages	Limits
• Not expensive • Easy to transport • Easy to handle	• Efficiency is user dependant • Work needs to be done at night • Difficult to have repeatable and constant fishing effort

Other glass eel recruitment monitoring methods used by countries not involved in the GFCM eel programme

Harrison *et al.*, (2014) reviewed glass eel sampling methods. Other refuge-type traps have been used in rivers (Silberschneider, Pease and Booth, 2005). A floating mobile eel trap has been successfully tested on a river (Watz *et al.*, 2017) and could be of use in places where a glass eel ladder cannot be installed at a suitable obstacle. However, a similar trap was tested in France, in the channel connecting Bages-Sigean lagoon to the sea, but did not give successful results. It was less efficient than the nearby refuge floating trap (*flottang*), suggesting that the brackish water pumped on the ramp was not attractive enough for glass eels just arriving from the sea (unpublished data). During the Interreg EU project SUDOANG, partners tried different methods in ten pilot river basins (Sudoang, 2021). Some used methods commonly used by professional fishers, such as sieves deployed from a boat (a method successfully used on the Oria river estuary in Spain since 2005, but less successful on Bages-Sigean lagoon tidal channel in France, probably because of less pronounced tides), and others tried using plankton nets attached to the shore (not successful on the Nivelle estuary). However, the same kind of horizontal plankton nets (0.4 m^2 cross-section, 0.8 mm mesh size) worked well in Mont-Saint-Michel Bay (Laffaille, Caraguel and Legault, 2007). Commercial fisheries data are also commonly used to monitor glass eel recruitment trends (Chapter 5 and Chapter 10).

14.3.2 Silver eel escapement monitoring

General overview of silver eel escapement monitoring

The escapement monitoring programmes for silver eels reported by partner countries were diverse in terms of site, habitat type, time periods covered, methods, organisations involved and management frameworks. They were all fishery independent except for monitoring carried out in Albania. Although some of them were compulsory under local, national or EU level frameworks, most were not long-term monitoring programmes (82 percent of past and present monitoring programmes had less than ten years of records). Overviews of the monitoring programmes are presented in Figure 14.15 and Figure 14.16.

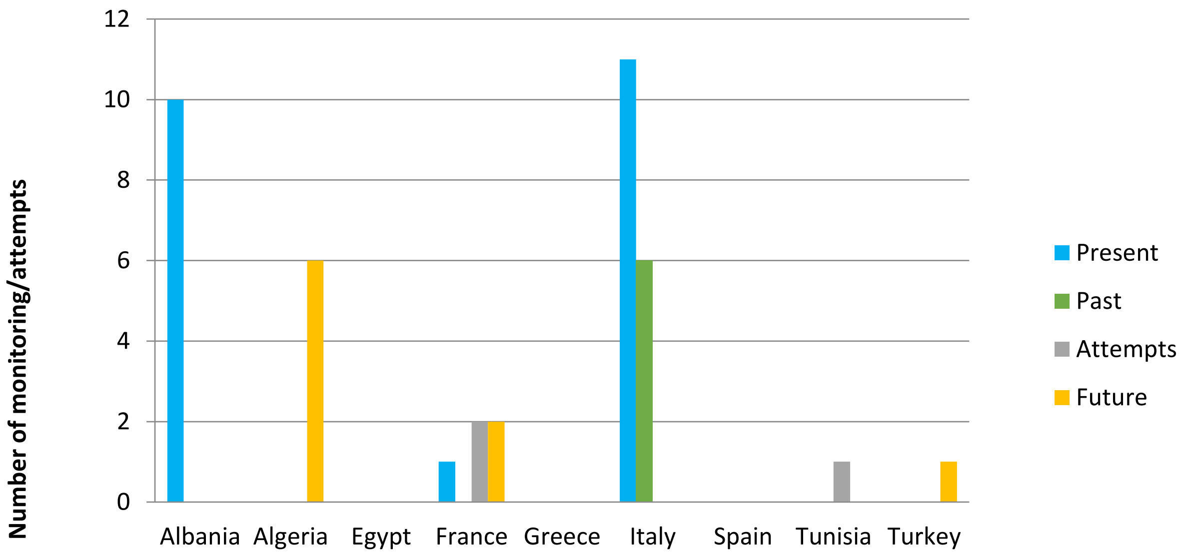

Figure 14.15. Silver eel escapement monitoring programmes (past, present and future) and monitoring attempts carried out in the Mediterranean region for the nine countries involved in the GFCM project.

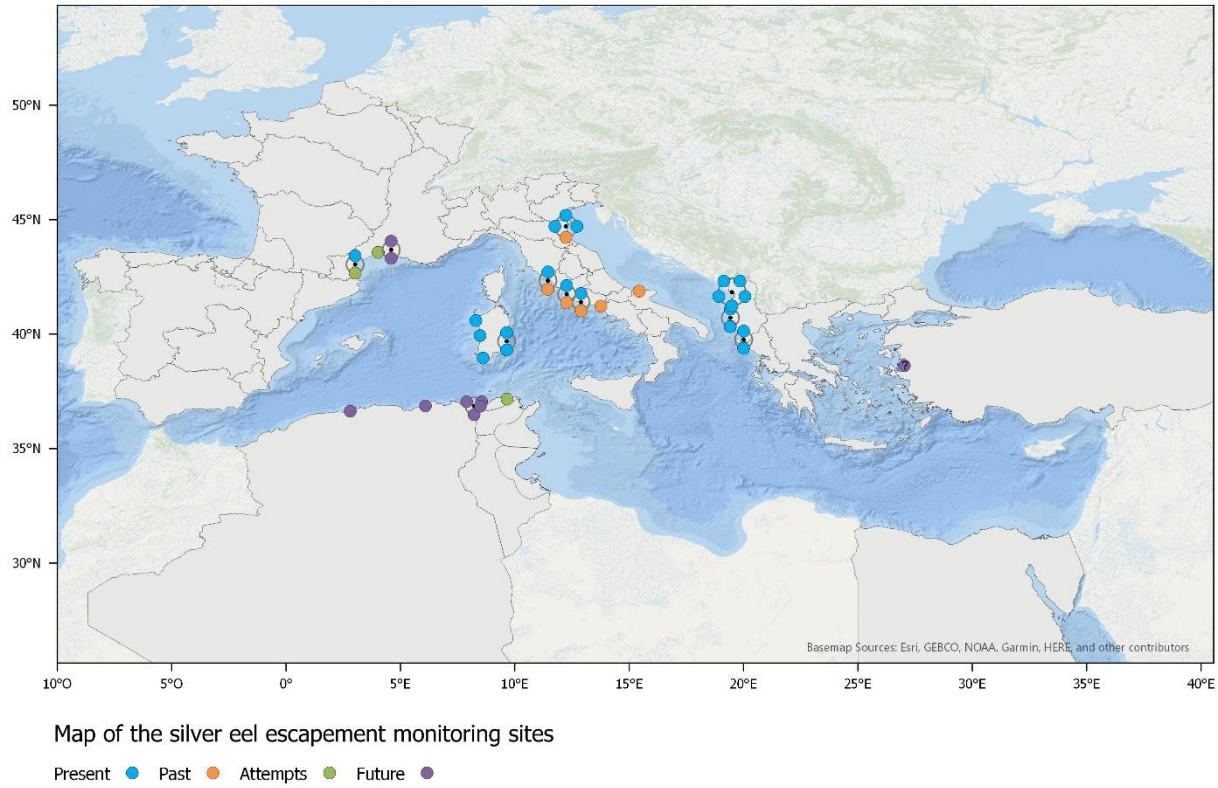

Figure 14.16. Map of the countries reporting silver eel escapement monitoring and monitoring attempts in the Mediterranean region for the nine countries involved in the GFCM project. In Türkiye the future monitoring sites are still unknown.

Among the nine partner countries, only Albania (ten monitoring programmes), France (one monitoring programme), Italy (11 monitoring programmes) are currently monitoring silver eel escapement (Table 14.16). In total, 28 current and past monitoring programmes were recorded. Italy was the only country having past monitoring programmes (Table 14.17) and was also the country recording the highest number of monitoring programmes (11 present and six in the past). It was also the country that monitored the largest surface area as these monitoring programmes are spread across the country, including Sardinia (Figure 14.16). The silver eel monitoring in Albania covered all the coastline in the Adriatic Sea. This was the only monitoring programme based on capture by professional fishers. Monitoring attempts (Table 14.18) were carried out in Italy (three studies), France (two studies) and Tunisia (one study). They were not successful or lacked sufficient funds to continue but at least gave information on the feasibility of future silver eel monitoring. Algeria, France and Türkiye are planning to start new monitoring programmes in the coming years (Table 14.19).

Table 14.16. Current silver eel escapement monitoring programmes in the nine countries participating in the GFCM eel project. (Site name: (s) indicates sites in Sardinia Island. Habitat: LAK = lake, LGN = lagoon, RIE = estuary)

Country	Site name	Type of habitat	First year	Number of years or seasons	Method	Framework
Albania	Shkodra	1 LAK	2019	3 seasons	Fixed barriers + fyke nets	National regulation DCM 407/2013 DCM256/2019

	Viluni, Vain, Kune, Patoku, Karavasta, Narta, Orikumi, Butrint Prita e Rrezes, Butrint vivar	9 LGN	2019	3 seasons	Fixed barriers+ fyke nets	National regulation DCM 407/2013 DCM256/2019
France	Bages sigean	1 RIE_lgn	2018	3 seasons	Acoustic camera	PLAGEPOMI
Italy	Comacchio	1 LGN	2013	9 years	Fixed barrier	
	Calich (s), Cabras (s), Porto Pino (s), Sa Praia (s), Tortoli (s)	5 LGN	2012	10 years	Fyke nets	Reg EC 1100/2007
	Orbetello	1 LGN	2019	2 seasons	barriers in nets + fyke nets	Pilot study Dec. EU 2016/1251 – for EU MAP 2022-2026
	Fogliano	1 RIE_lgn	2017	5 years	Fyke nets	Regional project for eel regulation
	Tevere	1 RIE_riv	2017	5 years	Fyke nets	Pilot study Dec. EU 2016/1251 – for EU MAP 2022-2026
	Po di Goro	1 RIE_riv	2019	2 seasons	Fyke nets	Pilot study Dec. EU 2016/1251 – for EU MAP 2022-2026
	Po di Volano	1 RIE_riv	2019	2 seasons	Fyke nets	Pilot study Dec. EU 2016/1251 – for EU MAP 2022-2026

Table 14.17. Past silver eel escapement monitoring programmes in the nine countries participating in the GFCM eel project. (Habitat: LGN = lagoon, RIE = estuary)

Country	Site name	Type of habitat	Starting year	Number of years	Method	Framework
Italy	Fogliano	1 LGN	2013	5	Fyke nets	Reg EC 1100/2007 regional project for eel regulation
	Comacchio	1 LGN	2010	4	Fixed barrier	
	Lesina	1 LGN	2017	3	barriers in nets + fyke nets	Pilot study Dec. EU 2019/910
	Tevere	1 RIE_riv	2013	5	Fyke nets	Reg EC 1100/2007
	Marta	1 RIE_riv	2013	3	Fyke nets	Reg EC 1100/2007
	Garigliano	1 RIE_riv	2017	3	Fyke nets	Pilot study Dec. EU 2019/910

Table 14.18. Silver eel escapement monitoring attempts in the nine countries participating in the GFCM eel project. CMR: capture mark recapture. (Habitat: LGN = lagoon)

Country	Site name	Type of habitat	Starting year	Number of seasons	Method	Framework
France	Bages-Sigean	1 LGN	2007	1	CMR	
	Or	1 LGN	2009	1	CMR	
Tunisia	Ichkeul	1 LGN	2013	1	CMR	

Table 14.19. Future silver eel escapement monitoring and potential sites in the nine countries participating in the GFCM eel project. (* indicates that the number of habitat types and starting date are unknown. ND = not determined. Habitat: LAK = lake, LGN = lagoon, RIE = estuary, RIV = river)

Country	Site name	Type of habitat	Starting year	Year end	Method	Framework
Algeria	Tonga, Oubeira	1 Lak	2022	2025	ND	
	Mellah	1 LGN	2022	2025	ND	
	Mafragh, El Kebir, Mazafran	3 RIE_riv	2022	2025	ND	
France	Rhône	1 RIV	2023?	ND	Guideau (static net)	PLAGEPOMI EU EMP
	Vaccarès	1 LGN	2023	2024	Acoustic telemetry	PLAGEPOMI EU EMP
Türkiye	ND	*LGN, *RIV	*	ND	ND	

Habitat type and area covered by silver eel escapement monitoring

Past and present monitoring programmes were recorded in lagoons (three past and 18 present monitoring programmes), rivers (three past monitoring and three present programmes) and one lake (one present monitoring programme) (Additional Results Part I). They were not equally distributed between countries and were only present in the northern part of the Mediterranean region. Albania was the only non-EU country to monitor silver eel escapement. It also recorded the highest number of lagoons monitored (nine) while Italy was the only country that was carrying out monitoring in an island (Sardinia).

At the present time, Albania is monitoring nine lagoons (Vilini, Vain, Kune, Patoku, Karavasta, Narta, Orikumi, Butrint pritae rrezes, Butrint vivar) and one lake (Shkodra), France is monitoring one lagoon (Bages-Sigean), Italy is monitoring three lagoons on its shoreline (Comacchio, Orbetello and Fogliano) and five lagoons in Sardinia (Calich, Cabras, Porto Pino, Sa Praia, Tortoli) and three rivers (Tevere, Po di Goro and Po di Volano). In total, 18 lagoons, three rivers and one lake were reported as being monitored for silver eel escapement (Figure 14.17, Figure 14.20 and Figure 14.21).

Past silver eel escapement monitoring programmes were only recorded in Italy (Figure 14.18, Figure 14.20 and Figure 14.22). Six sites were monitored including three rivers (Tevere, Marta and Garigliano) and three lagoons (Fogliano, Comacchio and Lesina). Monitoring attempts (Figure 14.19 and Figure 14.23) were recorded in France in two lagoons (Bages-Sigean and Or) and in one lagoon (Ichkeul) in Tunisia.

In the future, Algeria, France and Türkiye plan to implement new escapement monitoring programmes (Figure 14.24). In Algeria, the six potential sites are the three rivers Mafragh, El Kebir and Mazafran, Mellah lagoon and the two lakes, Tonga and Oubiera. In France, it is planned to monitor escapement in a river (Rhône) and in Vaccares lagoon where there is already recruitment monitoring. In Türkiye the sites have not yet been identified but lagoons and river habitats will be covered.

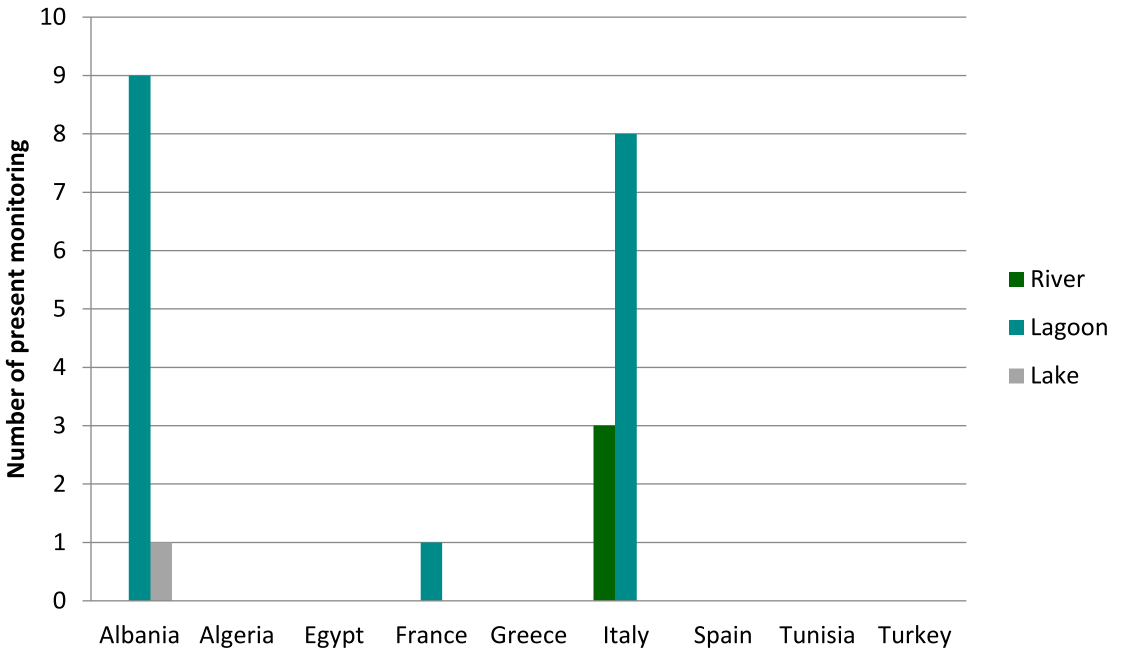

Figure 14.17. Number of present silver eel escapement monitoring programmes in the GFCM partner countries by habitat type.

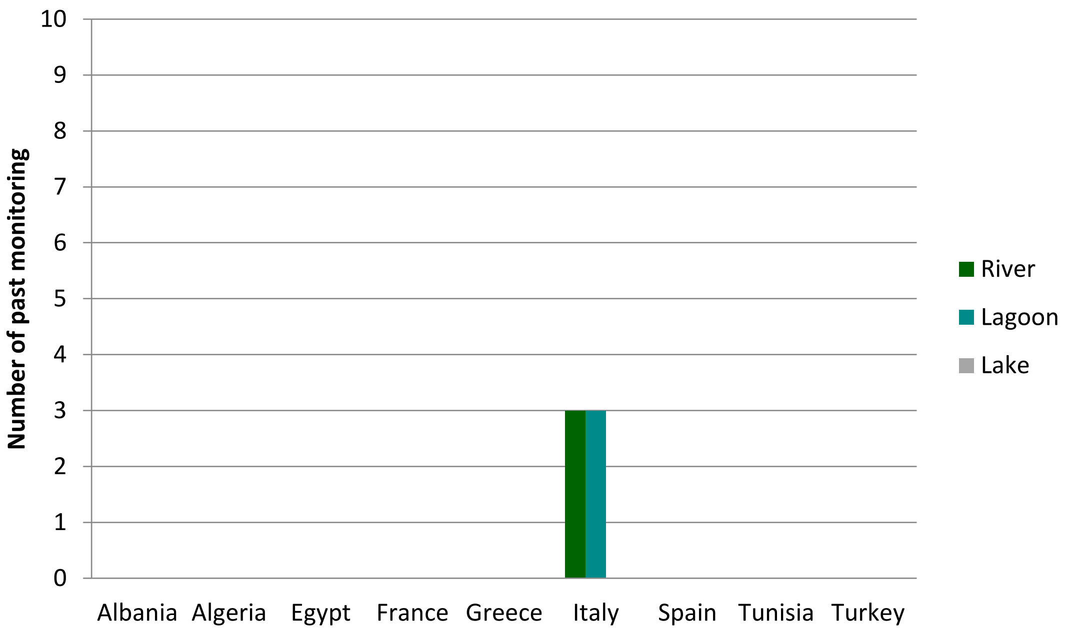

Figure 14.18. Number of past silver eel escapement monitoring programmes in GFCM partner countries by habitat type.

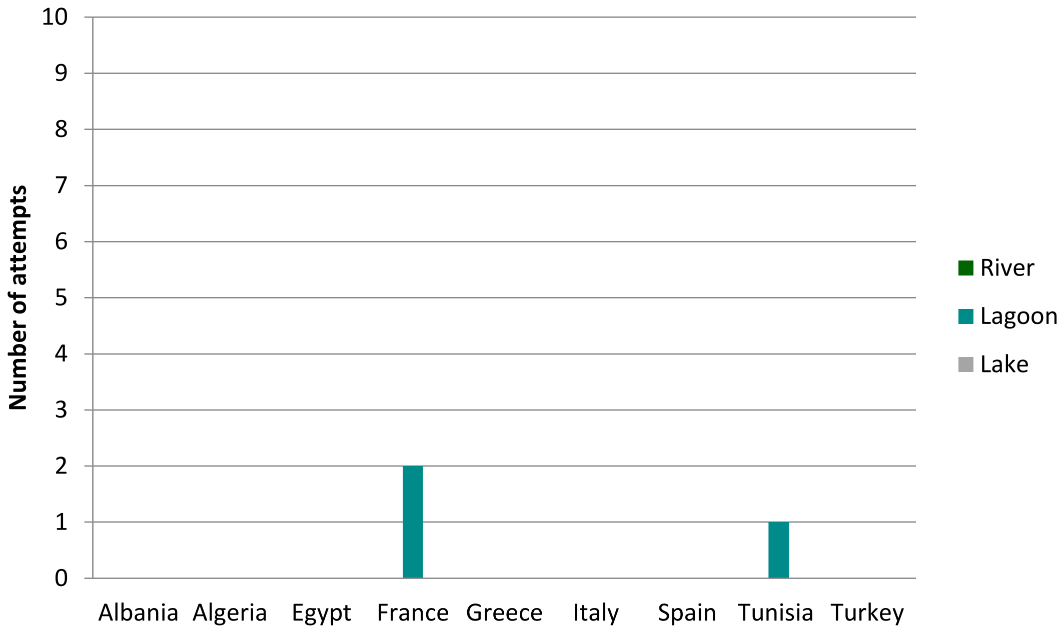

Figure 14.19. Number of silver eel escapement monitoring attempts in GFCM partner countries by habitat type.

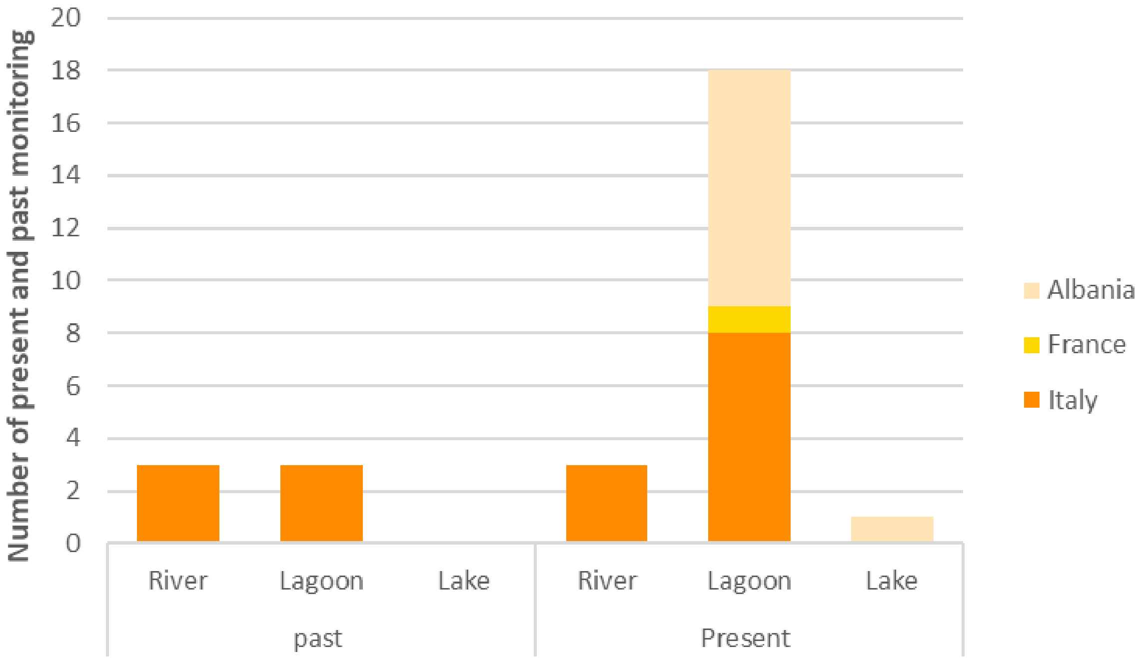

Figure 14.20. Number of present and past silver eel escapement monitoring programmes by habitat type and by country.

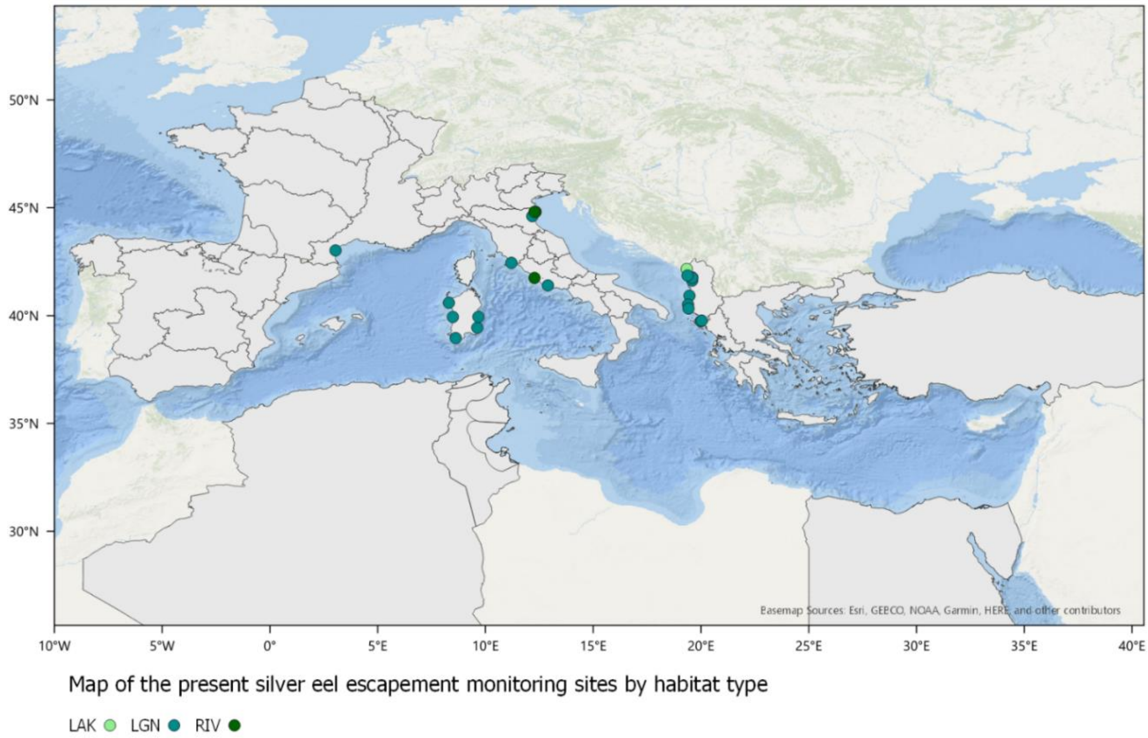

Figure 14.21. Location of present silver eel escapement monitoring sites by habitat type in the Mediterranean. Countries participating in the GFCM European eel research programme are highlighted in light grey.

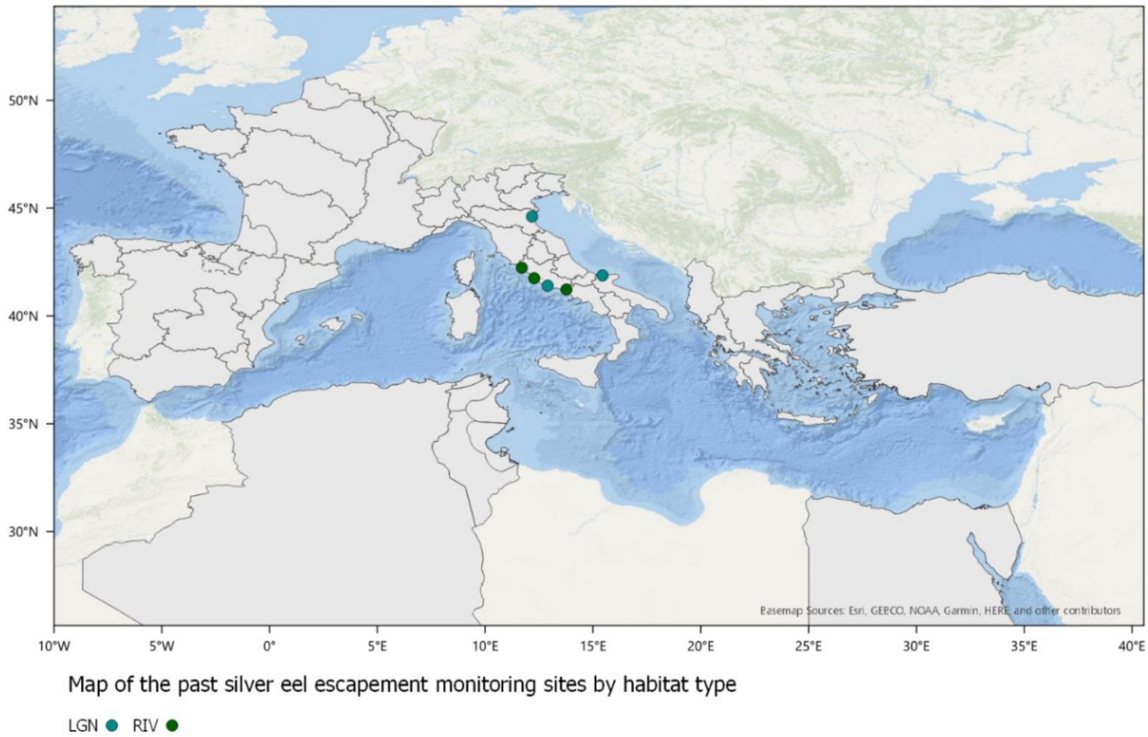

Figure 14.22. Location of past silver eel escapement monitoring sites by habitat type in the Mediterranean. Countries participating in the GFCM eel research project are highlighted in light grey.

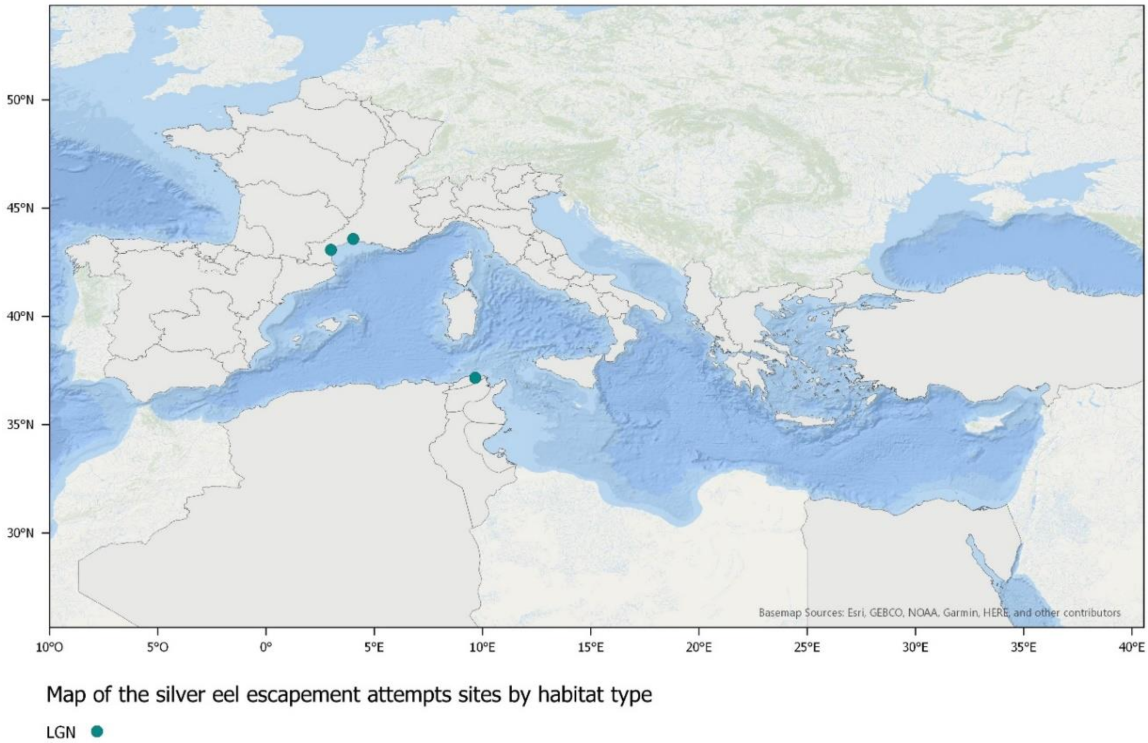

Figure 14.23. Location of the silver eel escapement monitoring attempt sites by habitat type in the Mediterranean. Countries participating in the GFCM eel research project are highlighted in light grey.

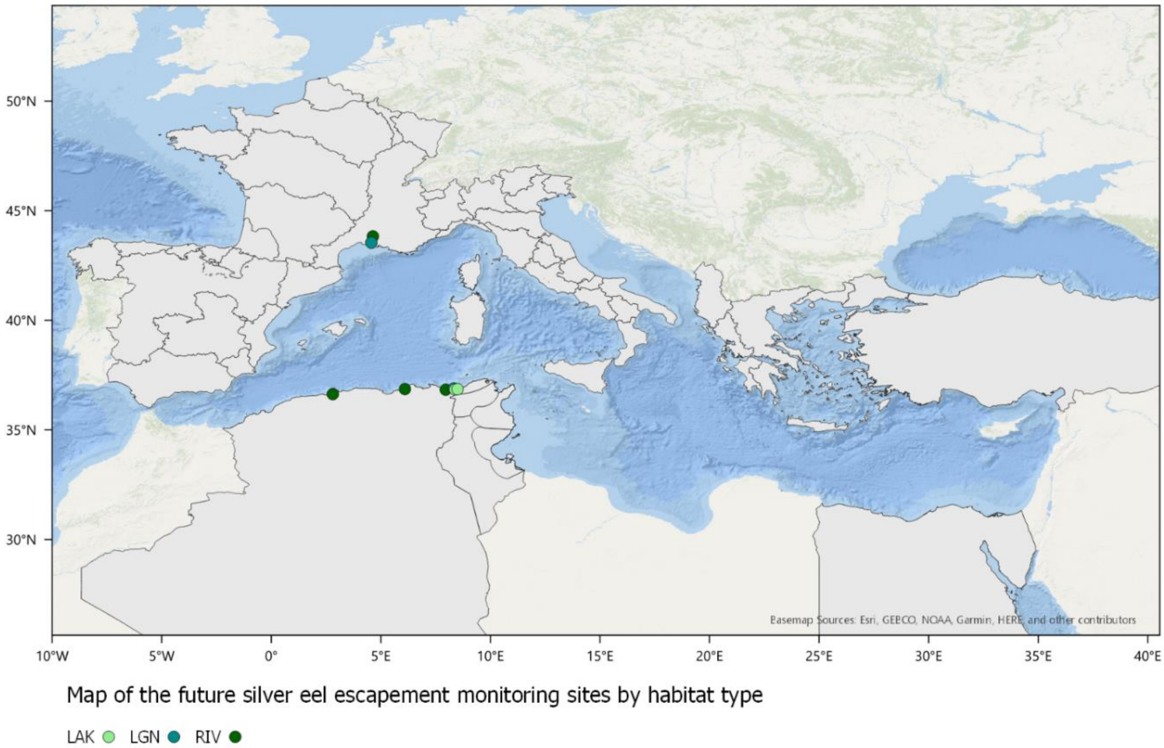

Figure 14.24. Location of future silver eel escapement monitoring sites by habitat type in the Mediterranean. Countries participating in the GFCM eel research project are highlighted in light grey.

Time coverage of silver eel escapement monitoring programmes

The reported time periods for silver eel monitoring programmes ranged from one season to ten years (Table 14.20) with the longest (the only long-term programmes) taking place since 2012 in five Sardinian lagoons (Italy); Calich, Cabras, Porto Pino, Sa Praia, and Tortoli.. The earliest implementation of silver eel monitoring started in 2010 in Italy at Comacchio lagoon but stopped three years later.

The periods monitored were shorter than those reported for recruitment monitoring. At the present time only Albania, France and Italy are monitoring escapement. Apart from the five Sardinian lagoons, the other ongoing monitoring recorded in Italy has been since 2013 at Comacchio (nine years), 2017 at Tevere and Fogliano (five years) and since 2019 in Orbetello, Po di Goro and Po di Volano (two seasons). In France, silver eel escapement at Bages-Sigean lagoon has been monitored since 2018 (three seasons), while in Albania, ten sites have been monitored since 2019 (three years).

Italy carried out six silver eel monitoring programmes in the past on six sites. Similarly to what happened with recruitment monitoring, there was a lot of monitoring carried out but for short time periods, as projects only were funded for two to four seasons.

Monitoring attempts were carried out in France and Tunisia for short periods. In France, Capture-Mark-Recapture experiments were set up in Bages-Sigean (2007–2008) and Or (2009–2010) lagoons (Amilhat *et al*., 2008, Charrier *et al.*, 2011) for one season. Tunisia had a similar experiment at Ichkeul lagoon from 2013 to 2014 (Derouiche, 2016).

Table 14.20. Time coverage for long-term monitoring of silver eel escapement (black hatched), present monitoring (black), past monitoring (light grey) and monitoring attempts (dark grey). (Habitat: LAK = lake, LGN = lagoon, RIE = estuary)

Country	Habitat	Site name	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Albanie	LAK	Shkodra															
	LGN	Viluni															
		Vain															
		Kune															
		Patoku															
		Karavasta															
		Narta															
		Orikumi															
		Butrint Prita e Rrezes															
		Butrint Vivar															
France	LGN	Bages Sigean															
		Or															
Italy	LGN	Comacchio															
		Fogliano															
		Lesina															
		Orbetello															
		Calich															
		Cabras															
		Porto Pino															
		Sa Praia															
		Tortoli															
	RIE	Tevere															
		Marta															
		Garigliano															
		Po di Goro															
		Po di Volano															
Tunisia	LGN	Ichkeul															

Future monitoring programmes are planned in Algeria, France and Türkiye. In Algeria, future monitoring is planned for 2022 and will last until 2025 (three years). At least one site will be selected from six potential sites. In France, two monitoring programmes should start in 2023 and last at least for one season. In Türkiye, monitoring programmes should start in 2022.

Methods used for silver eel escapement monitoring

General overview

Four methods were recorded to monitor silver eel escapement; fixed barriers in Albania and Italy, fyke nets in Albania and Italy, acoustic cameras in France and Capture-Mark-Recapture methods in France and Tunisia (Figure 14.25). Details on methods used in each habitat type are recorded in Table 14.21 and Figure 14.26 for on-going monitoring programmes and in Table 14.22 and Figure 14.27 for past monitoring and monitoring attempts. Fixed barriers associated with fyke nets were actually the most used methodologies in the Mediterranean with ten sites involved but only in Albanian lagoons and lakes, while Italy also used fixed barriers without fyke nets at Comacchio lagoon. The duration of the monitoring programmes and the frequency of capture differ according to the methods used and site characteristics (Table 14.23).

Table 14.21. Different methods used for present silver eel escapement monitoring by habitat type in the nine partner countries.

Methods	**Countries using the method**	**Number of river sites monitored**	**Number of lagoon sites monitored**	**Number of lake sites monitored**	**Total number of sites monitored**
Acoustic camera	France		1		1
Fixed barrier	Italy		1		1
Fixed barrier + fyke net	Albania		9	1	10
barriers in net + fyke net	Italy		1		1
Fyke net	Italy	3	6		9
Total		***3***	***18***	***1***	***22***

Table 14.22. Different methods used for past silver eel escapement monitoring and monitoring attempts by habitat type in the nine partner countries.

Methods	**Country using the method**	**Number of river sites monitored**	**Number of lagoon sites monitored**	**Number of lake sites monitored**	**Total number of sites monitored**
Fyke nets	Italy	3	1		4
barriers in net + fyke net	Italy		1		1
Fixed barriers	Italy		1		1
CMR	France, Tunisia		3		3
Total		***3***	***6***	***0***	***9***

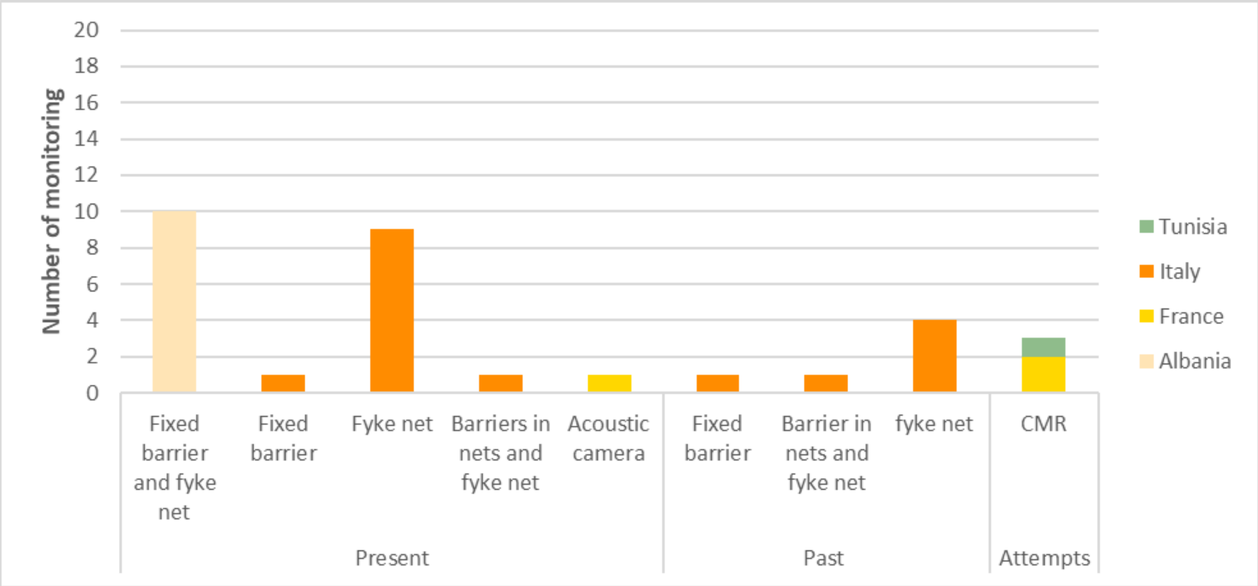

Figure 14.25. Methods used for present and past silver eel escapement monitoring and monitoring attempts in partner countries. CMR: Capture-Mark-Recapture.

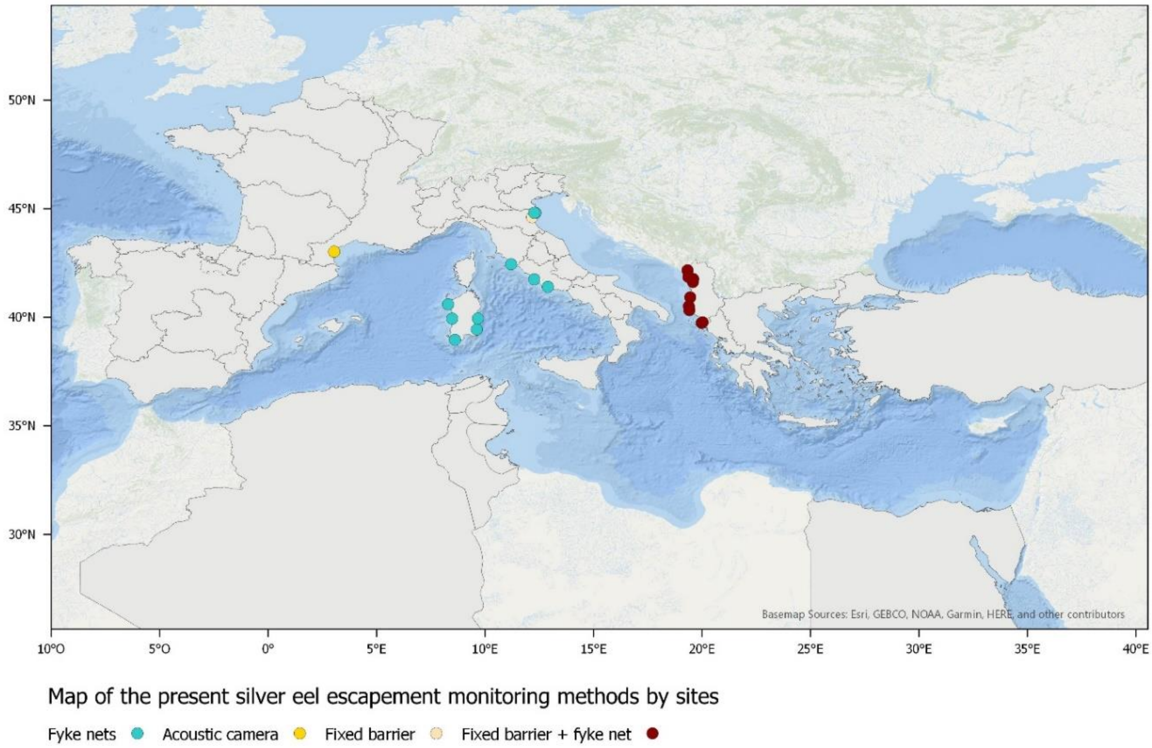

Figure 14.26. Location of present silver eel escapement monitoring methods used in the Mediterranean. Countries participating in the GFCM eel research project are highlighted in light grey.

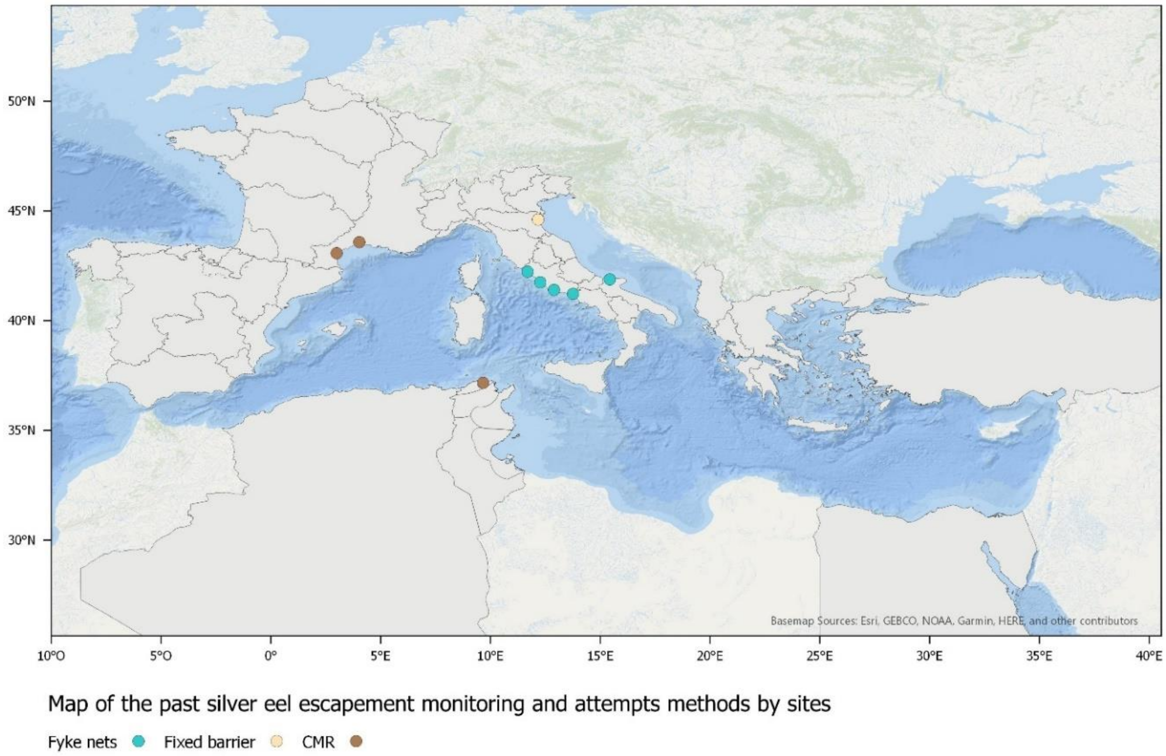

Figure 14.27. Location of past silver eel escapement monitoring and attempts methods used in the Mediterranean. Countries participating in the GFCM European eel research programme are highlighted in light grey.

Table 14.23. Detailed methods of present and past silver eel escapement monitoring programmes and monitoring attempts. (Months monitored: horizontal hatched cells show that only the middle of the months was monitored, dots show missing data. Total days: total number of days monitored in the year. Nb Gear: number of gears used for each monitoring/attempt. Mesh size: in mm. NP: non pertinent. NC: not collected. Habitat: LGN = lagoon, LAK = lake, RIV = river)

Method	Months monitored												Frequency	Total days	Nb gear	Mesh size	Site	Habitat	Country
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug							
Acoustic camera													24h/24h	**180**	1	NP	Bages Sigean	LGN	France
CMR													NP	NP	NP	NP	Ichkeul	LGN	Tunisia
																	Bages Sigean	LGN	France
																	Or	LGN	France
Fixed barrier													NC	**165**	NC	NC	Comacchio	LGN	Italy
Fixed barrier + fyke net													NC	90	NC	13	Shkodra	LAK	Albania
																NC	Butrint Prita e Rrezes	LGN	Albania
																	Butrint Vivar	LGN	Albania
																	Karavasta	LGN	Albania
																	Kune	LGN	Albania
																	Narta	LGN	Albania
																	Orikumi	LGN	Albania
																	Patoku	LGN	Albania
																	Vain	LGN	Albania
																	Viluni	LGN	Albania
Barrier in nets + fyke net													1 week/month	21	2	7,10,12	Lesina	LGN	Italy
																	Orbetello	LGN	Italy
Fyke net					10 days per season								daily or every 2 days during 10 days/season	40	4	NC	Cabras	LGN	Italy
					10 days per season												Calich	LGN	Italy
					10 days per season												Porto Pino	LGN	Italy
					10 days per season												Sa Praia	LGN	Italy
					10 days per season												Tortoli	LGN	Italy
													1 week/month	21	20	NC	Garigliano	RIV	Italy
																	Po di Goro	RIV	Italy
																	Po di Volano	RIV	Italy
													1week /month	35	2	NC	Fogliano	LGN	Italy
															20		Marta	RIV	Italy
															20		Tevere	RIV	Italy
															30		Tevere	RIV	Italy
													NC	NC	NC	NC	Fogliano	LGN	Italy

Fixed barriers

These are fixed structures, set up in the tidal channel of lagoons and lakes. The structure (shape, number of chambers, grid characteristics), size, design, building materials (reeds, wood, concrete or metal) of these devices have evolved significantly over centuries and differ between habitats and countries according to local traditions and the degree of technology. The general principle is to block and catch fish (not only eels) during their migratory phase when they are returning to the sea. The selectivity of fixed barriers can be adjusted so that small individuals can go through the structure, which is why, in Albania, fyke nets are added before and after the fixed structures. Plate 4 illustrates the diversity of this type of gear. Only Italy and Albania are using fixed barriers for monitoring while Greece and Türkiye also have these kind of structures. In Greece, they are not used to monitor escapement as, following a GFCM recommendation, the silver eel fishery is closed for the three escapement months, September to November.

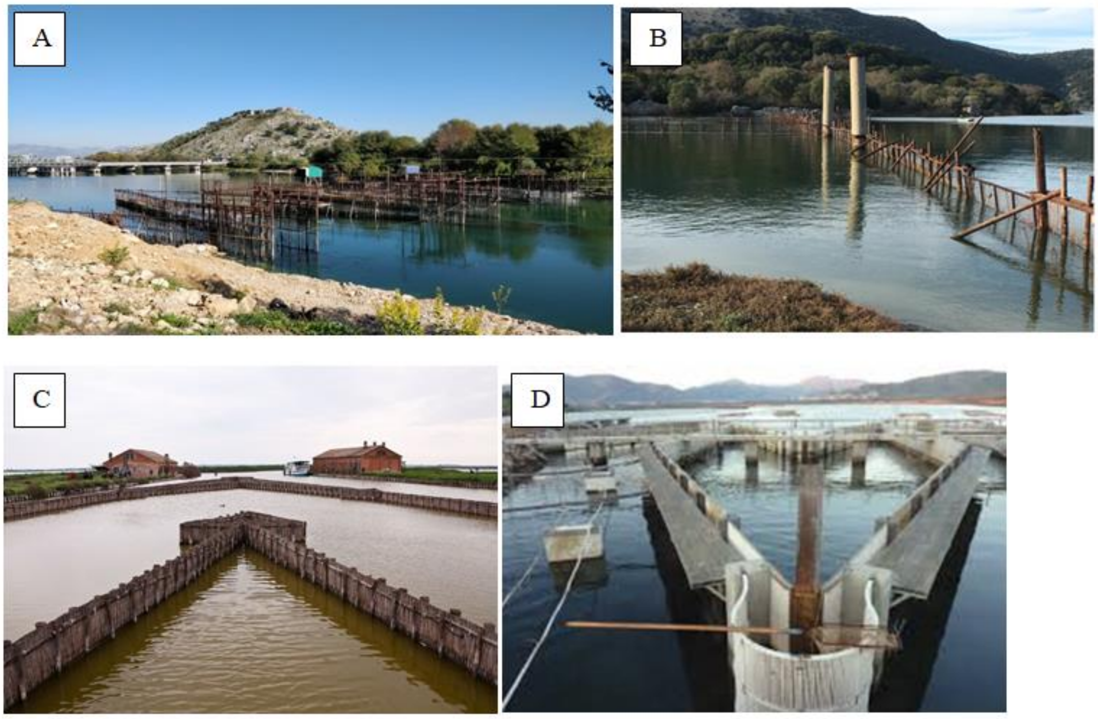

Plate 14.4. Examples of fixed barriers. A) Shkodra lake (set up in Buna river), Albania (©Edmond Hala). B) Brutint lagoon, Albania (©Edmond Hala). C and D) fixed barrier in Italy, Sardinia Island (©Chiara Leone).

Advantages and limitations to the use fixed barriers for monitoring silver eel escapement are shown in Table 14.24.

Table 14.24. Advantages and limitations to the use of fixed barriers for silver eel escapement monitoring.

Advantages	Limitations
• When the fixed barrier is set up at the unique outlet of the lagoon/lake, it provides the total number (or biomass) of escaping individuals at the whole site level • Permanent structure	• Small individuals may pass through the barrier • Monitoring is fishery dependant

Fyke nets

The method for operating fyke nets was described previously under glass eel recruitment monitoring. For escapement monitoring, the main differences are the gear dimensions and the mesh size which are adjusted to catch larger individuals. Italy is the only country that uses fyke nets alone to monitor silver eel escapement. In rivers, fyke nets are 80 cm to 100 cm in height and two metres in length, with two chambers, the innermost one usually having 8 mm to 9 mm mesh size. Two rows of fyke nets are set in chains (ten fyke nets each) parallel to the banks, four metres from each other. The number of fyke net chains depends on the width of the river. In lagoons, nets barriers are used, leading to the fyke nets. One net barrier (123 m to 150 m length and 12 mm mesh size) per river bank is set up, perpendicularly to the shore. At the end of each net barrier, two to three fyke nets are installed. The fyke nets are 50 cm to 80 cm in height, three metres to nine metres in length, with three chambers, the innermost one having a mesh size of seven mm to ten mm. Advantages and limitations are the same as those presented for monitoring glass eel recruitment.

Acoustic camera

Acoustic cameras are multibeam high-frequency sonars that create high-resolution images (Plate 5). They are powerful tools that allow the operator to count and measure eels that are moving towards the sea. They are non-invasive and can be used at night and in water with excessive turbidity levels. Eels are identified based on their undulatory swimming behaviour and morphology. France is using an ARIS EXPLORER 1800 (Sound Metrics) to monitor silver eel escapement from Bages-Sigean lagoon. The camera is positioned in the narrowest part of the tidal channel (53 m), at a depth of three metres and at a distance of 20 m from the closest bank in order to record horizontally towards the opposite bank and perpendicularly to the flow direction (Lagarde *et al.*, 2020). It was set at a frequency of 1.8 MHz which provided a range of images at a distance of 14 m to 15 m from the camera. Daily counts of eels were recorded on the video during the escapement season and were considered as an indicator of silver eel escapement from the lagoon. Although acoustic cameras are increasingly used for monitoring migratory fish population, many technical aspects have to be taken into consideration to obtain reliable surveys (Martignac *et al.*, 2015, Lagarde *et al.*, 2020).

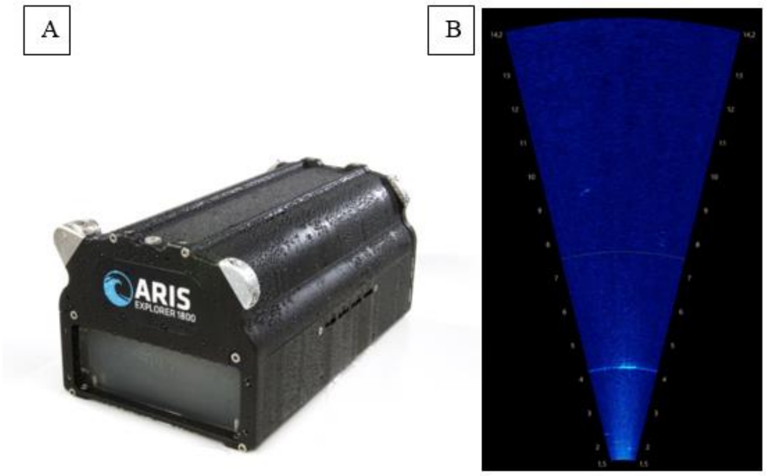

Plate 14.5. Acoustic camera ARIS used in France. A) Acoustic camera ARIS EXPLORER 1800 (http://www.soundmetrics.com/products/ARIS-Sonars/ARIS-Explorer-1800). B) Image of an eel recorded by the acoustic camera ARIS.

Advantages and limitations to the use acoustic cameras for escapement monitoring are recorded in Table 14.25.

Table 14.25. Advantages and limitations to the use of acoustic cameras for silver eel escapement monitoring.

Advantages	Limitations
• Well adapted for long-term monitoring, as it is installed on permanent structures • Videos are recorded automatically every day for 24hours and it is a non-intrusive method • Can work in turbid water • Eels can be counted and measured (an estimation of the sex-ratio can be determined) • Fishery independent	• Expensive initial cost (around Euro 80 000) • Needs an electricity supply • Needs to be installed in a safe place • Maintenance (cleaning) is needed every month • Large quantities of data generated • Acoustic camera has a limited field of view • Time consuming to carry out visual analysis (one day of video needs one day of work) • It is impossible to distinguish the life stage of eels on the video • Post analyses are necessary to evaluate the number of migrating individuals and estimate the number of silver and yellow eels

Capture-mark-recapture (CMR) method

The CMR method was used in two monitoring attempts in France (Amilhat *et al*., 2008, Charrier *et al.*, 2011) and in Tunisia (Derouiche, 2016). This method consists of capturing a number of individuals, marking them and then releasing them back to the population, so they can be recognized when recaptured. Different types of mark were used including simple paint and more sophisticated PIT tags. The estimate of the population size is then based on the number of marked individuals recaptured on subsequent sampling occasions (Seber, 1986). Several assumptions need to be met in order to use this method, including that the marks should remain on the animal during the entire experimental period, they do not affect the physiology or behaviour of the animals and individuals should have the same probability of being captured as non-marked animals.

Advantages and limitations of the CMR method for escapement monitoring are shown in Table 14.26.

Table 14.26. Advantages and limitations of the capture-mark-recapture (CMR) method for silver eel escapement monitoring.

Advantages	Limitations
• Can be a low cost method (depending on the type of mark) that is reproducible every year • Allows estimation of the population size (while respecting the assumptions) • Biometric characteristics of the population can be evaluated	• Data collection is fishery dependant as fishers and fishmongers need to be informed of the presence of marked eels and must communicate the number of marked individuals captured • There are biases related to the fishing season period and fishing conditions • A large number of eels must be marked

<u>Other methods used by countries not involved in the GFCM eel programme to monitor silver eel escapement</u>

In the other regions, similar methods have been used, apart from another method which consists of trapping silver eels in the rivers at a dam (Acou *et al.* 2008). The methods are sometimes combined to provide more robust results. The evaluation of silver eel escapement is usually carried out by the total count of the silver eels or partial count with the implementation of an estimation method.

All the methods can be coupled with telemetry or models. Telemetry has been used in several studies (Teichert *et al*., 2020, Calles *et al*., 2013, Winter, Jansen and Bruijs, 2006) to follow the movements of silver eels and indicates the percentage of migration success. A recent model developed by Teichert *et al*. (2020), showed that it is possible to provide threshold values (river flow and discharge pulse) to predict silver eel peaks. Although they need to be adapted to Mediterranean river characteristics, these models could help to implement decision rules for turbine shutdowns during escapement peaks.

EDA (Eel Density Analysis) is another modelling tool which allows the prediction of silver eel production based on eel density data in rivers (Briand *et al*., 2022). It was used recently in the European Interreg project SUDOANG, for Portugal, Spain and southwestern France (Sudoang, 2021). However, this model is less well adapted to lagoon habitats where eel densities are poorly known.

14.3.3 Yellow eel stock monitoring

General overview of yellow eel stock monitoring

As with glass eel and silver eel monitoring, yellow eel stock monitoring programmes reported by the partner countries were diverse in terms of sites (habitat types), time periods covered, methods, organisations involved and management frameworks. They can be fishery dependent or not, while some were compulsory under local, national or EU level frameworks. Most were not long-term; 72 percent of the past and present monitoring programmes had less than ten years of records. Overviews of the monitoring programmes are presented in Figure 14.28 and Figure 14.29.

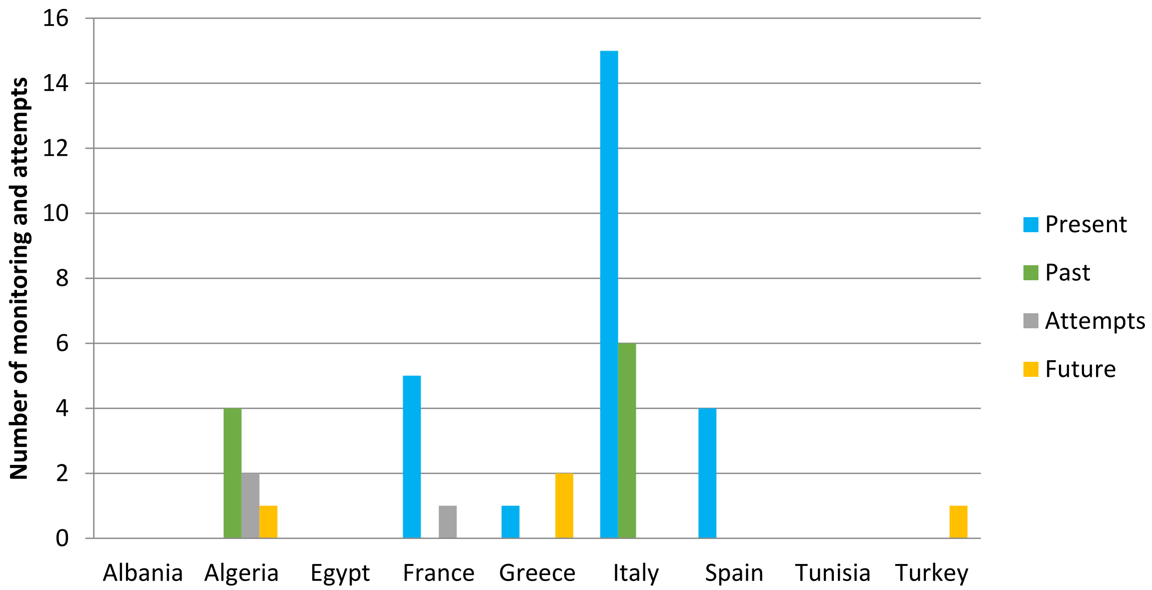

Figure 14.28. Yellow eel stock monitoring (past, present, future) and monitoring attempts in the Mediterranean region for the nine countries involved in the GFCM project.

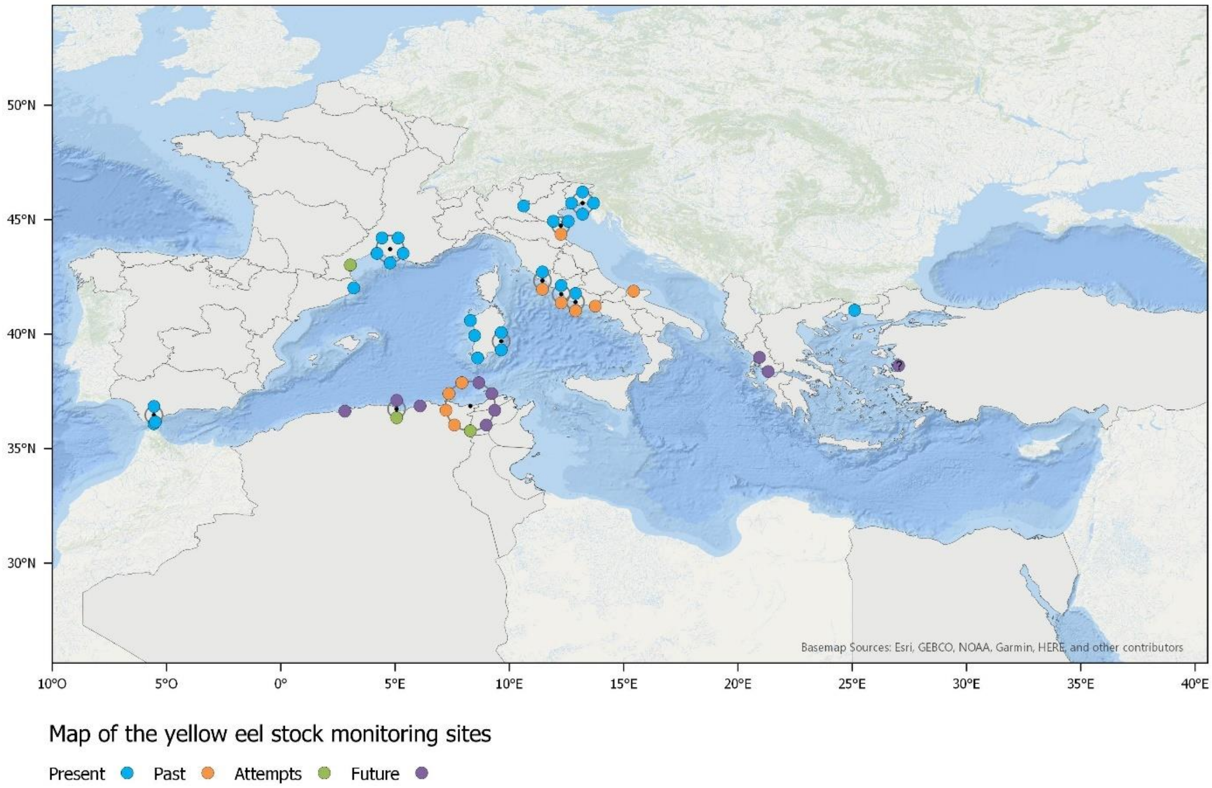

Figure 14.29. Countries reporting yellow eel stock monitoring and monitoring attempts in the Mediterranean region for the nine countries involved in the GFCM European eel research programme. In Türkiye, the exact locations of future monitoring sites are still unknown.

Over the nine partner countries, only France (five monitoring programmes and one electrofishing network), Greece (one monitoring programme), Italy (15 monitoring programmes) and Spain (four monitoring programmes) are currently monitoring yellow eel populations, making a total of 26 on-going monitoring programmes (Table 14.27).

In France and Spain, the majority of the data on yellow eels were collected by electrofishing monitoring programmes in rivers. These data are presented separately from the other monitoring programmes as several protocols are used depending on the river morphology, the sites and the frequency of monitoring and involve a large number of sampling stations in many river sites. The WP2 database was not built to support such a large amount of metadata but it is important to highlight the existence of these data for yellow eel stocks. These data are compiled in the SUDOANG database (Mateo *et al.*, 2022) and can be seen on the project website: https://sudoang.eu/en/visuang/. The SUDOANG project recorded data from 58 drainage basins in France and 65 in Spain, in the Mediterranean (Sudoang, 2021).

A total of ten past monitoring programmes (Table 14.28) were recorded with four programmes in Algeria and six in Italy. Monitoring attempts (Table 14.29) were implemented in Algeria (two studies) and France (one study). For Algeria, it was based on Ph.D. research while in France, it corresponded to an attempt to estimate yellow eel biomass using an enclosure in a lagoon.

Algeria (at least one monitoring programme, seven potential sites), Greece (two monitoring programmes) and Türkiye (at least one monitoring programme) are planning to start monitoring in the coming years (Table 14.30).

Table 14.27. Current yellow eel stock monitoring programmes in the nine countries participating in the GFCM eel project. (s) indicates sites in Sardinia. (Habitat: RIE = estuary, LGN = lagoon, RIV = river)

Country	Site name	Type of habitat	First year	Number of years	Method	Framework
France	Fumemorte Canal	1 RIE_can	1993	29	Fyke nets (verveux)	No
	Vaccarès, Capelière	1 LGN	1993	29	Fyke nets (capéchade)	No
	Beaucaire dam - Rhone	1 RIV	2008	13	Active fish pass traps	No
	Avignon dam-Rhone	1 RIV	2012	9	Active fish pass traps	No
	Mallemort dam - Rhone	1 RIV	2012	9	Active fish pass traps	No
Greece	Vistonida lake	1 LGN	2019	2	Fyke nets	DCF EU MAP
Italy	Orbetello	1 LGN	2017	4	Enclosure	Pilot study Dec. EU 2019/910
	Po di Volano	1 RIE_riv	2017	4	Fyke nets	Pilot study Dec. EU 2019/910
	Po di Goro	1 RIE_riv	2017	4	Fyke nets	Pilot study Dec. EU 2019/910
	Tevere	1 RIE_riv	2017	4	Fyke nets	Lazio Regional EMP (EU Eel Regulation)
	Fogliano	1 LGN	2017	4	Enclosure	Lazio Regional EMP (EU Eel Regulation)
	Marano	1 LGN	2014	8	Fyke nets	No
	Marano, Grado	2 RIV_RIE and LGN	2019	3	Fyke nets, electrofishing	No
	Marano, Grado	2 LGN	2019	3	Fyke nets	No
	Calich (s), Cabras (s), Porto Pino (s), Sa Praia (s), Tortoli (s)	5 LGN	2012	9	Fyke nets	Sardegna Regional EMP (EU Eel Regulation)
Spain*	Palmones, Guadalorce	2 RIV	2019	2	Fyke nets	Decretos 396/2010 de la Consejería de Medio Ambiente ; 209/2020 de la Consejería de Agricultura, Ganadería, Pesca y Desarrollo sostenible de la Junta de Andalucía. EU- MAP
	Guadarranque	1 RIV	2018	3	Fyke nets	
	Ter	1 RIV	2019	2	Electrofishing	EU-MAP

*Some discrepancies in the provision of the data will be further investigated

Table 14.28. Past yellow eel stock monitoring programmes in the nine countries participating in the GFCM eel project. (Habitat: LAK = lake, LGN = lagoon, RIE = estuary)

Country	Site name	Habitat	First year	Last year	Number of years	Method	Framework
Algeria	Tonga	1 LAK	2007	2014	7	Fyke nets	No
	Oubiera	1 LAK	2007	2011	4	Fyke nets	No
	Mellah	1 LGN	2008	2011	3	Fyke nets	No
	Mafragh	1 RIE_riv	2007	2010	3	Fyke nets	No
Italy	Tevere	1 RIE_riv	2013	2017	4	Fyke nets	Lazio Regional EMP (EU Eel Regulation)
	Marta	1 RIE_riv	2013	2015	2	Fyke nets	Lazio Regional EMP (EU Eel Regulation)
	Garigliano	1 RIE_riv	2017	2019	2	Fyke nets	Pilot study Dec. EU 2016/1251 – for EU MAP 2022-2026
	Lesina	1 LGN	2017	2019	2	Enclosure	Pilot study Dec. EU 2016/1251 – for EU MAP 2022-2026

	Fogliano	1 LGN	2013	2017	4	Fyke nets – enclosure?	Lazio Regional EMP (EU Eel Regulation)
	Comacchio	1 LGN	2010	2013	3	Fyke nets	No

Table 14.29. Summary of the yellow eel stock monitoring attempts in the nine countries participating in the GFCM eel project. (Habitats: LGN = lagoon, RIE = river)

Country	Site	Habitat	First year	Last year	Method	Framework
Algeria	Mellah	1 LGN	2013	2014	Fyke nets	No
	Soummam	1 RIE_riv	2012	2013	Fyke nets	No
France	Bages Sigean	1 LGN	2019	2020	Enclosure	No

Table 14.30. Future yellow eel stock monitoring programmes and potential sites in the nine countries participating in the GFCM eel project. ND: Not determined yet. (Habitat: LAK = lake, LGN = lagoon, RIE = estuary)

Country	Site	Habitat	First year	Last year	Method	Framework
Algeria	Tonga, Oubiera	2 Lak	2022	2025	ND	No
	Mellah	1 LGN	2022	2025	ND	No
	El Kebir, Mazafran, Soummam, Mafragh	4 RIE_riv	2022	2025	ND	No
Greece	Amvrakikos	1 LGN	2022	ND	Fyke nets	Dec. EU 2019/910
	Messolonghi-Aitoliko	1 LGN	2022	ND	Fyke nets	Dec. EU 2019/910
Türkiye	ND	ND	2022	2025	ND	ND

Habitat type and area covered by yellow eel stock monitoring

Past and present monitoring programmes were recorded in rivers, lagoons and lakes (Additional Results Part I). Most were in rivers (four past programmes and 11 present programmes) and lagoons (four past monitoring programmes and 15 present monitoring programmes) and in only two lakes (two past monitoring programmes). They were not equally distributed between countries as there were more in the northern Mediterranean countries than in the south (Figure 14.29).

At the present time, 26 on-going monitoring programmes were reported in the nine partner countries (Table 14.20, Figure 14.30 and Figure 14.33), all being carried out by European countries on the northern coast of the Mediterranean (Figure 14.34). France had five monitoring programmes, three in the river Rhône (at dams in the cities of Beaucaire, Avignon and Mallemort), one in Vaccarès lagoon and one in the Funemorte canal (RIE_chan). Greece had one monitoring programme in a lagoon called Vistonida lake. Italy had 15 monitoring programmes, three in rivers: Po di Volano (Po river branch), Po di Goro (Po river branch) and Tevere, and 12 programmes in 9 lagoons: Orbetello, Calich, Cabras, Porto Pino, Sa Praia, Tortoli, Fogliano, Marano and Grado. Spain is carrying out four monitoring programmes in rivers; Palmones, Guadarranque, Guadalorce and Ter.

Past yellow eel stock monitoring programmes were reported by Algeria and Italy (Figure 14.31, Figure 14.33 and Figure 14.35). Algeria reported four past monitoring programmes in Tonga and Oubiera lakes, Mellah lagoon and Mafragh river:. Italy had monitoring programmes in Lesina, Fogliano and Comacchio lagoons, and in Garigliano, Tevere and Marta rivers.

Monitoring attempts were implemented in Algeria in Mellah lagoon (LGN) and Soummam estuary (RIE_riv), while France had one monitoring attempt in Bages-Sigean lagoon (Figure 14.32 and Figure 14.36).

In the future, Algeria, Greece and Türkiye are planning to monitor yellow eel stocks (Figure 14.37). Algeria is planning to set up at least one monitoring programme and the potential sites are two lakes (Tonga and Oubiera), one lagoon (Mellah) and four rivers (El Kebir, Mazafran, Soummam and Mafragh). Greece is planning to carry out yellow eel monitoring in two lagoons (Amvrakikos and Messolonghi-Aitoliko) while Türkiye is also planning yellow eel monitoring but the exact number of programmes an sites are as yet unknown.

In Albania, Egypt and Tunisia, yellow eel stocks have never been monitored.

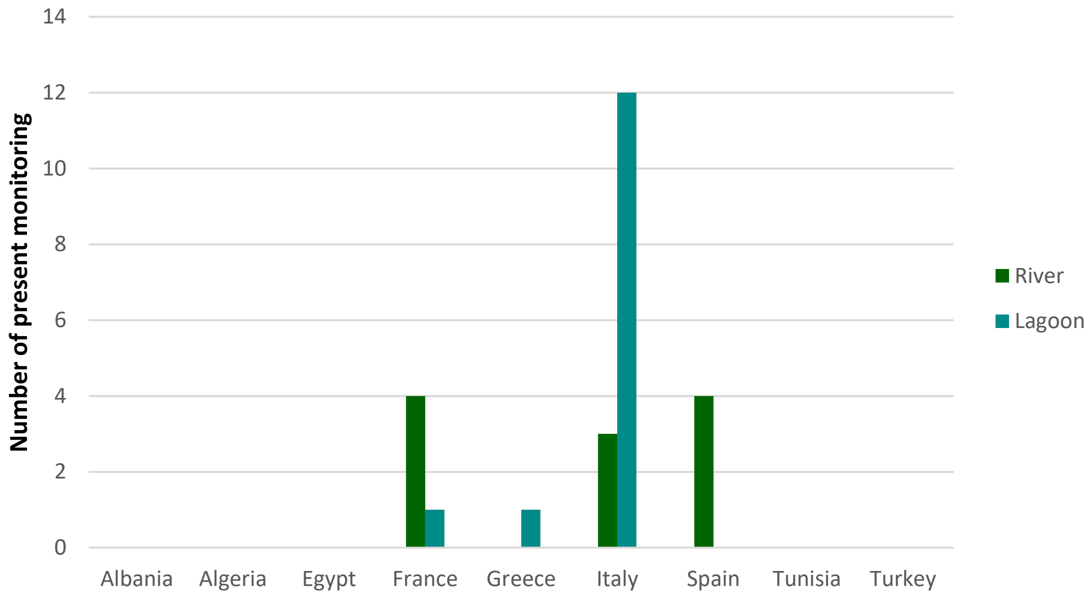

Figure 14.30. Number of present yellow eel stock monitoring programmes in GFCM partner countries by habitat type.

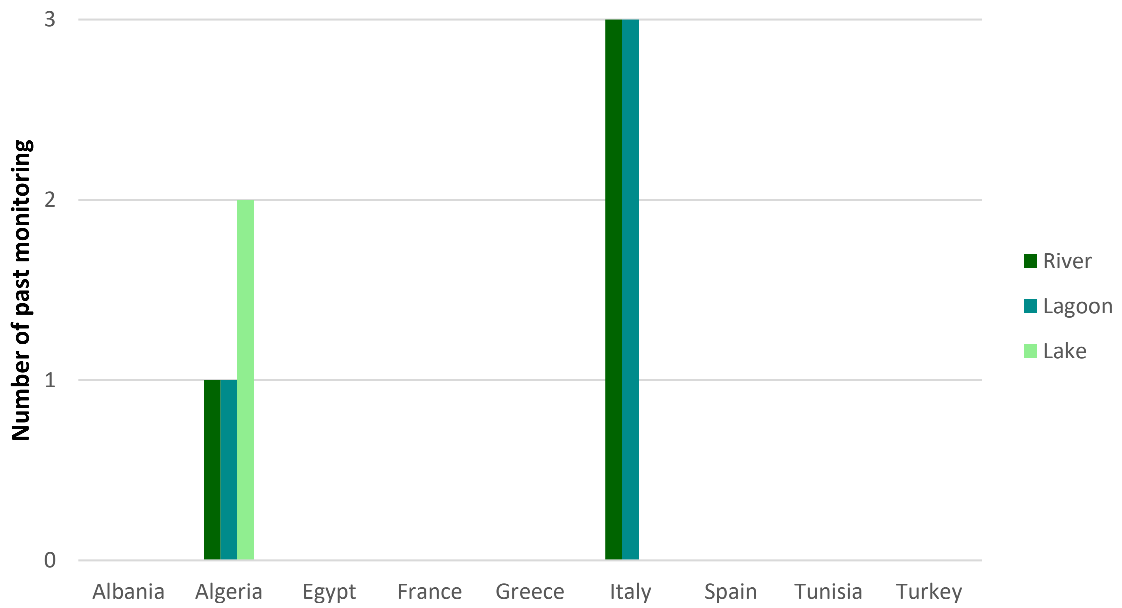

Figure 14.31. Number of past yellow eel stock monitoring programmes in GFCM partner countries by habitat type.

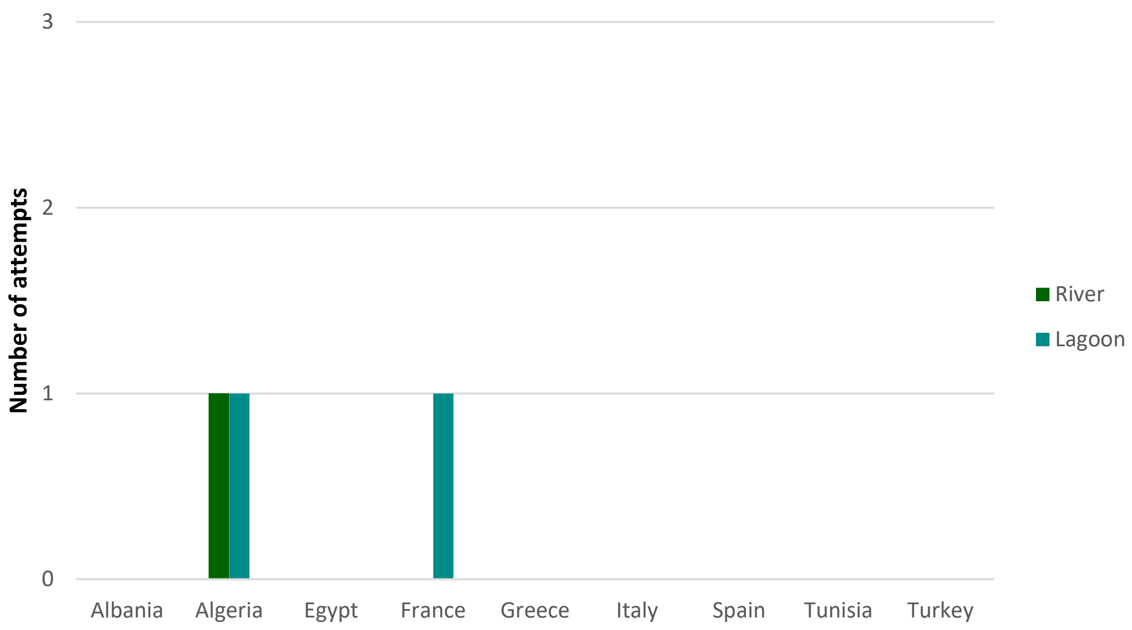

Figure 14.32. Number of yellow eel stock monitoring attempts in GFCM partner countries by habitat type.

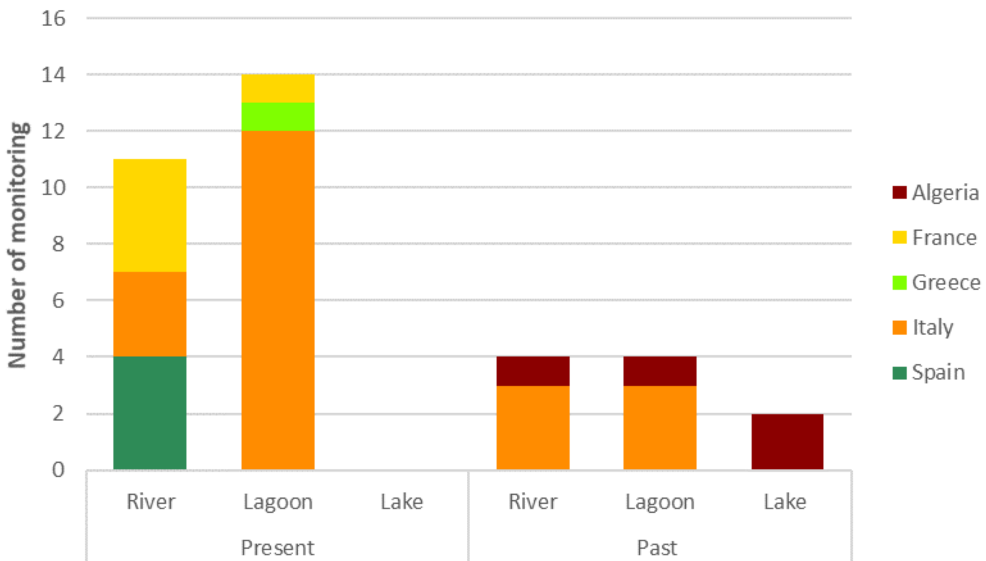

Figure 14.33. Number of present and past yellow eel stock monitoring programmes by habitat type and by country.

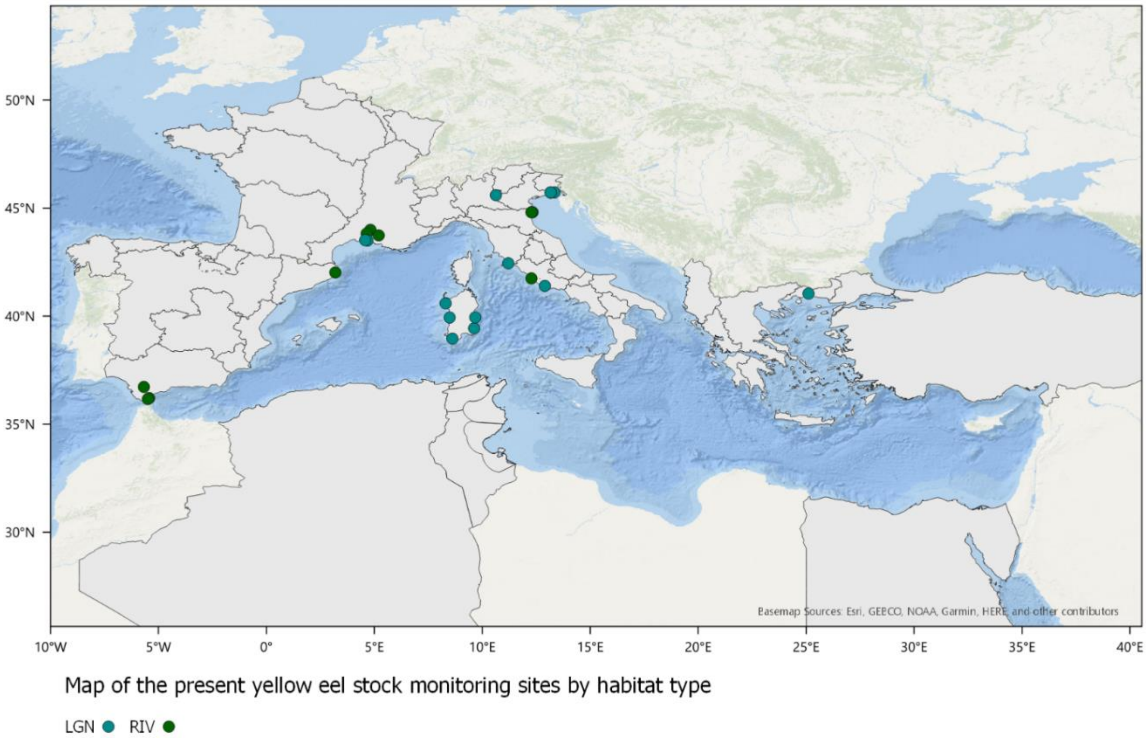

Figure 14.34. Location of current yellow eel stock monitoring sites by habitat type (LGN = lagoon, RIV = river) in the Mediterranean. Countries participating in the GFCM European eel research programme are highlighted in light grey. For France and Spain, electrofishing networks and SUDOANG data have not been presented.

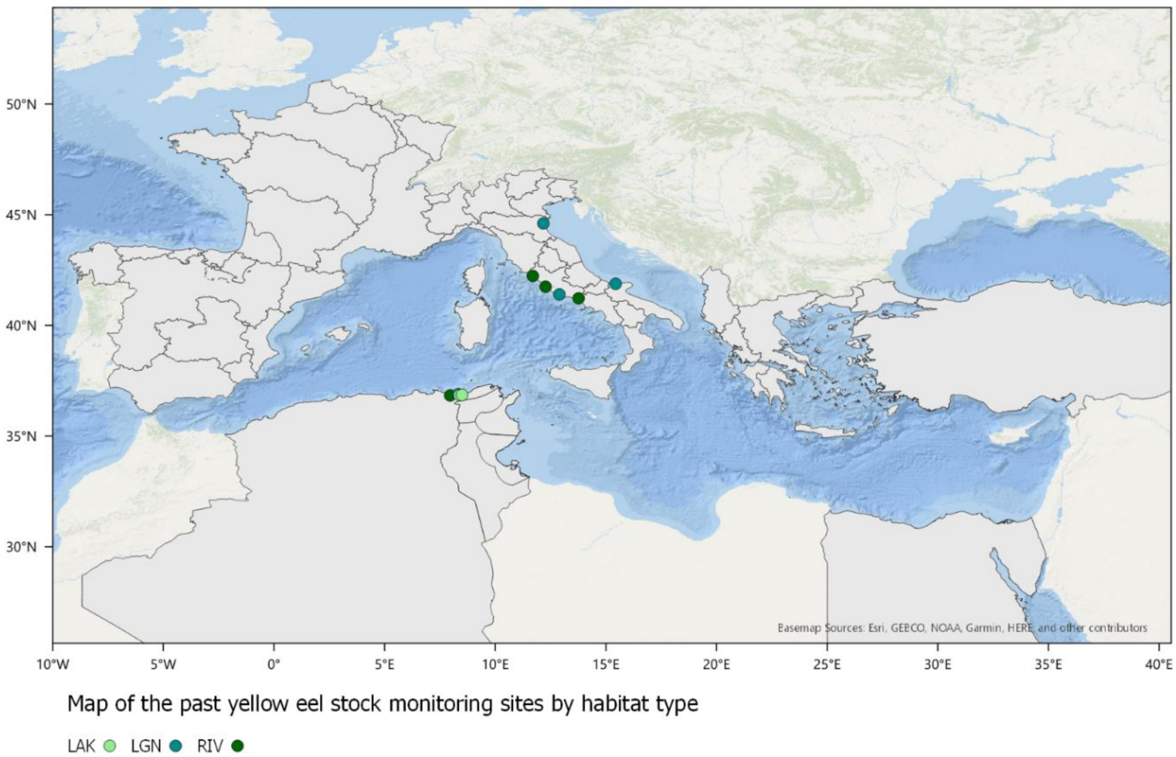

Figure 14.35. Location of past yellow eel stock monitoring sites by habitat type (LAK = lake, LGN = lagoon, RIV = river) in the Mediterranean. Countries participating in the GFCM European eel research programme are highlighted in light grey. For France and Spain, electrofishing networks and SUDOANG data have not been presented.

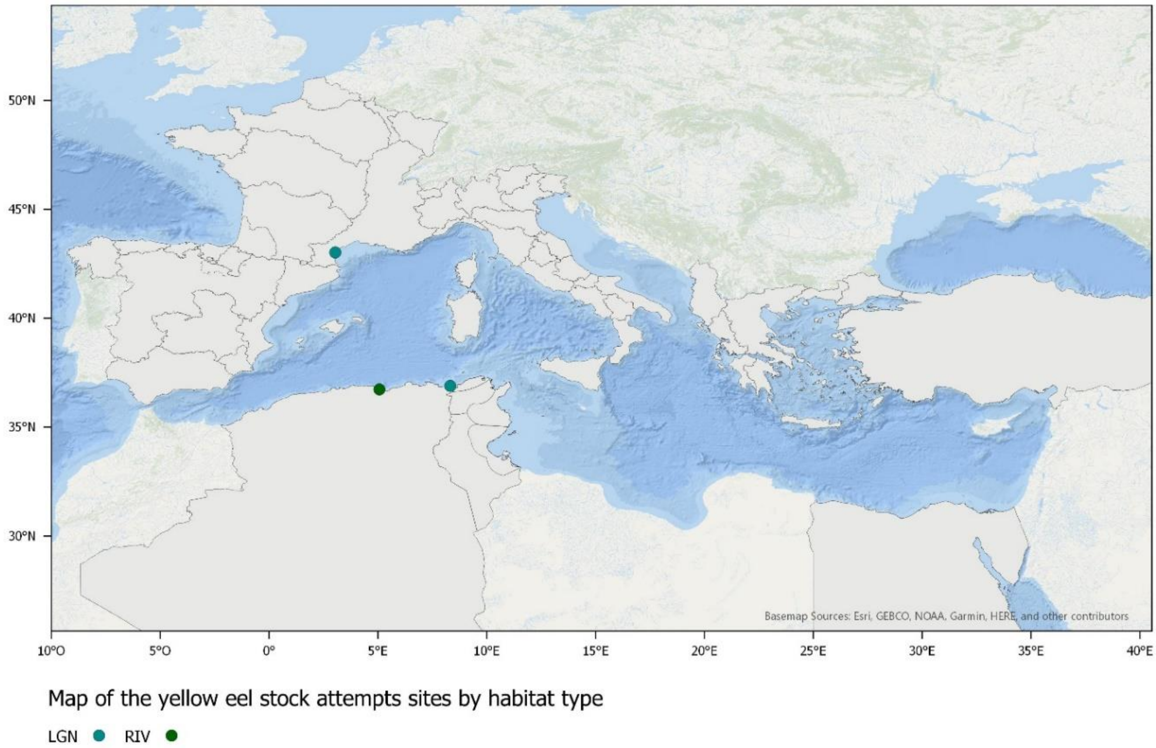

Figure 14.36. Location of yellow eel stock monitoring attempt sites by habitat type in the Mediterranean. Countries participating in the GFCM European eel research programme are highlighted in light grey. For France and Spain, electrofishing networks and SUDOANG data have not been presented.

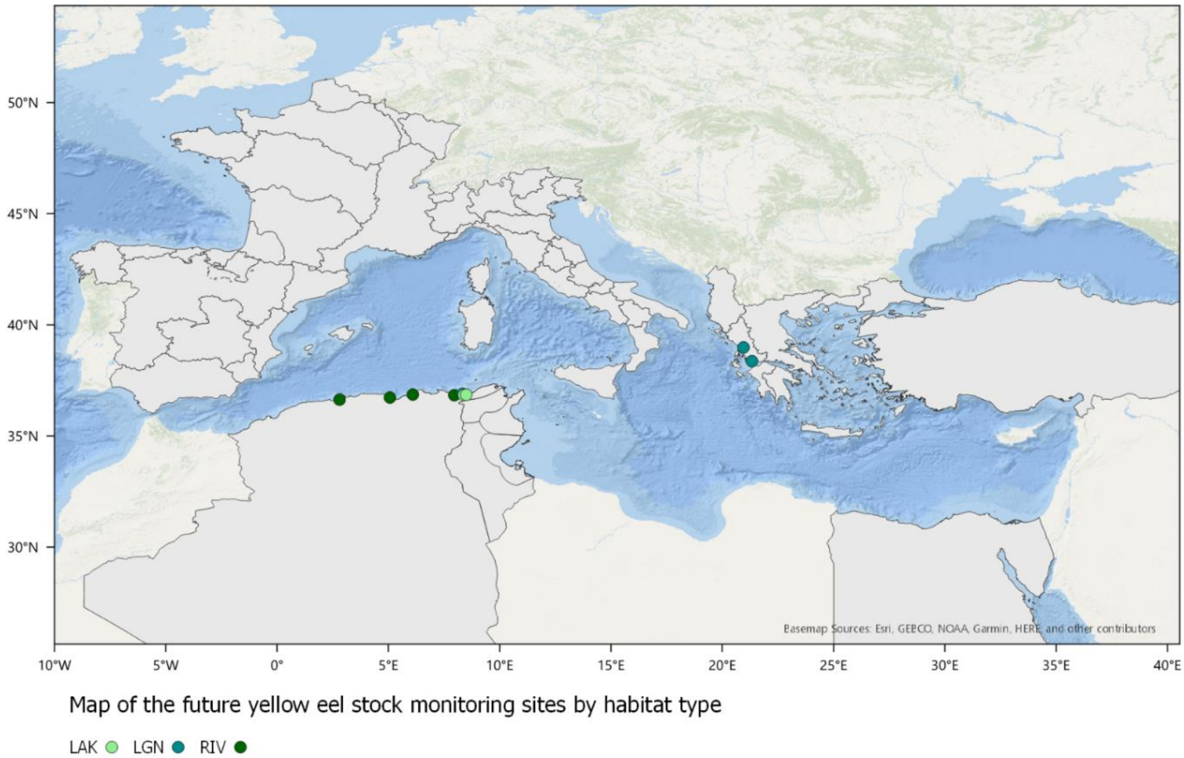

Figure 14.37. Location of the future yellow eel stock monitoring sites by habitat type in the

Mediterranean. Countries participating in the GFCM European eel research programme are highlighted in light grey. For France and Spain, electrofishing networks and SUDOANG data have not been shown.

Time coverage for yellow eel stock monitoring

The monitoring time period ranged from three years in Greece, Italy and Spain to 29 years in Vaccarès lagoon and Fumemorte canal in France (Table 14.31).

Long-term monitoring programmes were all ongoing and only being carried out in France and Italy (Table 14.31). In France, the two monitoring programmes mentioned above started in 1993 (29 years). However, both programmes have one year is missing (1994 for Funemorte canal and 2017 for Beaucaire dam) due to equipment malfunctions. In France, monitoring programmes were also set up in 2008 (13 years) at Beaucaire dam and in 2012 (ten years) at Avignon and Mallemort dams. In Italy, Sardinian lagoons (Calich, Cabras, Porto Pino, Sa Praia and Tortoli) have been monitored since 2012 (ten years).

The other ongoing monitoring programmes last from three to eight years and were reported in Greece (three years in Vistonida lagoon), Italy (five years in Tevere river and Fogliano lagoon, three years in Orbetello, Marano and Grado lagoons, three years in Po di Volano and Po di Goro estuaries) and Spain (four years in Guadarranque river and three years in Palmones, Guadalorce and Ter rivers).

Past monitoring programmes, ranged from three to eight years and were reported from Algeria (eight years in Tonga lake, five years in Oubiera lake, four years in Mellah lagoon and Mafragh river) and Italy (five years in Tevere river and Fogliano lagoon, four years in Comacchio, three years in Marta and Garigliano rivers, and Lesina lagoon) (Table 14.31).

Monitoring attempts were reported from Algeria in Mellah lagoon (2013–2014) and from Soummam river (2012–2013) as well as from France in Bages-Sigean lagoon (2019–2020).

Future monitoring programmes have been planned in Algeria, Greece, Italy, Spain and Türkiye. In Algeria future monitoring for yellow eels is planned for 2022 until 2025 (three years), in at least one site from eight potential sites (Table 14.30). Greece plans to start two monitoring programmes in 2022 under the EU-MAP framework, while Türkiye is planning future monitoring from 2022 to 2025 (three years).

Table 14.31. Time coverage for long-term monitoring of yellow eel stocks (black hatched), present monitoring (black), past monitoring (light grey) and monitoring attempts (dark grey). * Indicates that the protocol changed. (Habitat: LAK = lake, LGN = lagoon, RIE = estuary, RIV = river)

Country	Habitat	Site name	1993	###	1995	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Algeria	Lak	Toga																		
		Oubiera																		
	LGN	Mellah																		
	RIE_riv	Mafragh																		
		Soummam																		
France	RIE_can	Canal de Fumemorte																		
	RIE_lgn	Vaccarès Capelière																		
	RIV	Beaucaire, Rhône																		
		Avignon, Rhône																		
		Mallemort, Rhône																		
	LGN	Bages-Sigean																		
Greece	LGN	Vistonida lake																		
Italy	RIE_riv	Garigliano																		
		Po di Volano																		
		Po di Goro																		
		Tevere																		
		Marta																		
	LGN	Lesina																		
		Calich																		
		Cabras																		
		Porto Pino																		
		Sa Praia																		
		Tortoli																		
		Marano																*		
		Grado																		
		Marano																		
		Orbetello																		
		Comacchio																		
	RIE_lgn	Fogliano																		
		Marano																		
		Grado																		
Spain	RIV	Palmones																		
		Guadalorce																		
		Ter																		
		Guadarranque																		

Methods used for yellow eel stock monitoring

General overview

Four methods were recorded to monitor yellow eel stocks, fyke nets in France, Greece, Italy and Spain, electrofishing in France, Italy and Spain, fish pass traps in France and enclosures in France and Italy (Figure 14.39 and Figure 14.40). A description by habitat type is presented Table 14.32, Table 14.33 and Figure 14.38. Fyke nets were the most commonly used method as it was reported as being used in ten lagoons and six rivers. The duration of the monitoring programmes and the frequency of capture were different between methods and sites (Table 14.33).

Table 14.32. Different methods used for the current yellow eel stock monitoring programmes by habitat type in the nine partner countries. (N: represents several stations monitored by the French electrofishing network.)

Methods	Countries using the method	Number of river sites monitored	Number of lagoon sites monitored	Number of lake sites monitored	Total number of sites monitored
Fyke nets	France, Greece, Italy, Spain	6	10		16

Fish pass trap	France	1			1
Enclosure	Italy		2		2
Electrofishing	Spain, France	1+N			1+N
Electrofishing + fyke nets	Italy		2		2
Total		***8+N****	***14***	***0***	***22+N***

Table 14.33. Different methods used for past yellow eel stock monitoring programmes and monitoring attempts by habitat type in the nine partner countries. (*two lagoon channels (RIE habitat) were monitored using electrofishing in Italy.)

Methods	**Countries using the method**	**Number of river sites monitored**	**Number of lagoon sites monitored**	**Number of lake sites monitored**	**Total number of sites monitored**
Fyke nets	Algeria, Italy	5	3	2	10
Enclosure	France, Italy		2		2
Total		***5***	***5***	***2***	***12***

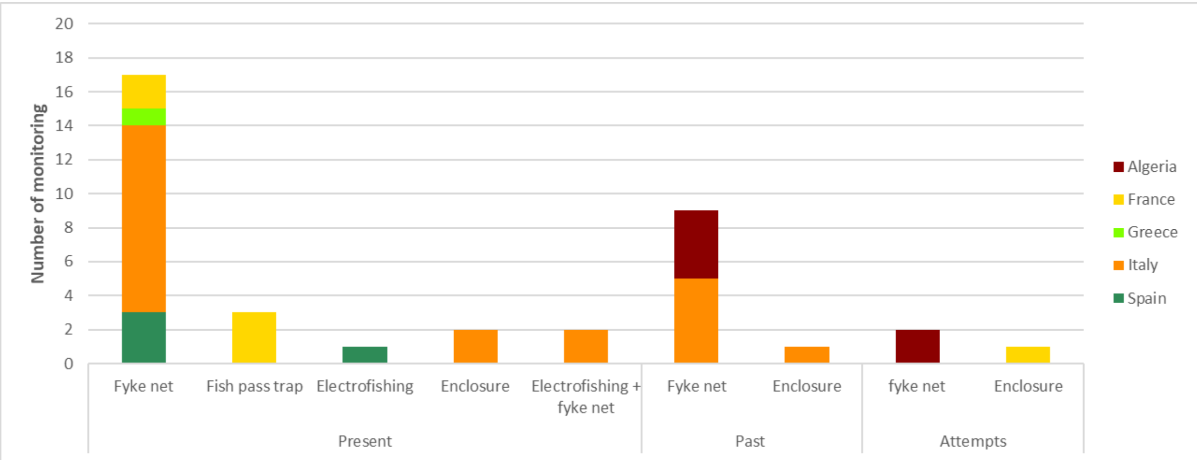

Figure 14.38. Methods used for present and past yellow eel stock monitoring and monitoring attempts by partner country. The ongoing French electrofishing network is not shown.

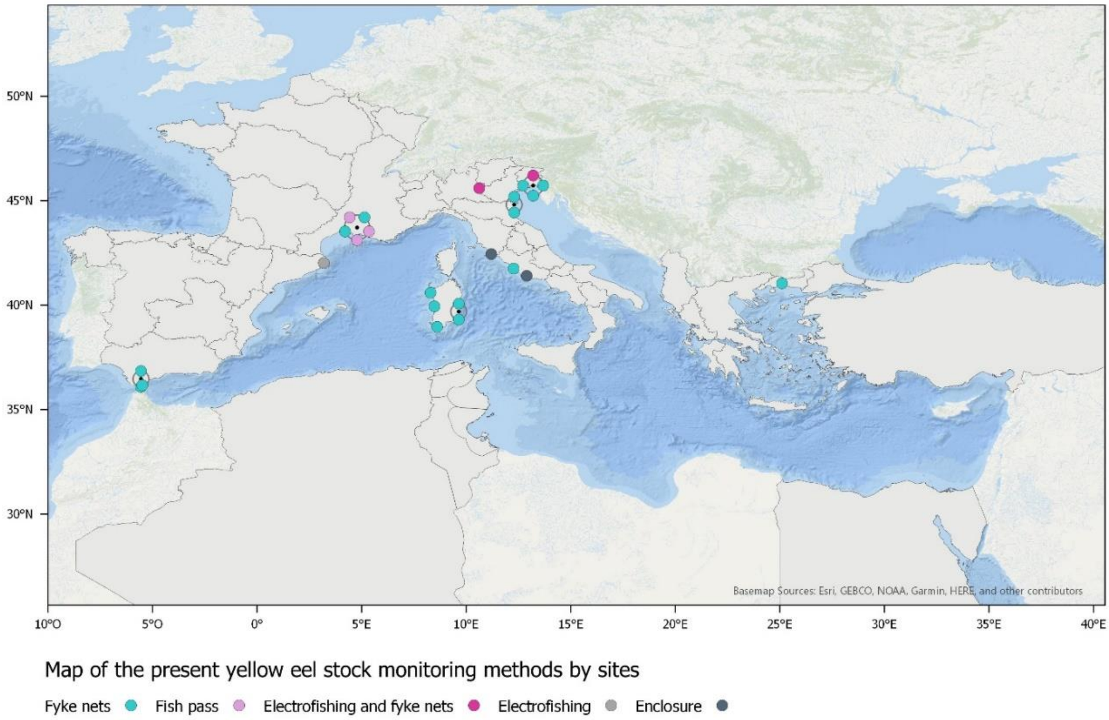

Figure 14.39. Location of the present yellow eel stock monitoring methods used in the Mediterranean. Countries participating in the GFCM European eel research programme are highlighted in light grey.

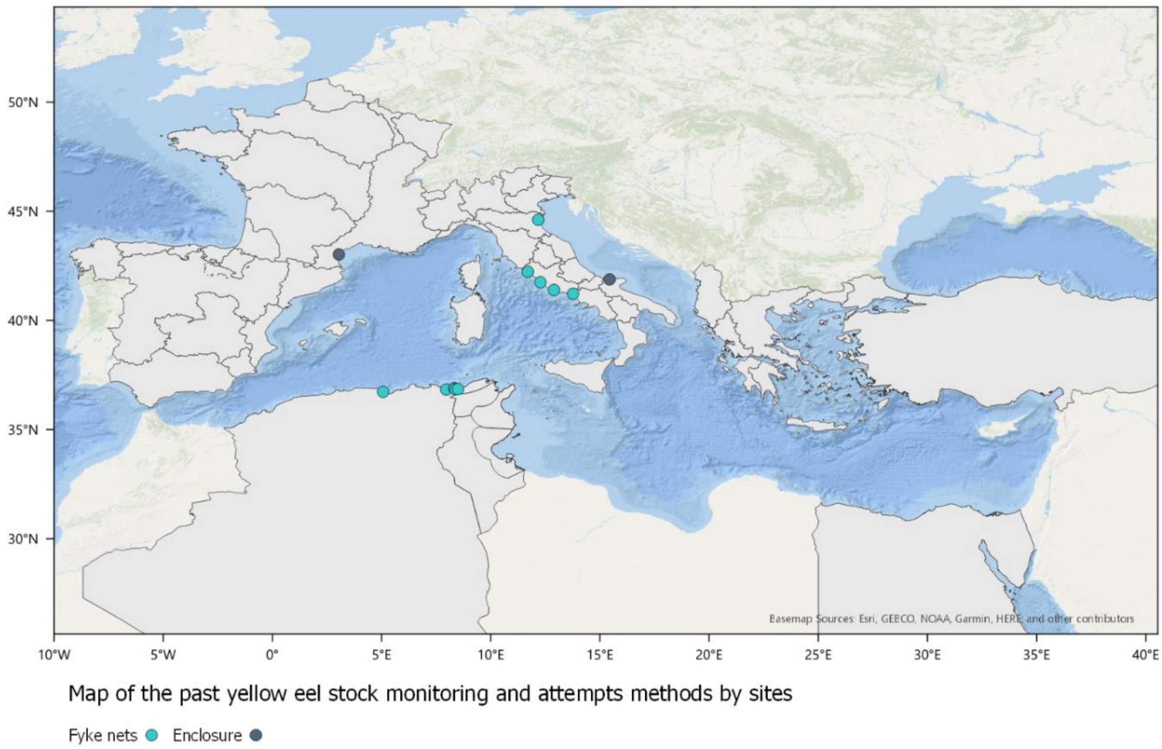

Figure 14.40. Location of past yellow eel stock monitoring programmes and monitoring attempts by methods used in the Mediterranean. Countries participating in the GFCM European eel research programme are highlighted in light grey.

Table 14.34. Details of the methods used in present and past yellow eel stock monitoring programmes and monitoring attempts (months monitored: dots show the missing data and light grey indicates that the monitoring last two months between April and October. Total Days: total number of days in the year monitored. Nb Gear: number of gears used for each monitoring or attempt. Mesh size: in mm. NC: not collected. Habitat: RIV = river, LGN = lagoon, LAK = lake)

Method	Months monitored (Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb)	Frequency	Total days	Nb gear	Mesh size	Site	Habitat
Electrofishing		1 data collection/year	NC	NC	NC	Ter	RIV
Electrofishing + fyke net		2 samples/year/station	NC	NC	NC	Grado	LGN
						Marano	LGN
Enclosure	2 months bwt. Apr. and Oct.	1week /month	14	NC	NC	Fogliano	LGN
		every day during the period	NC	NC	NC	Bages Sigean	LGN
		1 week/month	49	NC	12	Lesina Acquarotta	LGN
						Orbetello	LGN
Fish pass trap		2 at 3 times/week	360	NC	NC	Mallemort	RIV
		2 to 5 times/week	240	NC	NC	Beaucaire	RIV
		3 at 5 times/week	240	NC	NC	Avignon	RIV
Fyke net	2 months bwt. Apr. and Oct.	1week/month	14	2	NC	Fogliano	LGN
	2 months bwt. Apr. and Oct.			20	NC	Marta	RIV
	2 months bwt. Apr. and Oct.			20	NC	Tivere	RIV
	2 months bwt. Apr. and Oct.			30	NC	Tivere	RIV
	10 days per season	daily or every 2 days 10 days/season	40	4	NC	Cabras	LGN
	10 days per season					Calich	LGN
	10 days per season					Porto Pino	LGN
	10 days per season					Sa Praia	LGN
	10 days per season					Tortoli	LGN
		4 days consecutive/month	48	NC	6	Camargue Canal Fumemorte	LGN
		1 week/month	49	20	NC	Garigliano	RIV
						Po di Goro	RIV
						Po di Volano	RIV
		10 days/period	30	25	13 to 16	Marano	LGN
		1 week (every 2 days or once a week) /6 months period / station (15 stations)	7	20	NC	Vistonida	LGN
		NC	NC	NC	10	Mafragh	RIV
						Mellah	LGN
						Oubeira	LAK
						Soummam	RIV
						Tonga	LAK
		4 days/month	24	1	8	Vaccarès Capelière	LGN
		1 time/year (48h catch)	1	20	7 to 10	Guadalorce	RIV
						Guadarranque	RIV
						Palmones	RIV
		2 days / week	NC	NC	NC	Comacchio	LGN
		NC	NC	NC	NC	Grado	LGN
						Marano	LGN

Fyke nets

This is the same method that was used for silver eel monitoring and the fyke nets used in Italy are the same. Advantages and limitations are the same as presented in the section on glass eel recruitment (Table 14.12).

Fish pass trap

The fish pass traps used to capture yellow eels are the same as those used for glass eels. France is the only country that used this method at three fish passes on the Rhône river and its tributaries at Beaucaire, Avignon and Mallemort dams. Elvers were captured during the colonisation phase. The minimum average eel length was 110 mm and the maximum average length was 245 mm between 2012 and 2020 (WP3 data, from MRM data). The advantages and limitations are similar to those described for glass eel recruitment monitoring (Table 14.14). This method is particularly well suited to following the colonisation and dispersal phases of yellow eels in rivers with migration obstacles, as well as to gather information on their biometric characteristics.

Enclosures

The enclosure system (Figure 14.41) is a boundary net arranged in a 100 m × 100 m square that encloses an area of one hectare. Inside the enclosure, there are rows of fyke nets to trap the enclosed eels. Italy is the only country that used this method to monitor yellow eel stocks at Orbetello, Lesina and Fogliano lagoons. The boundary net had a mesh size of 12 mm. The fyke nets set in the enclosed area were 16–20 in number, 80 cm to100 cm in height, and two metres to three metres in length with two or three chambers, the innermost one having a mesh size ranging from seven mm to nine mm. There was a monitoring attempt in France at Bages Sigean lagoon that was not really successful because the eels were able to escape. Together with electrofishing, enclosure is the only method that gives a direct estimation of the yellow eel density. Contrary to electrofishing that can be only done in shallow waters and freshwater, the enclosure can be set up in deep, salty waters but with low flow velocity. One of the main limitations of the method is the possible escapement of eels outside the enclosure. Dorow *et al*. (2018) estimated that 42.8 percent of the individuals escaped the enclosure in 48 hours. As densities are calculated from a pass-removal experiment it is crucial to avoid the exit and entry of eels out of and into the enclosure. Another limitation is the dificulty of installing the structure which often requires help from professional fishers while enclosures are the difficult to build, transport and store.

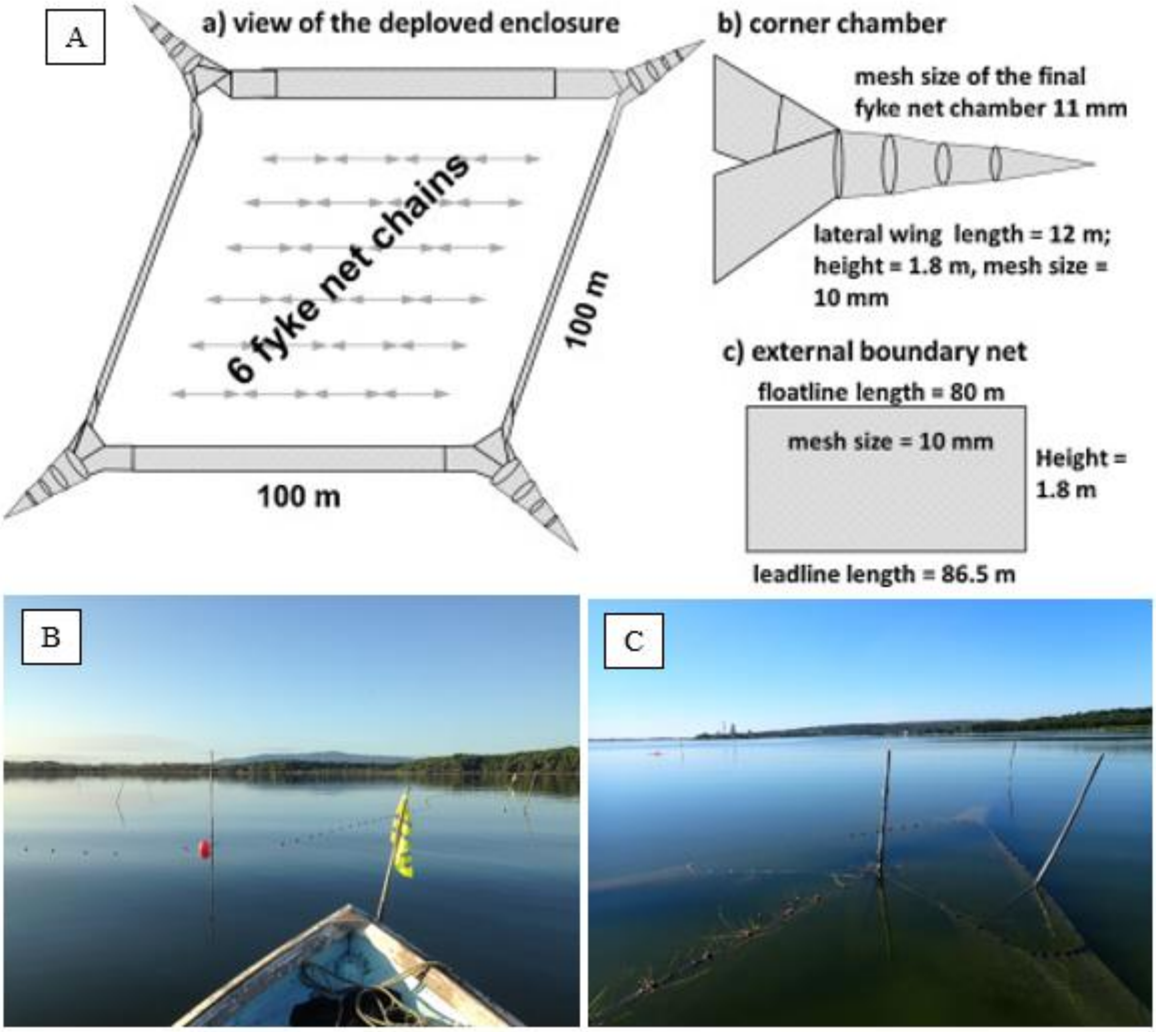

Figure 14.41. A) Enclosure from Ubl and Dorow (2015). B) General overview of the enclosure used in France. C) Focus on the enclosure corner used in France.

The advantages and limitations to the use of enclosures for yellow eel stock monitoring are shown in Table 14.35.

Table 14.35. Advantages and limitations of enclosures for yellow eel stock monitoring.

Advantages	Limits
• Allows estimation of yellow eel stock density • Method can be used in deep and brackish waters	• Eels escape from the enclosure • Equipment is hard to install and needs help from professional fishers • Can be expensive and difficult to build • Maintenance, storage and transport are difficult due to its volume

Electrofishing

Electrofishing is a sampling method based on the use of an electric current (circular anode) to immobilize and capture fish, including eels (Plate 6). It is only carried out in freshwater habitats, because in brackish water the current is too strong. For logistics, a minimum of four to six persons are necessary to operate the equipment, depending on the protocol. One person is in charge of the anode, one person is in charge of biometric measurements of captured eels and sampling times, while two persons are downstream with landing nets of different sizes and shapes to catch the immobilized eels. France, Italy and Spain use electrofishing to monitor yellow eel stocks and it is the most frequently used method in Europe to monitor ichtyofauna. Samples are reproducible and representative of the state of populations when the methods used remain constant over the years. However, there are several different methods, for example, by foot, by boat and with different types of curent generators, and protocols are not standardized, so results are difficult to compare. The main limitation is the logistics that necessite a minimum number of persons to carry out the survey safely.

Plate 14.6. Electrofishing method using a portable electrofisher (University of Cagliari, DISVA Sardinia, © A. Sabatini and C. Podda).

Advantages and limitations to the use of electrofishing for yellow eel stock monitoring are shown in Table 14.36.

Table 14.36. Advantages and limitations of electrofishing for yellow eel stock monitoring.

Advantages	Limitations
• Most used method in Europe to monitor ichthyofauna • Samples are reproducible and representative of population states when the methods are standardized • Depending on the protocol, it is possible to estimate densities and a quantitative estimation of the population in the site	• Only works in freshwater • People need to be trained to use the equipment • Dangerous if safety protocols are not followed • Equipment is expensive • Need at least four or six persons depending on the application • Efficiency depends on several parameters such as time the electrode is left in the water, water turbidity, mesh size of the net. Perhaps not efficient for very small individuals.

Electrofishing network and SUDOANG data in France and Spain

In France, monitoring by electrofishing in rivers has been operating since 1981 (40 years data). These monitoring programmes provide data on eel densities in the main rivers and cover a total of 58 drainage basins in the Mediterranean. Several networks were created (RHP, RCS, RRP, RCO) that are characterized by different protocols and frequencies of data collection (every two or three years). To complete these networks and under the needs of the French EMP, an eel specific network (RSA) was established. It consists of electrofishing at about 300 sites less than 200 km from the sea (Additional Results Part II). Data are stored in the DBMAP database (ONEMA historical database) and the BD Agglo database (AFB database gathering data after 2012). These data are public and were used to run models to estimate the number of escaping silver eels for the EMP (Briand *et al*., 2022).

In Spain, electrofishing campaigns were also conducted in several regions (from 1988) but were not coordinated at the national level as had happened in France. Recently, the SUDOANG project gathered and used Spanish and French electrofishing data to estimate yellow eel standing stocks at basin, region and country level (Sudoang, 2021; Mateo *et al.*, 2021).

14.3.4. Summary of the monitoring of the three eel stages in the Mediterranean

Across past and present monitoring programmes, the glass eel stage was the most monitored with 42 monitoring programmes (19 ongoing). For yellow eel, 35 monitoring programmes were recorded (25 ongoing) without considering the French national electrofishing network and the Spanish electrofishing data collected by the SUDOANG project. Silver eel was the least monitored stage with 28 monitoring programmes (22 ongoing). The Fogliano and Orbetello lagoons and the Po and Tevere rivers are all in Italy and are the only sites where all stages are monitored simultaneously. Most of the monitoring programmes are located in the northern Mediterranean and carried out by EU countries (Table 14.37), while there is an important monitoring gap in the south-eastern Mediterranean. There were 23 ongoing monitoring programmes in lagoons, 13 in rivers and only one in lakes (Table 14.38). Silver eels were monitored mostly in lagoons (mostly in large lagoons with salinity above 18 ppt). Glass eel recruitment was monitored mostly in rivers (particularly in large rivers), and yellow eel stocks were monitored both in rivers (large and medium sized) and lagoons (mostly large) (Table 14.38). Only one lake, Shkodra in Albania, has a monitoring programme at the present time, only for silver eel escapement. There is a general lack of long-term monitoring programmes. Only two sites for glass eel recruitment, five sites for silver eel escapement and ten sites for yellow eel stock have long-term programmes, covering only lagoon habitats for recruitment and escapement monitoring, and both lagoon and river habitats for yellow eel stocks.

A literature search was carried out for information from other Mediterranean countries not participating to the GFCM eel research project, including Bosnia and Herzegovina, Croatia, Cyprus, Israel, Libya, Malta, Monaco, Montenegro, Morocco, Slovenia and the Syrian Arab Republic, but very limited data were found (Table 14.37). Monitoring surveys were recorded only for yellow eel stocks in five rivers in Croatia and one lagoon tidal channel, also in Croatia (Piria *et al.*, 2014), while in Cyprus there were long-term monitoring records from 26 rivers (Griffiths *et al.*, 2021) . Monitoring attempts took place in Umm Hufayan lagoon in Libya for glass eel recruitment and silver eel escapement (Abdalhamid *et al.*, 2018). Monitoring attempts for yellow eel were carried out in Neretva river, between Bosnia-Herzegovina and Croatia (Glamuzina and Dobroslavić, 2020), in 18 Cypriot rivers (Zogaris *et al.*, 2012) and in Umm Hufayan lagoon in Libya (Abdalhamid *et al.*, 2018).

A large variety of methodologies with different types of gear, gear characteristics, sampling frequencies and sampling periods were observed that were not homogenous at the country or Mediterranean level. Deeper analyses are required to ensure the scientific quality of the data collected and evaluate their potential use to determine Mediterranean indicators for recruitment, escapement and yellow eel stock on a long-term basis. Fyke nets and related gear types were the most common gears used to carry out monitoring for glass eels, yellow eels and silver eels. They are also some of the most common gears used in fisheries in the Mediterranean (Chapter 9 on fishing effort) and may be an interesting gear type to compare between countries to use as a common method.

It would also be useful to display the information from all the Mediterranean ongoing monitoring programmes, for all eel life stages, on an updated web platform where records could be maintained of monitoring sites, descriptions of the methods used, duration of monitoring programmes and the results. These data could be added to the existing platforms such as those managed by ICES that currently display information from most of the Atlantic and northern European eel monitoring programmes but only a few of the Mediterranean monitoring programmes or the Migratory Fish Observatory of the Rhône Mediterranean Basin (https://www.observatoire-rhonemediterranee.fr/).

Table 14.37. Summary of ongoing scientific monitoring reported in all Mediterranean countries. Grey cells indicate GFCM partner countries. (Bold indicates the presence of long-term monitoring [ten years minimum]. The number in brackets indicates the number of sites monitored in each habitat. EN: electrofishing network. (LAK=lake, LGN=lagoon, RIV=river. Country names ordered from north to south.)

Country	Recruitment	Escapement	Yellow stock
Spain	RIV (1) LGN (1)		RIV (4)
France	**RIV (1)** **LGN (2)**	LGN (1)	**RIV (1 + EN)** **LGN (1)**
Monaco			
Italy	RIV (8) LGN (3)	RIV (2) **LGN (8)**	RIV (2) **LGN (10)**
Malta			
Slovenia			
Croatia			RIV (5)
Bosnia-Herzegovina			
Montenegro			
Albania		LAK (1) LGN (9)	
Greece			LGN (1)

Türkiye			
Cyprus			**RIV (26)**
Syria			
Lebanon			
Israel			
Egypt			
Lybia			
Tunisia			
Algeria			
Morocco			

Table 14.38. Summary of the number of reported ongoing monitoring programmes (glass eel recruitment, yellow eel stocks and silver eel escapement) in the different habitat types. Habitats are categorised by their average annual flow (AF) for rivers, surface (S) and salinity (Sal) for lagoons, and ecoregion type (latitude) for lakes. For rivers: AF>10 m^3s^{-1}: large, 2<AF<10: medium, 0.3<AF<2: stable stream, AF<0.3: seasonal stream. For lagoons: S<0.5km^2: small, 0.5<S<2.5 km^2: medium, >2.5 km^2: large; 0,5<Sal<5: oligohaline, 5<Sal<18: mesohaline, 18<Sal<30: polyhaline, 30<Sal<40: euhaline, Sal>40: hyperhaline. For lakes: LAT ≥44'00 N: Alpine, LAT <44'00 N: Mediterranean.

				Number of monitoring sites		
Habitat	Typology	Salinity	Number of sites with at least one monitoring programme	Glass	Yellow	Silver
River			13	9	7	2
	large		6	4	5	2
	medium		4	2	2	
	seasonal stream		1	1		
	stable stream		2	2		
Lagoon			23	6	11	18
	large	hyperhaline	3	1	1	2
		euhaline	7	3	4	5
		polyhaline	5		1	4
		mesohaline	2	1	2	1
	medium	hyperhaline	1			1
		euhaline	2		2	2
		polyhaline	2	1	1	2
	small	Poly/euhaline	1			1
Lake			1			1
	Mediterranean					1

14.4. DISCUSSION AND CONCLUSIONS

14.4.1. Overview of frameworks used for scientific monitoring

Different kinds of frameworks can support eel monitoring. Under the "Eel Regulation" (Council Regulation (EC) No 1100/2007) framework, each member state has to provide the best available estimates of: (a) the proportion of the silver eel biomass that escapes to the sea to spawn, or (b) the proportion of the silver eel biomass leaving the territory of that member state as part of a seaward migration to spawn, relative to the target level of escapement (at least 40 percent of the silver eel biomass relative to the best estimate of historic escapement that would have existed if no anthropogenic influences had impacted the stock). Under the DCF EU-MAP (Reg. 199/2008; EC Decision C (2016) 8906 – 12/19/2016) framework, member states must collect data on eels annually in at least one river basin by EMU on glass eel abundance, yellow eel stock and silver eel escapement abundance, weight and sex ratio. Other frameworks can be national, regional or local.

Considering the fishery independent monitoring reported in this work, only a few frameworks were linked to monitoring programmes being carried out by partner countries and most of these were linked to EU regulations. Italy reported 22 ongoing monitoring programmes and Spain reported six programmes under the regional EMP framework (derived from the Eel Regulation, Council Regulation (EC) No 1100/2007). Four countries reported monitoring under the DCF EU-MAP framework: France (one monitoring programme for glass eels), Greece (one yellow eel stock monitoring programme), Italy (nine monitoring programmes, for all three stages) and Spain (two monitoring programmes for glass eels and four for yellow eel stocks). Albania was the only non-EU-country to have monitoring (silver eel escapement) incentivized by the EU Eel Regulation (Council Regulation (EC) No 1100/2007) and the GFCM recommendation (GFCM/42/2018/1). French monitoring programmes (one each for glass eels, yellow eel stocks and silver eel escapement) were indirectly linked to the Regional EMP (which derives from the EU Eel Regulation) via the PLAGEPOMI, a regional action plan for the sustainable management of migratory fish species. In Spain, three yellow eel monitoring programmes were recorded under a regional framework.

As the DCF Regulation obliges EU member states to collect data on glass eel recruitment, silver eel escapement and yellow eel stocks and the EU can provide financial support for these data collection programmes, other EU countries should evaluate the opportunity to start new monitoring activities or maintain existing programmes through this framework.

14.4.2 Proposal for long-term monitoring in the Mediterranean Sea

Proposal for potential key sites

One objective of the GFCM eel project was to define a long-term monitoring framework at the Mediterranean scale. A way to achieve this is to first identify key sites allowing balanced coverage of Mediterranean eel habitats to give a good overview of the status of eel stocks in the region. Then, it is necessary to define adapted and reliable monitoring methods for each life stage and habitat type. For countries willing to start new monitoring programmes, the silver eel stage should receive special attention because it includes all the mortalities through previous life stages. Increasing the number and biomass of silver eels migrating to sea is a key point for stock recovery as well as being one of the main objectives of the EU Eel Regulation.

There is the need to continue operating or establishing monitoring in a network of key sites, in order to follow, in the long term, the evolution of glass eel recruitment, silver eel escapement and yellow eel stocks in the Mediterranean. Such a network needs to include all the different eel habitats, distributed in such a way as to cover the different areas of the Mediterranean.

Two categories of potential key sites can be distinguished:

- Sites where monitoring already exists, with long or short time-series data available and where repeatable and consistent methodologies have been used.
- Sites proposed by data providers to start new monitoring programmes in order to fill information gaps.

Sites with long or medium-term monitoring already in place

Sites where historical long-time series data are available (at least ten years of data) and monitoring is still ongoing should be considered as key sites (Figure 14.42, Figure 14.35 and Figure 14.36). Data collection protocols are well established at these sites and they provide precious data for trend analysis. These seven key sites are as follows:

- Vaccarès lagoon in France has been monitored since 1993 for glass eel recruitment and yellow eel stocks.
- The five Italian lagoons (in Sardinia) Calich, Cabras, Porto Pino Sa Praia and Tortoli have been monitored since 2012 for escapement of silver eels and yellow eel stocks.
- The Rhône river in France has been monitored since 2008 for yellow eel stocks.
- French and Spanish river stations have been monitored by electrofishing for more than ten years should also be considered as key sites. While they are too numerous to be cited here, they are listed on the SUDOANG project web site (Sudoang, 2021).

Another interesting site that could be selected as a key site is the Guadalquivir river in Spain (Figure 14.42). Although it is not directly in the Mediterranean Sea, it records recruitment at its entrance, on the Atlantic side, next to the Strait of Gibraltar. Glass eel recruitment has been monitored (with nets from an anchored boat) in the estuary since 1997 (25 years) and is providing precious information on the trend at the entrance of the Mediterranean Sea, while also providing information on the western part of the region that is currently not covered.

As only a few sites have recorded ten years of data, it seems sensible to consider sites that already have four years of data as potential key sites (Figure 14.42, Figure 14.43 and Figure 14.44). These 13 sites are as follows:

- The Tevere river and Fogliano lagoon in Italy has been monitored for glass eel recruitment since 2013, silver eel escapement since 2017 and yellow eel stocks since 2017. These two sites are particularly interesting as the three eel stages have been monitored at the same time and could give better understanding of population dynamics, in the long term.
- The Marta river (Italy) has been monitored for glass eel recruitment since 2013.
- Comacchio lagoon (Italy) has been monitored for silver eel escapement since 2013.
- Marano lagoon (Italy) has been monitored since 2014 for yellow eel stocks.
- Chia, Coghinas, Pesaria, Pramaera rivers and Calich lagoon in Sardinia Island (Italy) have been monitored since 2017 for glass eel recruitment.
- In France, the Bages Sigean lagoon has been monitored since 2018 for glass eel recruitment and silver eel escapement.
- In Spain, the Ter river has been monitored for glass eel recruitment since 2018 and the Guadarranque river has been monitored for yellow eel stocks since 2013.

In Italy, pilot studies to monitor the three eel stages have been implemented under the DCF-EU-MAP framework on the Po river delta (Po di Volano and Po di Goro) and Orbetello lagoon. These monitoring programmes will at least be repeated during the new EU MAP phase 2022–2026 and should therefore be considered as key sites.

Additionally, sites where permanent structures are already in place should be considered as interesting key sites as they can often provide data on the total catch of the moving individual eels. For example, fish pass traps in France or fixed barriers in Albania, Greece, Italy and Türkiye.

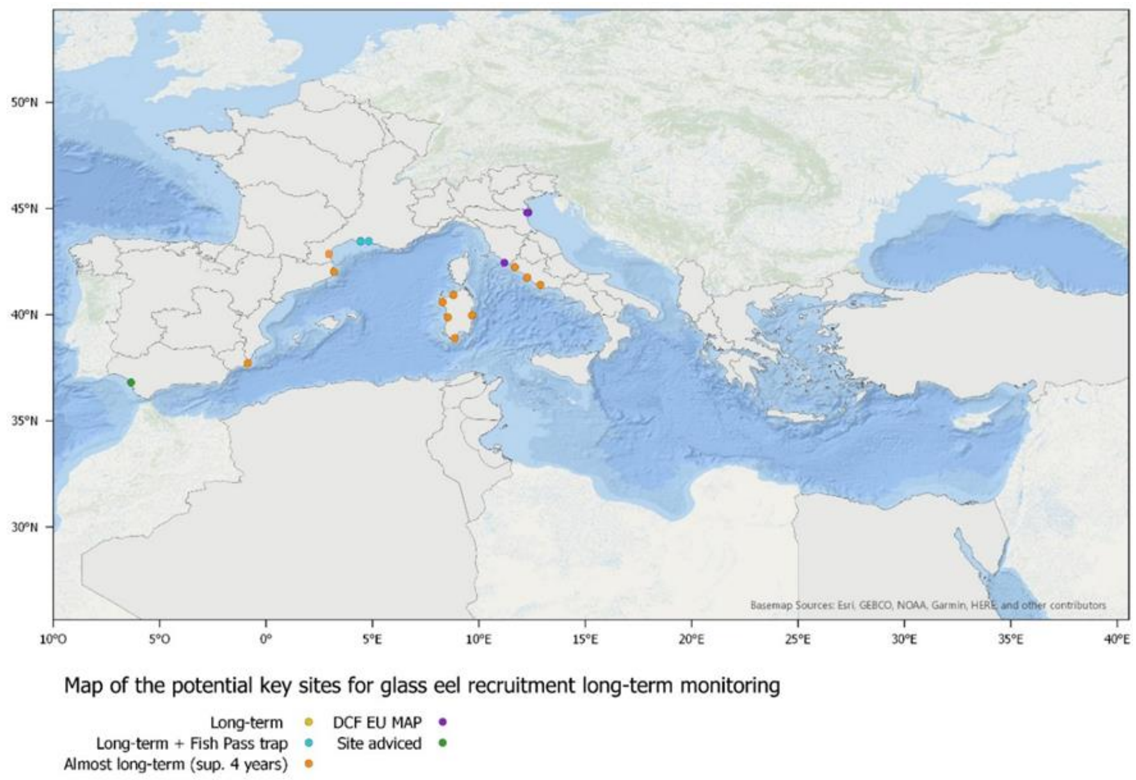

Figure 14.42. Location of potential key sites for glass eel recruitment long-term monitoring.

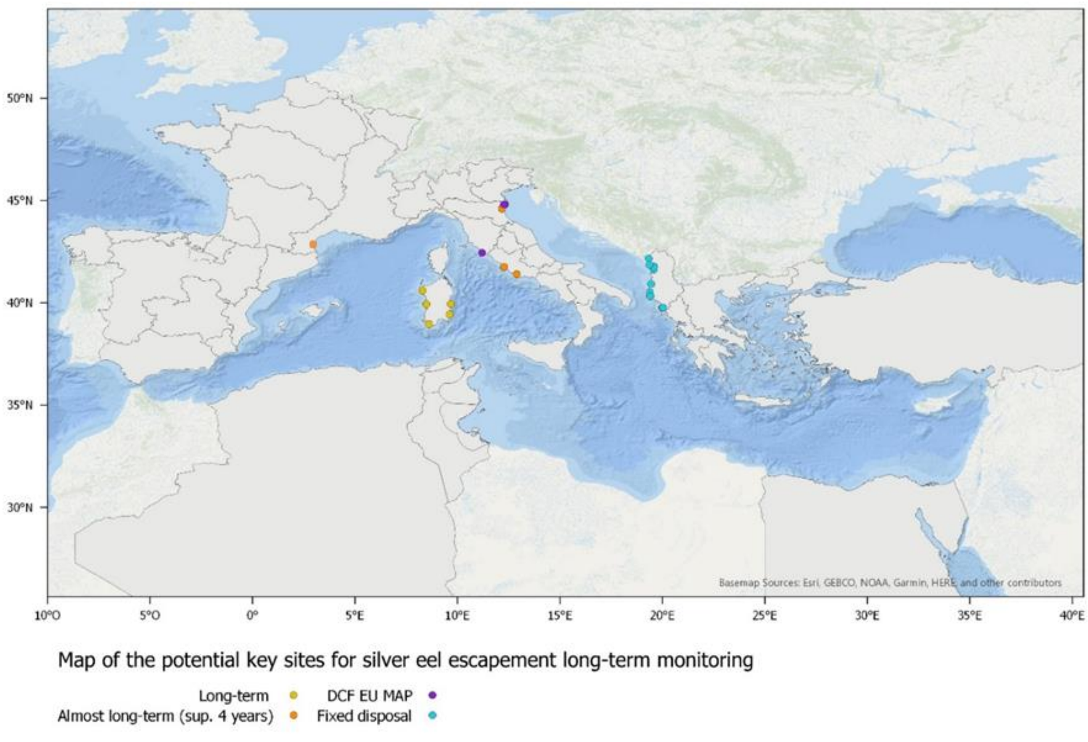

Figure 14.43. Location of potential key sites for silver eel escapement long-term monitoring.

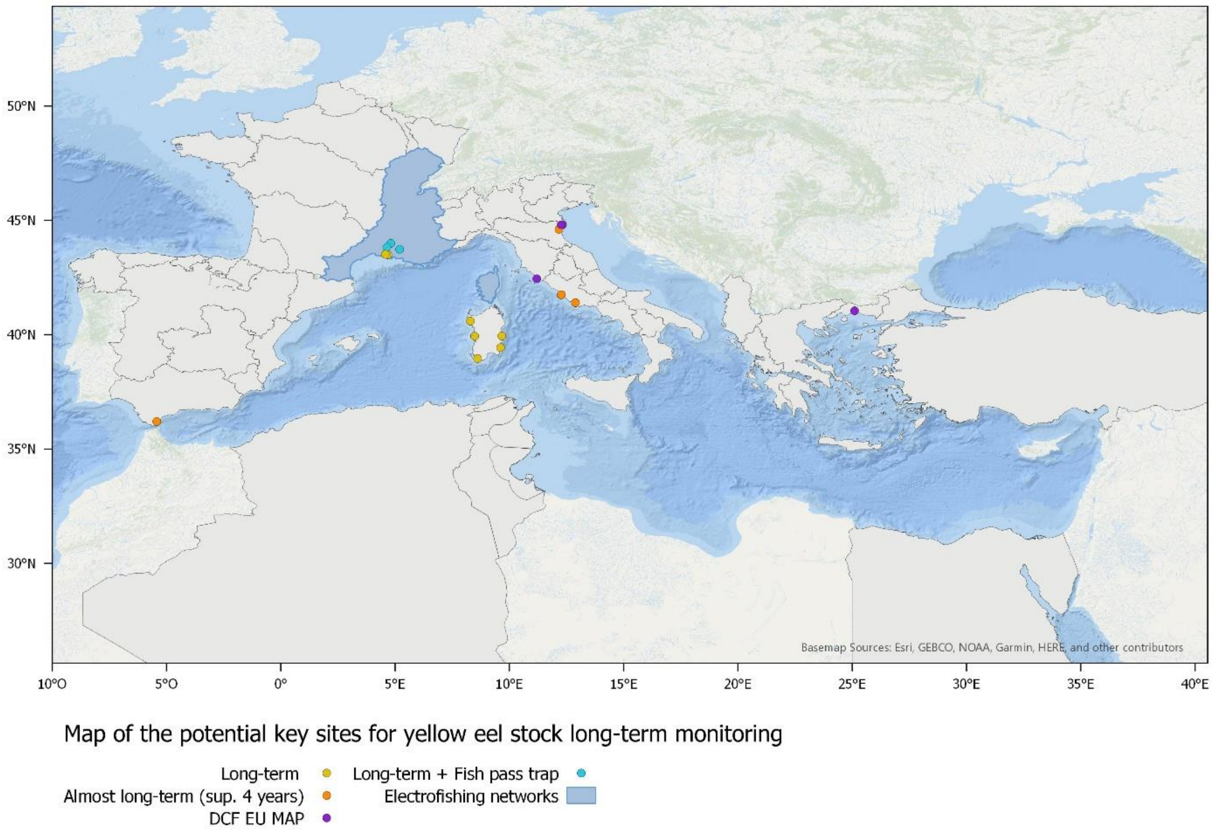

Figure 14.44. Location of potential key sites for yellow eel stock long-term monitoring.

The classification of the habitats based on simple criteria (Chapter 1) was used to try to identify missing or under-represented habitat categories at the Mediterranean region scale (Table 14.39). Rivers have been categorised based on their annual average flow (large, medium, stable, seasonal); lagoons based on their surface area (small, medium, large) and their salinity (oligohaline, mesohaline polyhaline, euhaline, hyperhaline) and lakes based on their ecoregion type (alpine or Mediterranean). Unfortunately, descriptive criteria were missing (ND) for many sites (Table 14.39), especially for rivers (49 percent) and lagoons (41 percent). Results must therefore be considered with caution. Some sites, especially in the lake habitat category may not be viable eel habitats, while ongoing monitoring programmes represent a small proportion of the reported rivers (8.2 percent), lagoons (8.4 percent) and lakes (0.8 percent). The under-represented habitats seem to be the stable streams (seven percent), medium-sized, euhaline lagoons (seven percent), small, hyperhaline lagoons (zero percent), small euhaline lagoons (11 percent) and lakes in general (0.8 percent).

Table 14.39. Comparison of the habitats monitored at present with the available habitats at the Mediterranean Region (based on WP3 habitats database). Habitats are categorised following values of average annual flow (AF) for rivers (RIV), surface (S) and salinity (Sal) for lagoons (LGN), and ecoregion type for lakes (LAK). For rivers: AF>10 m^3s^{-1}: large, 2<AF<10: medium, 0.3<AF<2: stable stream, AF<0.3: seasonal stream. For lagoons: S<0.5km^2: small, 0.5<S<2.5 km^2: medium, >2.5 km^2 :large; 0,5<Sal<5: oligohaline, 5<Sal<18: mesohaline, 18<Sal<30: polyhaline, 30<Sal<40: euhaline, Sal>40: hyperhaline. For lakes: LAT ≥44'00 N: Alpine, LAT <44'00 N: Mediterranean. Glass eel recruitment (G), yellow eel stock (Y) and silver eel escapement (S) monitoring are indicated in numbers (Nb.) and in percentages (%) of represented habitat.

			Total No. of sites (wp3)	No. site with at least one monitoring	Proportion of sites with at least one monitoring (percent)	No. of glass eel	No. of yellow eel	No. of silver eel	G (percent)	Y (percent)	S (percent)
Rivers			**158**	**13**	**8.2**						
	large		21	6	28.6	4	5	2	19.0	23.8	9.5
	medium		24	4	16.7	2	2		8.3	8.3	
	stable		30	2	6.7	2			6.7		
	seasonal		5	1	20.0	1			20.0		
	ND		78								
Lagoons			**274**	**28**	**10.2**						
	large		**150**	**17**	**11.3**						
		hyperhaline	8	3	37.5	1	1	2	12.5	12.5	25.0
		euhaline	40	7	17.5	3	4	5	7.5	10.0	12.5
		polyhaline	17	5	29.4		1	4		5.9	23.5
		mesohaline	13	2	15.4	1	2	1	7.7	15.4	7.7
		oligohaline	6								
		freshwater	1								
		ND	65								
	medium		**71**	**5**	**7.0**						
		hyperhaline	4	1	25.0			1			25.0
		euhaline	29	2	6.9		2	2		6.9	6.9
		polyhaline	9	2	22.2	1	1	2	11.1	11.1	22.2
		mesohaline	5								
		oligohaline	2								
		ND	22								
	small		**24**	**2**	**8.3**						
		hyperhaline	8								
		euhaline	9	1	11.1						
		polyhaline	5	1	20.0						
		mesohaline	3								
		oligohaline	1								
		ND	24					1			4.2
	ND	ND	2								
		polyhaline	1								
Lakes			**125**	**1**	**0.8**						
	Alpine		50								
	Med		75	1	1.3			1			1.3

Potential key sites to start new long-term monitoring programmes

Sites where new long-term monitoring could start, need to fill the information gaps at the Mediterranean scale. Spatially, the most important information gap concerns the south and east of the Mediterranean and lake habitats. Other important factors need to be taken into consideration. Selected sites need to be permanently accessible for eels, so habitats such as lagoons or rivers that naturally lose access to the sea each year should be avoided. Sites with obstacles to migration, such as dams on rivers or gates at lagoon entrances, to regulate the connection to the sea, should also be avoided, unless it allows the installation of a fish pass trap that helps monitoring of migration patterns. Where possible, it would be very valuable to monitor all three eel stages at the same site, allowing a better understanding of population dynamics under the same environmental conditions and such sites should be prioritised. Considering that the most common gear used to monitor glass eel recruitment are fyke nets, rivers with high water discharges should be avoided as they are not compatible with this method. Habitats known to have high glass eel recruitment could be prioritised as it will be easier to capture the eels and therefore implement the monitoring programme. Natural rivers and sites without human interventions are also interesting as they may represent pristine habitats for eel.

Figure 14.45 illustrates potential key sites for future monitoring programmes. Algeria identified six sites, Tonga lake, Oubiera lake, Mellah lagoon, Mafragh river, El-Kebir river and Mazafran river, where glass eel recruitment, silver eel escapement and yellow eel stocks could be monitored at the same time. They also proposed monitoring in Agerioun river (glass eel recruitment) and Soumman river (glass eel recruitment and yellow eel stocks). All sites in Algeria and particularly Tonga and Oubiera lakes are interesting key sites as they could fill the information gaps in the southern Mediterranean as well as lake habitats.

Monitoring in Türkiye would also be strategic and valuable as it would provide information for the eastern Mediterranean, where there is currently a lack of information. In 2021, some data were collected from two lagoons and a lake but need to be evaluated. These sites and others that will be tested in 2022, could be potential key sites for future long-term monitoring.

In order to cover the Southern Adriatic, Lesina lagoon in Italy, where past monitoring programmes have been already carried out, could be an interesting site to monitor on a long-term basis for the three eel stages. In Greece, there are discussions with the universities to set up monitoring for all three eel stages on Amvrakikos and Messolonghi lagoons. There are also some other sites such as Kalamas river and Sagiada lagoon that seem interesting and may be tested for long-term glass eel monitoring. Although no sites have been proposed yet in Egypt and Tunisia, new monitoring programmes in these two countries would be strategic to fill the lack of information from the southern Mediterranean.

All the new sites that have been identified will need to be tested before deciding if they can be maintained on a long-term basis. Selection of the sites will depend on the trade-off between different factors including man-power needs and costs, cost of the installation and maintenance of the monitoring equipment, accessibility of the site, risk of vandalism and the potential to maintain the monitoring over the long-term, for example, by securing recurrent funding through an existing framework.

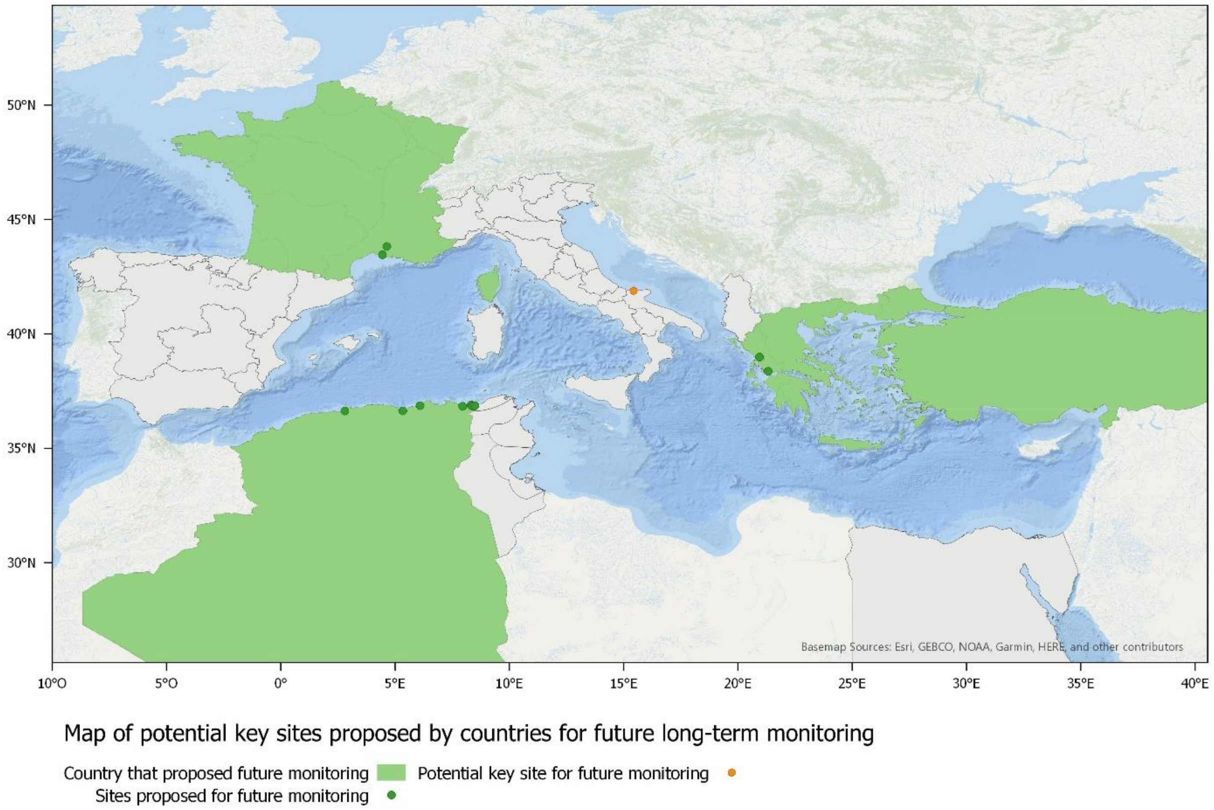

Figure 14.45. Location of potential key sites for future long-term monitoring (glass eel recruitment, silver eel escapement and yellow eel stock).

Proposal for common methodologies

Long-term monitoring programmes are used to follow a trend over time at site level. To be able to compare data between years, the methodology has to be consistent and identical over the years.

The monitoring methodology is based on the choice of:

- time period;
- frequency of collection or capturing eels;
- variables that will be recorded; and,
- methods to record these variables.

These parameters need to be carefully considered as the collected data need to reflect the annual quantity of glass eels being recruited, of silver eels escaping and the yellow eel stock in place in the studied habitat. A compromise must be reached between the cost of data collection and the time spent to ensure that the data is sufficiently representative.

The time period

The time period is a key parameter, especially for monitoring glass eel recruitment and silver eel escapement as they are seasonal phenomena, often occurring during peaks related to environmental and climatic parameters. If the monitoring is conducted during the wrong time period, the data will not be representative. Whenever possible, the ideal method would be to monitor the migrations over a full year before selecting the most representative and suitable months.

A recent ICES workshop on the temporal migration patterns of European eel (WKEELMIGRATION) produced a review (from available landings and monitoring series and literature) to determine the seasonality of glass eel arrival and silver eel departure (ICES, 2020b). This highlighted the complexity of glass eel arrival patterns in the Mediterranean compared to the Atlantic. Although arrivals can happen all year round, they mainly occur between December and March, with seasonal peaks depending on local climatic and environmental factors (Elie and Rochart, 1994; Kara and Quignard, 2019). Arrivals start in Spain in November–December and last until January–March with a peak in January (ICES, 2020b). Peaks were recorded in October and March in Ter river (Zamora and Costarrosa, 2019) and Bages Sigean lagoon (unpublished data) but slightly later in the east with higher recruitment between December and April in Vaccarès lagoon (Crivelli *et al.*, 2008), the Tevere (Ciccotti *et al.*, 1995) and the Pramaera rivers (Podda *et al.*, 2020). On the Atlantic side, it starts earlier in Morocco in September–October, compared with Spain, Portugal, and South France observed in November–December (Bruijs and Durif, 2009). Several parameters such as the water flow (Bureau Du Colombier *et al*., 2007), pollution state (Bolliet *et al*., 2017), temperature (Laffaille, Caraguel and Legault, 2007) and daylength (Bureau Du Colombier *et al*. 2007) are known to influence glass eel recruitment and therefore should be considered when selecting the monitoring period.

Table 14.40 summarises the monitoring periods recorded from the partner countries for glass eel (past, present monitoring and attempts). Various patterns can be observed making it difficult to provide advice on an exact period but November to March seems the most commonly used monitoring period in the studied sites. Monitoring can cover two to 12 months but most cover four to six months which seems a reasonable period to cover the main peaks. Comparable results were obtained from the analyses of all the available recruitment series with the main peaks occurring in the winter months December to March (Chapter 5 on recruitment). The final decision should take into account specific local conditions to cover the main arrival periods for glass eels.

Silver eel migration seasonality is related to the distance to the spawning ground (ICES, 2020b), starting earlier and extending for a longer period with increasing distance to the Sargasso Sea. Moreover, silver eel landings are also observed earlier and over an extended time-period in freshwater locations compared to those in coastal waters (ICES, 2020b). In Mediterranean coastal lagoons, the migration occurs between October and February with a peak mainly between December and January (ICES, 2020b). The escapement season in Tunisia at Ichkeul lake was observed mainly from October to February (Derouiche *et al*., 2016), in France in lagoons from October to January (Amilhat *et al*., 2008; Amilhat *et al*., 2014; pers. com. from the silver eel release programme), and in Albanian lagoons and lakes, from October to December (pers. com. from the silver eels release programme). In Umm Hufayan lagoon in Eastern Libya, migration occurs from October to the beginning of February (Abdalhamid *et al.*, 2018). Little is known about the migration dynamics in Mediterranean rivers and efforts should be undertaken to cover this information gap. Periods are often deduced from commercial fisheries and may not reflect the entire period of migration. Fishers concentrate their efforts during the peak periods when the catches are optimal. Therefore, fishery-independent monitoring programmes are important to understand the migration dynamics. From the monitoring programmes recorded in this project, the most common period was the three months October to December (Table 14.40) with some extending to March. As with the glass eel recruitment, it is essential to take into account specific characteristics of sites when selecting monitoring periods.

Table 14.40: Monitoring periods for the past, present monitoring and attempts recorded in the 9 partner countries. (Tot: total number of monitoring. Nb. Mo.: total number of months monitored. Dark grey indicates two months of monitoring in the seven month period. Dashed cells represent half month. Light grey represents possible extension of the monitoring. LGN = lagoon, LAK = lake, RIV = river)

					Months												
Glass eel recruitement	**LGN**	**LAK**	**RIV**	**Tot**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Nb Mo.**
fyke nets, Italy (East coast)			2	**2**													**2**
fyke nets, Italy (West coast)	1			**1**													**2**
fyke nets, Italy (East coast)			5	**5**													**3**
fyke nets, Italy (East coast in LGN and West Coast in RIV))	1		1	**1**													**3**
fish pass trap, Italy (West coast)	1			**1**													**3.5 and 2.5**
fyke nets, Italy (East coast)	2		1	**3**													**4**
fyke nets, France	2			**2**													**4**
fyke nets, Italy (West coast), Spain in LGN	4		9	**13**													**5**
fyke nets: Italy (6 LGN: East and West coasts), and Spain in RIV. Traps : France in one LGN	7		1	**8**													**6**
fish pass trap, France	1			**1**													**7**
fyke nets, France	1			**1**													**8**
fyke nets, France	1			**1**													**8**
fish pass trap in RIV France, fyke nets in Italy (Sardinia : 1 LGN and 4 RIV)	1		5	**6**													**12**
Silver eel escapement	**LGN**	**LAK**	**RIV**	**Tot**	1	2	3	4	5	6	7	8	9	10	11	12	**Nb Mo.**
fixed barrier and fyke net, Albania	9	1		**10**													**3**
fixed barrier in nets and fyke nets, Italy (East and West coasts)	2			**2**													**3**
fyke nets, Italy (East and West coasts)			3	**3**													**3**
fyke nets, Italy (Sardinia)	5			**5**	4 seasons												
fyke nets, Italy (West coast)	1		3	**4**													**5**
fixed barrier, Italy (East coast)	2			**2**													**5.5**
acoustic camera, France	1			**1**													**6**
Yellow eel stock	**LGN**	**LAK**	**RIV**	***Tot***	1	2	3	4	5	6	7	8	9	10	11	12	**Nb Mo.**
enclosure, Italy (West coast)	1			**1**													**2**
fyke nets, Italy (West coast)	1		3	**4**													**2**
fyke nets, Italy (Sardinia)	5			**5**	4 seasons												
fyke nets, Italy (East coast)	1			**1**													**5**
fyke nets, Greece	1			**1**													**6**
fyke nets, France	1			**1**													**6**
enclosure, Italy (East and West coasts)	2			**2**													**7**
fyke nets, Italy (East and West coasts)			3	**3**													**7**
fish pass trap, France			2	**2**													**8**
fish pass trap, France			1	**1**													**12**
fyke net, France	1			**1**													**12**

The monitoring period for yellow eel stocks and methods will depend on whether the eels are in their colonisation phase (elvers) or in their sedentary phase (usually after 20 cm). Studying the colonisation phase is important to understand eel distribution in the catchment, their habitat preferences and the impact of obstacles on their colonisation. It can also be used as a population indicator when recorded annually on a fish pass trap, for example. But the main purpose of yellow eel stock monitoring is often to collect annual data on the quantity and density of sedentary eels to be able to infer trends for a particular site. Several studies showed a daily periodicity in eel activity, with higher activity at night, related to feeding behaviour (Jellyman and Sykes, 2003, Verhelst *et al.* 2018) and when the temperature was higher than 10–13°C (Verhelst *et al.* 2018, Lagarde *et al.* 2021b). The period of monitoring will depend on the method and the ability to maintain the same protocol over time, in order to analyse comparable data. If the method uses passive gears, as is the mostly the case (Table 14.40), the monitoring period needs to take into account the fact that eels need to be active and looking for food to be caught, which may be during the night. Periods that are too cold or too hot should be avoided as there will be lower or no feeding activity, while meteorological factors also need to be taken into account as they usually influence the catch. For example, low catches in fyke nets are often associated with calm weather while windy or stormy weather results in higher catch rates. Therefore, if the monitoring is only based on a few days per year and they fall in a calm period, the catch may not be representative of stock trends. Most of the monitoring recorded in partner countries was carried out in spring, summer and early autumn (Table 14.40), during the highest activity periods for eels. The selected months in this period will depend on the local specifics of each site, but several months will be preferable in order to have a representative picture of the stock. Special environmental conditions leading to abnormal eel activity, such as higher movement of eels causing higher catches, anoxic events related to high temperatures, nutrient discharges or pollution spills should be avoided. Because of all these unpredictable factors, it is important to have long-term data collection to smooth the intra- and inter-annual variations and have a global understanding of trends.

Global climate change is another important parameter to consider in the choice of seasons to be monitored. Precipitation and river discharges are important triggers for migrations and their modification or reduction, perhaps through water extraction for agriculture and industry, will impact the start and the duration of the migration seasons (Drouineau *et al.*, 2018). Therefore, it is important to regularly follow these changes, either through the commercial fishery or through independent surveys, in order to reframe the monitoring season, if needed. A comparison of glass eel recruitment series for the two periods, 1980–2009 and post 2009 (Chapter 5 on recruitment) demonstrated a shift forward in the season for two French sites and in the river Marta (Italy). The reverse seemed to occur on the Tevere river (Italy) with a shift in the main peak of abundance from January to December. Some recent cases have also been reported in Mediterranean, such as in Ter river (Spain) where glass eel peaks seemed to move from late November–December to January and in Greece, where the silver eel escapement peaks seemed to have moved from early November to the end of December to early January in Lake Vistonida (pers. comm.).

Frequency of data collection

Once the optimal time period has been decided, a trade-off between data collection frequency and data accuracy needs to be found. The ideal survey design would be to collect data every day, but this is rarely feasible due to the cost and man-power needs. When possible, preliminary tests should be done to evaluate the best compromise to have reliable and representative results according to the number of days spent to collect field data, as well as the number of gears and the man-power needed. To be representative of the season, the period and frequency selected must cover the peaks of eel arrival and departure. A large variety of data collection frequencies were observed (Table 14.41), between two and 180 days per year, depending on the eel stage being monitored and the gear used, with the most common gear being fyke nets in rivers and lagoons. Considering that recruitment and escapement events are cyclical, it would be valuable to collect data during at least one week per month. The week around the new moon is often considered as the most suitable. However, it does not always fit with the peaks as has been shown from the results of the glass eel fishery on the Tevere river in Italy. For this reason, it is advisable to plan an extended monitoring period, also including waning and waxing crescent moon days, over a period of two weeks, through all the months of the recruitment season (see Chapter 5 on recruitment). Similar results, that is, peaks that did not always fit with new moon weeks have been observed from silver eel monitoring using acoustic cameras in Bages Sigean lagoon in France.

Preliminary studies over longer time periods may help to identify suitable monitoring frequencies to avoid missing migration peaks, while the same considerations could be applied to yellow eels, regardless of the moon phase. When monitoring recruitment using open traps (artificial habitats such as *fottangs* used in France or plastic traps used in Tunisia), glass eels can escape at any time so it is important to collect the eels frequently, every day if possible, to obtain reliable data,.

Table 14.41: Data collection frequency for glass eel recruitment, silver eel escapement and yellow eel stock monitoring in the nine partner countries (past, present monitoring and attempts). TotDaysYear corresponds to the number of days monitored in the year. LGN = lagoon habitat, RIV = river habitat. TotMonit: total number of monitoring recorded.

Glass eel recruitment						
Frequency	**TotDaysYear**	**Method**	**Country**	**LGN**	**RIV**	**TotMonit**
1 day/month (new moon)	5-6	fyke nets	Spain	1	1	2
2-3 days/month	9	fyke nets	Italy		2	2
3 days/month	6-12	fyke nets	Italy, France	1	2	3
4 days/month	32	fyke nets	France	2		2
5 days/month	15	fyke nets	Italy	1		1
6 times/month	18	fyke nets	Italy		1	1
7 days/month	35-53-84	fyke nets	Italy	3	6	9
2 days/week/month	24	fyke nets	Italy		3	3
3 days/week/month	12-48	fyke nets	Italy, France	3	1	4
daily	180	trap	France	1		1
daily	150-180	fyke nets	Italy	8	7	15
Silver eel escapment						
Frequency	**TotDaysYear**	**Method**	**Country**	**LGN**	**RIV**	**TotMonit**
1 week/month	21-35	fixed barrier in nets and fyke nets	Italy	3	6	9
24h/24h	180	acoustic camera	France	1		1
10 days/season	40	fyke nets	Italy (Sardinia)	5		5
Yellow eel stock						
Frequency	**TotDaysYear**	**Method**	**Country**	**LGN**	**RIV**	**TotMonit**
2 days/week	ND	fyke net	Italy	1		1
1 time/year (48h catch)	2	fyke net	Spain		3	3
1 week/year	7	fyke net	Greece	1		1
1 week/month	14-49	enclosure	Italy	3		3
1week/month	14-49	fyke net	Italy	1	6	7
10 days/period	30	fyke net	Italy	1		1
4 days/ month	48	fyke net	France	2		2
10 days/season	40	fyke net	Italy	5		5

Variables recorded

To be able to analyse and understand the trends year on year, it is essential to collect quantitative data, such as the number or weight of the individuals caught per unit of effort and qualitative data, such as the eel life stage, and for glass eels, the pigmentation stage to differentiate glass eels just arriving from the sea.

Although not essential, other variables are collected, not only to characterise the population, but also to describe the quality of the eels. Some parameters do not require the eels to be killed, including length, weight, silver Durif index and external pathologies, while others can only be measured on dead samples, such as prevalence of pathogens, lipid levels (unless using a fat meter), age and sex. When eels cannot be killed, a simplified way to estimate the sex ratio is to consider silver eels below 45 cm in length as males and above 45 cm as females (Deelder, 1984). This method was used to determine the sex-ratio of eels released in French lagoons. Environmental parameters (such as temperature, salinity, water current, depth and moon phase) are important to measure as they influence the capture rates and are essential to understand short and long-term variations.

The catch can be partial or total, depending on the method used. When partial, the catch will have to be linked to fishing effort (CPUE). A relative index of abundance can be then calculated from this CPUE. Additional experiments may be carried out to estimate the total migrating flux by evaluating the proportion that the catch represents, for example, by carrying out a catch-mark-recapture experiment. Information provided by partner countries were scattered but most of the monitoring programmes recorded CPUE, eel life stage, individual length and weight as well as environmental parameters.

If a sample of eels is sacrificed, for example, for age and sex determination, this presents an opportunity to analyse the health status of the specimen. ICES (2021a) recently reviewed the effects of contaminants (chemicals, parasites, pathogens, and other related to the spawner quality) on the reproductive capacity of eel and highlighted that it was an important aspect for stock assessment. Monitoring of silver eel quality should be considered as part of new or existing programmes (ICES, 2021a).

It is interesting to note that biometric data have been included since 2019 in the WGEEL Data Call. Data are from two sources, one from the monitoring programmes that provide time-series of abundance to the WGEEL and the other from monitoring programmes such as the DCF programme (ICES, 2020a). The 2020 analysis highlighted the low number of data-series and the insufficient details in the data that prevented clear interpretation of the observed patterns. In order to improve the analysis, a number of suggestions were made, including where mixed life stages are being reported, at least give an approximate percentage of each stage and specify the method especially if it may bias the sizes being captured while also indicating if there have been changes in the series, such as the sampling period or sampling methods, that may lead to changes in the time trends (ICES, 2020a). These aspects should be taken into account for biometric data collection on eel populations in the Mediterranean.

Potential common monitoring methods

Due to the diversity of eel habitats and specific local conditions, it is not possible to decide on a unique common methodology for each type of monitoring. The methodology needs to be selected according to the parameters that need to be recorded, the constraints linked to the field conditions, the logistical needs and the available budget. A standardised sampling methodology is needed to provide accurate estimates of the variables recorded through the years and to get reliable long-term data series. Effectiveness of the method in a particular site will depend on the sampling period and frequency of sampling in relation to the habitat type and eel behaviour. All the methods have their advantages and limitations and have to be selected according to several criteria including:

- initial costs for installation of materials and the equipment;
- the need to transport equipment to the field;
- maintenance and cleaning costs;
- requirements for electricity supplies in the field;
- desired sampling periods and frequency of data collection;
- man-power needed to carry out the data collection;
- likelihood of vandalism, and the need to install sampling equipment in a secure place; and,
- the need to train staff to use the material and perform data collection protocols.

For glass eel recruitment and silver eel escapement monitoring, when a partial or less than total catch has been recorded, where possible, an estimate should be made of the proportion that the partial catch represents, compared to the total migration . The use of different methods will make it difficult to make comparisons between sites, while local environmental and hydrodynamic factors will also affect the results. However, timing and intensity (abundance index) trends will be comparable between sites.

Glass eel recruitment monitoring methodologies

For glass eel recruitment, three methods could be recommended. In shallow waters (rivers, lagoons and lakes) fyke net methods (the different types used in the Mediterranean are described earlier in this chapter) may be more appropriate and are actually used in France, Italy and Spain. They often require collaboration between researchers and professional fishers to use their equipment (such as, fyke nets and boats) and to benefit from their experience of local field conditions in terms of the best sites to fish for eels and best way to set up the fishing gears. Fyke nets need to be regularly cleaned to avoid being clogged. The efficacy of intercepting glass eels will also depend on the weather conditions and the state of the river (floods or low levels) that may prevent the installation of fyke nets and would affect the final number of fishing days that could be used for the calculation of CPUE over the entire monitoring season.

In deeper water (rivers, lagoons and lakes), passive traps can be recommended because they are not expensive to build and can be deployed easily in different habitats. Trial experiments should be carried out beforehand to test the method before starting long-term monitoring. Both fyke nets and passive traps could be set up with relatively reasonable budgets. However, if funding is available to set up a fish pass trap, usually on an obstacle close to the sea, and to ensure its maintenance, this method would be recommended. It is less dependent on the data collection frequency as glass eels are continuously trapped and can be stocked in a tank. With proper maintenance of the system, it provides more constant capture efficiency. The equipment is more secure if integrated into a permanent building and is well adapted for long-term monitoring. However, the efficiency of the fish pass needs to be tested and this method requires a physical obstacle that is not suitable for all sites (Baran and Basilico, 2012).

Methods used in other countries could also be tested including the use of a boat equipped with sieves (bongo nets) that was tested in the channel of Bages-Sigean lagoon in France over two seasons (2019–2020 during the SUDOANG project). However, this method required nets to be set up on a fishing boat that had never used these type of nets before. The survey was carried out on only one night per month (around the new moon) and did not always fit with the entry period for glass eels (the capture rates were often low), but it had the advantage of having a standardized CPUE in terms of the number of glass eels captured compared to the volume of water. This method has been successfully used in a long-term monitoring programme on the Atlantic coast (the Oria estuary in Spain), with the results being currently used in the annual ICES stock assessment. A protocol to standardize the methodology for surveying glass eel recruitment was developed during the SUDOANG project (Sudoang, 2021) and could be useful for countries starting monitoring for the first time.

Silver eel escapement methodology

Permanent structures such as fixed barriers are particularly interesting to quantify silver eel escapement as they can entrap all silver eels when they migrate to sea. They should be used for long-term monitoring in all sites where possible but they are currently only used in Albania. Fixed barriers were recorded in Albania, Greece, Italy and Türkiye. They are usually old traditional fishing structures used not only to catch eel but all migratory fish species and operated by fishers. However, they will not be suitable for escapement monitoring if they are not active during the whole period of escapement. For example, this is the case in Greece, as following a GFCM recommendation, a fishing closure period has been applied. It is also important to collect information on the characteristics of the structures, such as mesh size, to know if small silver eels are also being captured and if there is bypass. For example, in Albania, fixed barriers are coupled with fyke nets before and after the structure to capture the small individual eels that were not caught by the fixed barrier. Although these systems seem to be ideal to record silver eel escapement, scientists need to be closely associated with the experiment in order to accurately record the catches and sample the eels.

For sites without fixed barriers, assemblages of fyke nets, which is a method that has been tested in Italy (data are under analysis), could be used. Several chains of fyke nets are set up along the channel or the river on each side of the bank. However, this method needs to be tested locally before starting a long-term monitoring programme to ensure the catch covers the migration peaks. Using this method, only a proportion of the migrant eels is collected and additional experiments should be carried out to estimate the total biomass escaping. In lagoons, where a fishery exists, silver eel escapement can be estimated with CMR but this method relies heavily on logistics as fishers must record all the marked eels they have captured. This method has been used in the past in France and Tunisia. Another interesting method is the acoustic camera although only one camera has been used so far in the Mediterranean to monitor silver eel escapement. It is a non-intrusive method that can be used in narrow channels or rivers (Martignac *et al.,* 2015). Migrating eels can be counted without the need for fishing gears but on the other hand, the camera is very expensive and requires special installation and regular maintenance. Analysis of video recordings is time consuming (artificial intelligence is still under development) and any bias associated with this method needs to be quantified and corrected (Lagarde *et al.,* 2020).

Yellow eel stock monitoring methodology

To monitor sedentary yellow eels, several methods could be used depending on the water salinity and depth. In shallow, freshwater (less than 70 cm depth) the best method for density estimation is electrofishing, as already implemented in France, Italy and Spain. A common, standardized protocol has recently been used in the SUDOANG project and could be a starting point for electrofishing new users (Sudoang, 2021). Where electrofishing cannot be used because of lack of funding or manpower, fyke nets could be an alternative option in shallow water for small rivers or channels. Fyke nets are used in France, Greece, Italy and Spain. However, this method will not give an estimate of population density but a CPUE that could be used as an index in long-term series. The optimal way to place fyke nets is through collaboration with fishers as they can help with decisions over where and when to set them. This method can also be applied in lagoons and has been used in France, Greece and Italy.

In deep, freshwater (more than 70 cm depth) and brackish water, electrofishing does not work efficiently (Lamarque and Cuinat, 1960) and installation of fyke nets is rarely possible. Allou *et al.* (2018) tested different methods in deep water in France in the Oir and Vilaine rivers. They concluded that the most efficient trap with homogeneous capture rates was a modified eel pot, called "*bourgne*" with a PVC lip, used without bait. This eel pot has a six mm sized metal mesh, a length of 80 cm, and a width and height of 17 cm. Its installation and use were easier than fyke nets and traditional eel pots. The use of passive traps will not give densities, but CPUE to be used as index. The sampling protocol will have to be standardised and cover enough surface area for a sufficient time period to record active eels and be representative of the yellow eel stock at that location.

Enclosures (described earlier in this chapter) have been increasingly used in recent years, including in Germany, Ireland and Estonia, and have also been used in Italy to monitor yellow eel stocks. Enclosures and electrofishing are the only methods that can provide estimates of yellow eel densities. However, the results have been mixed. Dorow *et al.* (2018) combined acoustic telemetry with an enclosure system in an area of coastal water in Germany and showed that 42.8 percent of the eels escaped the enclosure within 48 hours. A similar experiment was carried out in Bages-Siegan lagoon (France) with an enclosure coupled with acoustic telemetry confirming that some eels were able to escape the enclosure in less than 24 hours. The removal population estimates that are based on the rate of declines in catch rates following repeated sampling will be affected by escapement of enclosed eels as well as immigration. Capture efficiency needs to be calculated using specific models and correction factors need to be applied which make this method difficult to use in a straightforward manner. The enclosure set up is difficult and may require the help of fishers.

To monitor yellow eel colonisation in rivers, a fish pass trap installed on a dam or obstacle would be a reliable method, as has been used in France. The same constraints noted above on the use of fish pass traps for glass eel monitoring will apply for yellow eels. Eel quantity (CPUE), biometry and quality can be monitored quite easily as all captured individuals are collected in a tank once they have climbed the ramp. Another possible method is electrofishing but only in shallow, freshwater parts of rivers and the efficiency of catching small eels will depend on a number of factors including turbidity and the length of time the anode is left in the water.

In all type of habitats, acoustic telemetry could be used along with the other methods to better understand yellow eel behaviour and spatial distribution. This could reduce the uncertainties around estimates obtained with passive gears such as fyke nets, traps or acoustic cameras.

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Supplementary Material on the Methodology Part I – Structure of the spreadsheet for the collection of information on eel monitoring frameworks currently in place in Mediterranean countries for the purpose of compilation of the WP2-monitoring database

Table 14SM1.1

Country	
Region	
EMU code	
Do you have a monitoring on fish contamination in place ? (Yes/No)	
If Yes, since what year	
Is this monitoring linked to a regulation?(Yes/No)	
If Yes what regulation	
Is this monitoring incule eels? (Yes/No)	
If No monitoring in place , did you have a contamination monitoring (including eels) in the past ? (Yes/No)	
If Yes, what was the period of this monitoring (year start - year end)	
Do you plan to have a monitoring in the future? (Yes/No)	
If Yes, what would be the period of this monitoring? (year start - year end)	
Who would be responsible for this monitoring? (ministry, institute...?)	
About the monitoring on fish contiamination in place :	
Who is in charge of the monitoring (ministry, institute...)	
Is it compulsory? (Yes/No)	
If Yes, from which institute(s)?	
Where are the data (electronic files)	
What is the quality of the data	
Owner/ access to the data	
Aim	
Use	
End users	
Contact name and address to get access to the data	
On what spacial level are you recording the contamination data ? Site (river, lagoon), river bassin, fishermen comity, region, country...	
What variables are conpulsary ?	
What variables are recorded in real	
Data series period of time- start (mm/yyyy)	
Data series period of time- end (mm/yyyy)	
Record periodicity	
Missing data periods	
Remark	

Supplementary Material on the Methodology Part II – Questionnaires for the collection of information on the methodologies currently used for eel monitoring in Mediterranean countries

Table 14SM2.1. Glass eel questionnaire

GFCM Eel Program 2020 - Methods used
Country:
Institute:
Remark: It is possible to have various methods for one life stage

	Method	**Habitat type**	**Description**
Sampling			
Life stage identification			
Age reading			

Table 14SM2.2. Yellow eel questionnaire

GFCM Eel Program 2020 - Methods used
Country:
Institute:
Remark: It is possible to have various methods for one life stage

	Method	**Habitat type**	**Description**
Sampling			
Life stage identification			
Age reading			

Table 14SM2.3. Silver eel questionnaire

GFCM Eel Program 2020 - Methods used
Country:
Institute:
Remark: It is possible to have various methods for one life stage

	Method	**Habitat type**	**Description**
Sampling			
Life stage identification			
Age reading			

Additional Results Part I – Past, present, and prospective eel monitoring programmes for each eel life stage by country and habitat

Table 14AR1.1. Number of glass eel recruitment monitoring (past, present and future) by countries and by habitat type. Blue colour indicates EU countries. * indicates the number of potential sites for the future monitoring for each habitat. "?" indicates that the number of monitoring is unknown yet, but there will be at least one monitoring in the future.

Type of monitoring	Habitat	Albania	Algeria	Egypt	France	Greece	Italy	Spain	Tunisia	Turkey	Total
Past	River						12				**12**
	Lagoon				3		7		1		**11**
	Lake										**0**
	Total	**0**	**0**	**0**	**3**	**0**	**19**	**0**	**1**	**0**	**23**
Present	River				1		10	1			**12**
	Lagoon				3		1	1			**5**
	Lake										**0**
	Total	**0**	**0**	**0**	**4**	**0**	**11**	**2**	**0**	**0**	**17**
Future	River		5*								5*
	Lagoon		1*								1*
	Lake		2*								2*
	Total	**0**	**?**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**?**

Table 14AR1.2. Number of silver eel escapement monitoring (past, present and future) by countries and by habitat type. Blue colour indicates EU countries. * indicates the number of potential sites for the future monitoring for each habitat. "?" indicates that the number of monitoring is unknown yet, but there will be at least one monitoring in the future.

Type of monitoring	Habitat	Albania	Algeria	Egypt	France	Greece	Italy	Spain	Tunisia	Turkey	Total
Past	River						3				**3**
	Lagoon						3				**3**
	Lake										**0**
	Total	**0**	**0**	**0**	**0**	**0**	**6**	**0**	**0**	**0**	**6**
Present	River						3				3
	Lagoon	9			1		8				18
	Lake	1									1
	Total	**10**	**0**	**0**	**1**	**0**	**11**	**0**	**0**	**0**	**22**
Future	River		3*		1					?	**4***
	Lagoon		1*		1					?	**2***
	Lake		2*								**2***
	Total	**0**	**6**	**0**	**2**	**0**	**0**	**0**	**0**	**?**	**?**

Table 14AR1.3. Number of yellow eel stock monitoring (past, present and future) by countries and by habitat type. Blue colour indicates EU countries. 4° indicates that four sites are monitored but three of them belong to the same river: Rhone (in France). * indicates the number of potential sites for the future monitoring for each habitat. "?" indicates that the number of monitoring is unknown yet, but there will be at least one monitoring in the future.

Type of monitoring	Habitat	Albania	Algeria	Egypt	France	Greece	Italy	Spain	Tunisia	Turkey	Total
Past	River		1				3				4
	Lagoon		1				3				4

	Lake		2				0				2
	Total	**0**	**4**	**0**	**0**	**0**	**6**	**0**	**0**	**0**	**10**
Present	River				4 °	0	3	4			11
	Lagoon				1	1	12	0			14
	Lake				0	0	0	0			0
	Total	**0**	**0**	**0**	**5**	**1**	**15**	**4**	**0**	**0**	**25**
Future	River		4*			0				6*	10*
	Lagoon		1*			2				6*	9*
	Lake		2*			0				0	2*
	Total	**0**	**?**	**0**	**0**	**2**	**0**	**0**	**0**	**?**	**?**

Additional Results Part II – Map showing the location of sites for electrofishing surveys in France (EMU level), from Onema, 2015

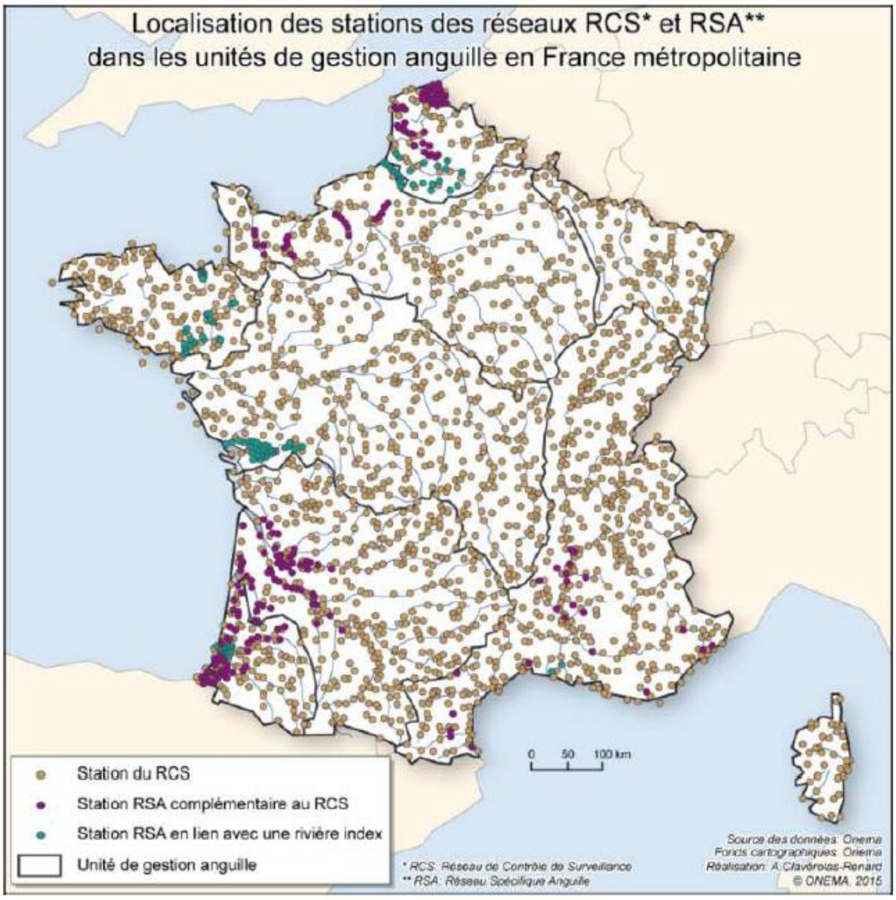

Figure 14AR2.1 Location of French electrofishing stations. © ONEMA 2015. Two networks are shown: RCS: electrofishing network not specific to eels and RSA: electrofishing network specific to eels (in purple the one complementary to the RCS and in blue the one in association to an index river).

CHAPTER 15. WP5 – REVISION OF DCRF TASK VII EEL

ABSTRACT

Work package 5 was designed to provide coordination, supervision and capacity building. It included a major task aimed at the revision of the current structure of Task VII.6 European eel under the GFCM Data Collection Reference Framework (DCRF). Currently, the DCRF offers guidance on the information to be provided on European eel fisheries within the GFCM area of application. The DCRF is expected to be filled by national administrations, in line with the relevant GFCM recommendation (GFCM, 2018), in order to provide information on existing fisheries in their countries and does not necessarily cover the minimum requirements for assessment of this stock at any level. Therefore, this chapter provides an analysis of the DCRF Task VII.6, carried out jointly by the GFCM Secretariat and partner countries, involving both scientific partners and national focal points.

The results provide a review of the current state of fisheries data collection for eel as performed by contracting parties and cooperating non-contracting parties of the GFCM. Most partner countries participating in the GFCM Research Programme on European eel in the Mediterranean, as well as other contracting parties and cooperating non-contracting parties, submit eel fishery-related data via the DCRF online platform, even if compliance reveals uneven data coverage between countries. Eel fishery-related data collection used for submission to the GFCM stems from many different data collection frameworks with variable methodologies, such as national statistical systems and European Union data collection frameworks.

A quality check of the submitted data was conducted, to compare with fisheries data (landings, fishing effort) collected within Work Package 3. The quality check highlighted discrepancies in most countries between available fishery data and data submitted via the on-line platform.

The DCRF reporting requirements for eel were compared with other frameworks (national and international) for eel data collection, as well as the monitoring frameworks reviewed in Work Package 2. The implementation of DCRF Task VII with a dedicated system for European eel assessment-related input data was taken into consideration. The crucial need for fishery-independent monitoring surveys in the Mediterranean region to correctly assess the eel stock on a long-term basis is deemed essential, and additional data are needed on biological variables, collected on a consistent basis with standardized methodologies, as well as specific indicators of glass eel recruitment, yellow eel standing stock and silver eel escapement.

The results constitute the basis to discuss a revision of DCRF Task VII.6 European eel and its implementation arrangements in order to fulfil the needs for European eel assessment and management in the Mediterranean, in coordination with other relevant frameworks and end-users, particularly the joint Internationa Council for Exploration of the Sea (ICES)/European Inland Fisheries and Aquaculture Commission (EIFAAC)/GFCM Working Group on Eels (WGEEL).

HIGHLIGHTS

- Eel fishery-related data collection submitted to the GFCM stems from many frameworks, resulting in extremely variable methodologies between countries. A standardization of methodologies for fishery-related data collection is therefore recommended and specific suggestions are given towards this aim.
- The coverage of fishers and fishing sites should be complete for each country, should rely on logbooks integrated with interviews, and the time frame should be revised accordingly to allow for aggregation at different levels and for different uses.

- The collection of data for fishing effort should be completely revised, with catch data for fishing using each of the eight described gear (Chapter 8) also taking into account information on technical characteristics, numbers and operational time.
- Raw data should undergo a quality check prior to being uploaded on the DCRF database and internal quality check routines should be revised, supported by national-level eel scientists in each country.
- Implementation of DCRF Task VII European eel with a dedicated system for European eel assessment-related input of data is recommended. Specific monitoring surveys are required to provide additional data on biological variables, collected on a consistent basis with standardised methodologies, as well as for specific indicators of glass eel recruitment, yellow eel standing stock and silver eel escapement. Minimum requirements for each country are to establish a monitoring network of sites at the Mediterranean level and to agree on standard methodologies and time coverage, although these must be adapted to specific local conditions in the different habitat typologies.

15.1. INTRODUCTION

15.1.1. Overview of the Data Collection Reference Framework

The GFCM Data Collection Reference Framework (DCRF) was conceived in 2014 as the GFCM's first comprehensive framework for the collection and transmission of fisheries-related data. These data are requested as a result of GFCM Recommendations and are necessary for relevant GFCM subsidiary bodies to formulate advice in accordance with their mandate.

The DCRF is constituted by the following components:

- The DCRF manual, which was endorsed by the Commission at its thirty-ninth session (Italy, May 2015) and outlines the DCRF principles by encompassing all the necessary information for the collection of fisheries data by GFCM contracting parties and cooperating non-contracting parties (CPCs) and their submission to the GFCM in a standardized way. It has two main parts: "Structure of data collection" and "Common practices in data collection".
- The DCRF online platform, which is the online environment that provides CPCs with online tools for data-entry and submission, in line with the requirements of existing GFCM decisions.

The DCRF is a dynamic tool that is subject to annual revisions by relevant GFCM subsidiary bodies based on requirements from the GFCM annual session, including through new recommendations. Since 2020, new annually recurring, fisheries data requirements of the GFCM which were not yet part of the DCRF have been progressively incorporated into the DCRF itself through a harmonization process.

The DCRF is based on seven different data-related tasks:

I. global figures on national fisheries production;

II. catch (landing data, catch data per species, fishing activities, landing points and ports);

III. incidental catch of vulnerable species;

IV. fishing fleet (fleet register, vessels in fisheries restricted areas, authorized vessels);

V. fishing effort (fleet segment, fishing gear, catch-per-unit effort);

VI. socioeconomics (economic and social data, operating costs, species value and other aspects); and

VII. biological information (stock assessment input data, length data, other biological data, dolphin fish, red coral, European eel, ecosystem indicators).

Each DCRF task may have different subtasks (data tables), each of them with the same structure: a description, the names of involved CPCs, the list of data fields with the related definitions, information about data confidentiality, frequency of reporting and deadlines for transmission.

15.1.2. Coordination of eel fishery-related data collection frameworks

European Union (EU) member states currently operate an eel fishery-related data collection system under the remit of the Data Collection Framework (EU DCF), to provide data to support the Common Fisheries Policy (CFP) through scientific advice. The EU DCF has existed since 2000 and was set out in Regulation (EU) 2017/1004 (EU, 2017). European Union member states collect data following their national work plans and report annually on their implementation. They coordinate their activities in regional groups that may also prepare regional work plans. Changes to the EU DCF in 2007 introduced requirements to collect data on eel and salmon, their data collection being addressed specifically by Council Regulation (EC) No. 199/2008 (EC, 2008), where the overall requirements specifically affecting eel were addressed (Chapter 2, Section 1, Article 3). Recreational eel fisheries were also addressed under these frameworks. Further requirements for collecting data on diadromous species, and therefore eel, and their fisheries were introduced by Commission Decision 2010/93/EU (EU, 2010). In particular, Section B of Chapter III relates to the collection of biological data and includes subsections on métier-related (fishing gear-related) data and stock-related variables (Section A relates to the collection of economic data, and Section C to transversal variables). All entries for eel in Appendix VII put the species in Group 1, indicating that they are "species that drive the international management process including species under EU management plans or EU recovery plans or EU long term multi-annual plans or EU action plans for conservation and management based on Council Regulation (EC) No. 2371/2002" (EC, 2002).

In 2007, the Eel Regulation (No. 1100/2007) set up requirements for reporting, although they are not specific or detailed (EC, 2007). Article 10 requires that "Member States establish a control and catch monitoring system adapted to the circumstances and to the legal framework already applicable to their inland fisheries", while Article 11 concerns information on fishing activities to be established by each Member State. There are no specific requirements for data collection and monitoring in the Regulation, but based on the Regulation, all eel-related activities are delegated to national or regional levels and management as well as assessment are delegated to the national, eel management unit (EMU), river basin district or individual river level, as set out in eel management plans. Over the years, such activities, carried out within many projects and frameworks, have provided data and information for the evaluation of eel stocks.

In 2012, a specific working group (ICES, 2012) reviewed data collection programmes for eel and salmon implemented under the EU DCF and the problems and concerns identified by EU Member States. It was evident that member states had adopted very different approaches to meeting the requirements of the EU DCF, highlighting ambiguities in the measures relating to diadromous species. For both eel and salmon, monitoring programmes need to be locally adapted and in many cases, this has resulted in different methods being developed to meet both national and international obligations. This means that full international standardization may need to be more flexible than for traditional marine fisheries.

Some critical issues were resolved in the EU Multiannual Programme (EU MAP) following reform of the CFP in 2013, introducing new requirements for diadromous fish, and hence for eel, requiring the collection of specific indicators on glass eel recruitment, yellow eel standing stock and silver eel escapement in index rivers or specific catchments. However, these new requirements have posed problems for the standardization of methods and the possibility of meeting requirements by Member States, that again adopted different methods and schemes to comply with requests. The framework currently in place is under the EU Commission Delegated Decision 2021/1167 of 27 April 2021 and the related EU Commission Implementing Decision 2021/1168 of 27 April 2021 (EU, 2021a; EU, 2021b). Both commercial and recreational fisheries are included for eel and data collection is required on biological parameters, as well as scientific monitoring for glass eel recruitment, yellow eel standing stock and silver eel escapement, at management unit or river level, while also specifying the water body. Each Member State has presented its national work plan.

Some of the data collected under the DCF of the EU MAP by Member States are uploaded to Joint Research Centre (JRC) databases, in response to data calls issued by the European Commission's Directorate-General for Maritime Affairs and Fisheries (DG MARE). Data stored in its databases are analysed by the JRC, their quality is assessed and information is prepared for communication to Scientific, Technical and Economic Committee for Fisheries (STECF) working groups. Once the STECF reports have been finalized, the aggregated data are published for further use in scientific analyses and policy-making. Other end-users also partly base their scientific advice on the EU DCF data including the International Council for the Exploration of the Sea (ICES), regional fisheries management organisations and sustainable fisheries partnership agreements. The main end-user for eel is ICES, as it issues an annual data call on eels for the joint ICES/ European Inland Fisheries and Aquaculture Commission (EIFAAC)/GFCM Working Group on Eels (WGEEL).

Over the years, non-European Union countries have also contributed to the initiative of eel scientists participating in the WGEEL. In the years 2017–2018, following the GFCM Pilot Action, there was an attempt to involve other countries in the GFCM area of application, but only some CPCs managed to answer the data call due to its timing, the complexity of the annexes, as well as the limited scope and availability of data. In the following years, the joint ICES/EIFAAC/GFCM data call was forwarded to eel scientists from non-European Union countries participating in the WGEEL, that were already forwarding annexes in response to annual data calls. In 2021, within coordination provided by the GFCM Eel Research Programme, the five non-European Union partners in the programme, Albania, Algeria, Egypt, Tunisia and Türkiye, participated in the WGEEL, while also contributing to Part I (online, 7 September – 10 September 2021) of the WGEEL to prepare and integrate all data provided in response to the 2021 ICES data call on eel for the WGEEL database.

15.1.3. GFCM recommendations on European eel data submission and related amendments

The GFCM legal framework for the submission of national data on European eel by CPCs dates back to 2016, when the GFCM at its fortieth annual session adopted, for a transitional period of one year, Recommendation GFCM/40/2016/2 on the progressive implementation of data submission in line with the DCRF. For the first time, through this decision, the GFCM introduced an annual data call for European eel with a deadline in September each year for transmission of data to the DCRF online platform (GFCM, 2016).

In 2017, the forty-first annual session of the GFCM adopted Recommendation GFCM/41/2017/6 on the submission of data on fishing activities in the GFCM area of application (GFCM, 2017), that is the current GFCM framework for the European eel data submission (DCRF Task VII.6 European eel). The decision was then amended in 2018, in its eel data component, (GFCM, 2018) on the basis of the technical inputs from the GFCM workshop on the management of European eel (WKMEASURES-EEL), as shown in Table 15.1.

Table 15.1. Amendments to the Data Collection Reference Framework eel data requirements made in 2018

European Eel - Data Collection Reference Framework data fields -	**Data reference year**	
	2015–2017	**From 2018**
Habitat	X	X
Site	X	X
Gear type	X	X
Mesh size	X	X
Number of fishers	X	X
Fishing days	X	X
Average number of “gear units” per day per fisher	X	X
Total catch of silver eel	X	X
Total catch of yellow eel	X	X
Total catch of silver and yellow eel		X
Total catch of glass eel	X	X
Stocking life stage		X
Stocking (kg/year)		X

Through the amendment, the need for the reporting of “0” values to distinguish between “no data” and “zero” value was introduced with the breakdown shown in Table 15.2.

Table 15.2. Codes and definitions of zero values to be used when submitting data to the Data Collection Reference Framework

Code	Name	Definition
NR	Not reported	Data or activity exist but numbers are not reported to authorities, for example for commercial confidentiality reasons.
ND	No data	Where there are insufficient data to estimate a derived parameter, for example where there are insufficient data to estimate the stock indicators (biomass and/or mortality).
NC	Not collected	Activity/habitat exists but data are not collected by authorities, for example where a fishery exists but the catch data are not collected at the relevant level or at all.
NP	Not pertinent	Where the question asked does not apply to the individual case, for example where catch data are absent as there is no fishery or where a habitat type does not exist in an eel management unit.

Given the complexity of the frameworks for European eel data collection, the different levels of involvement by European Union and non-European Union countries across the GFCM area of application, as well as the need to ensure a reliable and standardized system for eel data collection, Task VII.6 of the GFCM Research Programme on European eel in the Mediterranean (RP) aimed specifically at:

- reviewing the current state of fisheries data collection for eel as performed by CPCs;
- evaluating data reporting by CPCs to the GFCM through the DCRF online platform;
- comparing GFCM requirements with other frameworks (national and international) for eel data collection;
- checking the quality of the submitted data;
- revising and adapting DCRF Task VII.6 European eel to the needs of European eel assessment and management in the Mediterranean; and,
- coordinating with other frameworks and end-users, including the EIFAAC/ICES/GFCM WGEEL.

15.2. MATERIALS AND METHODS

15.2.1 Eel fishery-related data collection methods and relative transmission

The first part of the task examined how eel fishery-related data are collected and transmitted by CPCs to the GFCM. To this end, an exploratory questionnaire (Supplementary Material on the Methodology Part I) was sent to all CPC administrations, including those from partner countries of the RP and other non-partner countries, in order to identify relevant contacts for further steps. Specific questionnaires were then sent to relevant institutions via the national focal points, that ensured compilation from the officers and scientists actually carrying out technical activities for eel fishery-related data collection, processing and transmission to national authorities. A first questionnaire (Supplementary Material on the Methodology Part II) was aimed at collecting information on the methods for collecting eel fishing data at the national level, also in compliance with DCRF Task VII.6 European eel. The purpose of the second questionnaire (Supplementary Material on the Methodology Part III) was to collect information on the methods for reporting and transmission of data in compliance with DCRF Task VII.6 European eel, specifically for its annual transmission to the GFCM through the DCRF online platform.

All information and data provided through the returned questionnaires were archived in a specific database and were analysed to gain an overview of the present state of fishery-related data collection for eel and its transmission to the GFCM.

15.2.2 Analysis of data officially reported by through the Data Collection Reference Framework online platform

Along with the above-mentioned survey, data officially reported by CPCs to the GFCM through the DCRF online platform for eel were retrieved from the GFCM database and analysed, in order to assess the compliance of CPCs in submitting data. The analysis examined the type of data submitted, its level of completeness and highlighted any potential problems due to inadequacies or discrepancies.

15.2.3 Eel fishery-related data quality check

A further step was aimed at comparing eel landings data collected in the WP3-Fishery task with the DCRF data submitted by CPCs, to verify their consistency and homogeneity with a view to the harmonization of data in official data collection frameworks. This quality check was performed with the additional aim of identifying any critical issues in the current DCRF Task VII.6 European eel regarding the use of data for the overall process of assessment and to propose changes for its revision.

Along with landings data obtained through different national sources, scientific partners of the RP were asked to provide information on data shared for the purpose of DCRF Task VII.6. Meanwhile, national focal points were also asked to share DCRF Task VII.6 European eel data officially sent to the GFCM.

The WP3-Fishery database and DCRF Task VII.6 European eel require data to be entered at the site level or above (EMU, region or country) and to provide data for habitat types and fishing gear that are not entirely consistent. In this sense, the purpose of comparing data coming from the two data sources focused mainly on verifying that the total quantities declared per year matched, while also identifying inconsistencies due to data processing at different levels of aggregation (habitat, gear or life stage) and identifying critical technical issues in the current DCRF Table VII.6.

15.3. RESULTS

15.3.1. Data collection

Table 15.3 gives an overview of the countries involved in this investigation and of their participation in the different activities. Among all CPCs, the nine countries participating in the RP are highlighted, all of them having significant eel fisheries, and most of them contributing to the DCRF by collecting data (reference years from 2015 to 2019) and submitting them through the DCRF online platform. Egypt and Türkiye are still implementing their data collection and management for DCRF purposes. Algeria and Greece did not share data officially submitted to the DCRF, so the quality check was not performed entirely. Among other CPCs, Croatia and Montenegro have eel fisheries and submit fishery-related data, thereby making a partial contribution, even if they are not involved in the research programme. Israel and Morocco declared that they did not have eel fisheries (Morocco referring only to Mediterranean waters). All the other CPCs did not answer requests for collaboration and nothing is known officially about eel fisheries in these countries.

Table 15.3. The status of the Data Collection Reference Framework and GFCM eel research programme activities in GFCM contracting parties and cooperating non-contracting parties.

	DCRF activities			*GFCM eel research programme*			
Country	**Eel fisheries present**	**Task VII.6 Europe an Eel**	**DCRF online platform submission**	**Participation in the research programme**	**Eel fishery-related data collection survey**	**Eel fishery-related data management survey**	**Quality check of landings Work package 3 - DCRF**
Albania	Yes	Yes	2016–2019	Yes	Yes	Yes	Yes
Algeria	Yes	Yes	2015–2019	Yes	Yes	Yes	Not complete
Bulgaria	Unknown	No	No	No	-	-	-
Croatia	Yes	Yes	2016–2019	No	Yes	Yes	No
Cyprus	Unknown	No	No	No	-	-	-
Egypt	Yes	No	No	Yes	Yes	Yes	No
France	Yes	Yes	2015–2019	Yes	Yes	Yes	Yes
Greece	Yes	Yes	2016–2019	Yes	Yes	Yes	Not complete
Israel	No	No	No	No	-	-	-
Italy	Yes	Yes	2015–2018	Yes	Yes	Yes	Yes
Lebanon	Unknown	No	No	No	-	-	-
Libya	Yes	No	No	No	-	-	-
Malta	Unknown	No	No	No	-	-	-
Monaco	Unknown	No	No	No	-	-	-
Montenegro	Yes	Yes	2017–2019	No	No	Yes	No
Morocco	No	No	No	No	-	-	-
Romania	Unknown	No	No	No	-	-	-
Slovenia	Unknown	No	No	No	-	-	-
Spain	Yes	Yes	2015–2019	Yes	Yes[a]	Yes	Yes
Syria	Unknown	No	No	No	-	-	-
Tunisia	Yes	Yes	2015–2019	Yes	Yes	Yes	Yes
Türkiye	Yes	Yes	No	Yes	Yes	Yes	No

Note: [a] For Spain, the five autonomous regions in the Mediterranean were considered.

15.3.2 Eel fishery-related data collection methods and transmission of data

All nine countries participating in the RP contributed to the survey while other CPCs were also involved, such as the answer received only from Croatia for the questionnaire on the methods for collecting eel fishing data at the national level (Table 15.1). In nine out of ten countries, fishery data collection is carried out centrally, by ministries and related institutions that oversee both the collection of data and their transmission to the GFCM Secretariat and other end-users for data calls and data use. On the other hand, in Spain, eel fishery-related data collection is carried out by autonomous regions and each autonomous government oversees the control, regulation and management of eel fisheries and local eel stocks. Each region comprises an eel EMU. However, this causes differences between the autonomous regions as different stages are targeted, different fishing techniques are allowed and the data collection and reporting systems are different. Therefore, answers from the five Spanish EMUs are treated separately, at the same level as other countries, making a total of 14 respondents (nine countries and five Spanish autonomous regions).

An eel fishery data collection system is in place in all countries where eel fisheries occur, to meet multiple needs (Figure 15.1), although in Spain, data collection is only happening in three of the five regions as eel fisheries are closed in Andalucía and the Balearic Islands. In most cases, the data collection is not specifically linked to the DCRF Task VII.6 European eel, but takes place as a result of activities stemming from overlapping operational frameworks. All respondents declared that eel fishery-related data collection fulfils multiple needs (Figure 15.2). In Albania, Algeria, Croatia, Egypt, France, Tunisia and Türkiye, the main purpose for data collection and the operational methodology were linked to the need to collect statistics for national purposes, while for France, Italy and the EMUs in Spain, the main purpose was the EU DCF and the current EU MAP. For seven countries, data collection was also meeting requirements under the Eel Regulation (Greece and Albania as well as France, Italy and the EMUs in Spain).

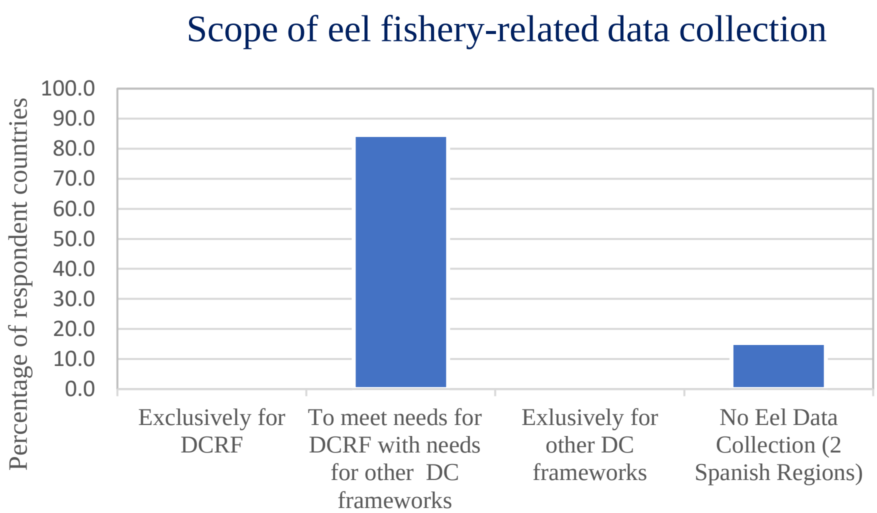

Figure 15.1. Percentage of respondent countries performing eel fishery-related data collection by intended purpose or use

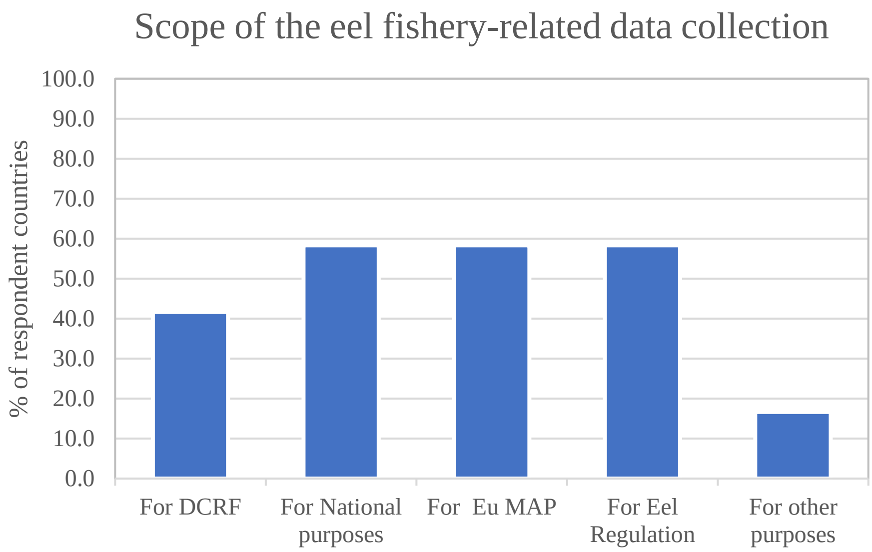

Figure 15.2. Percentage of respondent countries performing eel fishery-related data collection by framework

As a consequence of this diverse background, the general methodology for collection of raw eel fishery data, as well as for data storage, synthesis and analysis, is not uniform. In all countries, a protocol for a standard operating procedure is in place (Figure 15.3). In six countries, the procedure was established for the specific purpose of data collection for eel fisheries, while in another six, the procedure was adapted from protocols in place for other fisheries (generally marine coastal fisheries). In the Spanish Andalucía EMU, as mentioned, a specific eel monitoring activity is carried out that does not meet DCRF requirements. In all cases, except in Andalucía, the data collection methodology is fishery-dependent.

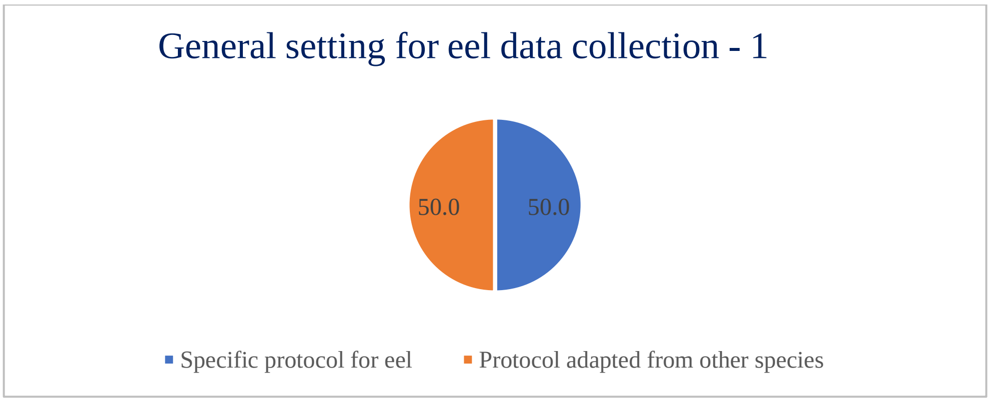

Figure 15.3. Percentage of respondent countries using data collection protocols specifically for eels or adapted from other species

Figure 15.4 shows that the collection of raw fishery data relied either on records from fishers, fishing companies or fishing vessels (eight countries, 67 percent), or on direct observations of landings (four countries, 33 percent).

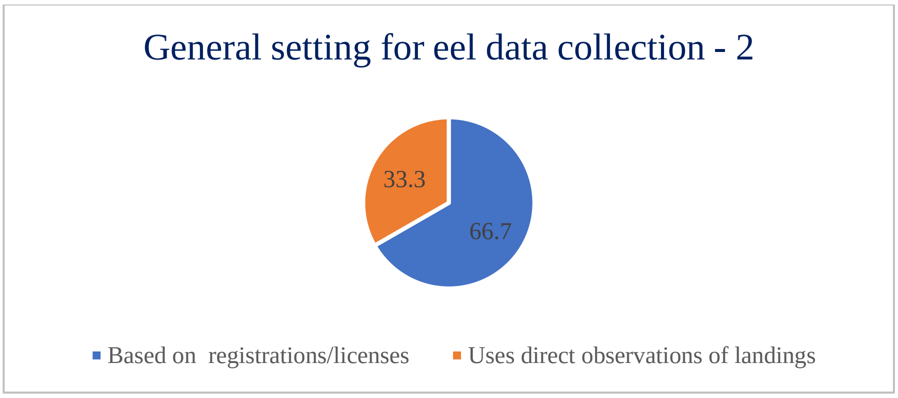

Figure 15.4. Percentage of respondent countries using eel fishery data collection from fishers or from direct observations of landings

Among the countries that depend on data collection from fishers through licensing or registrations, seven (58 percent) used methodology that relied on logbooks, which were either mandatory or not, generally structured for reporting catches for all fisheries, or on logbooks specifically designed for eel data collection (Figure 15.5). Some countries also relied on the use of questionnaires (two countries, 17 percent) and structured interviews (three countries, 25 percent), usually filled in by dedicated personnel based on individual interviews or panel interviews with groups and rarely filled in autonomously by fishers. Combined methods were also used, or different methods within the same country when addressing different fisheries.

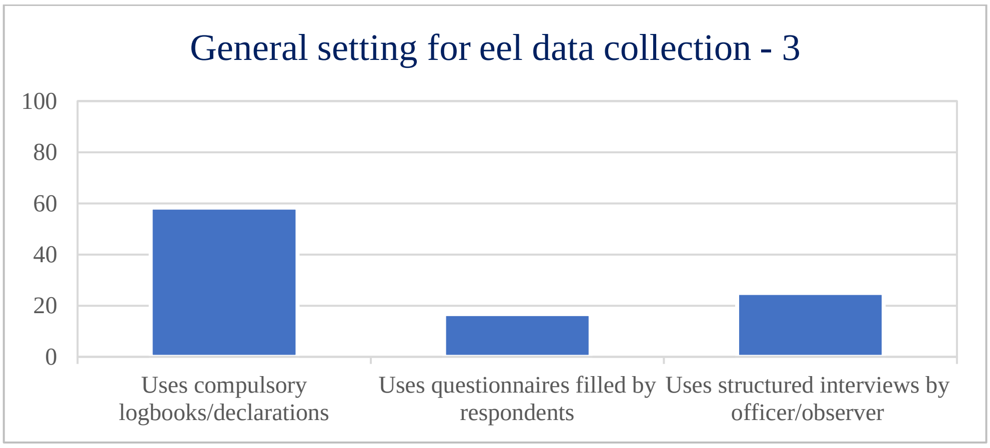

Figure 15.5. Percentage of respondent countries that relied on eel data collection from fishers using logbooks, questionnaires and structured interviews

Eel data collection was carried out separately for the different eel life stages in five countries (42 percent), while records from Egypt and Tunisia used the total catch data for all stages. In seven countries, a combined system for the registration of catches was used, separated by life stage or pulled together, depending on the site (Figure 15.6). This was due to the fact that, in some situations, fishers cannot discriminate between yellow and silver eel.

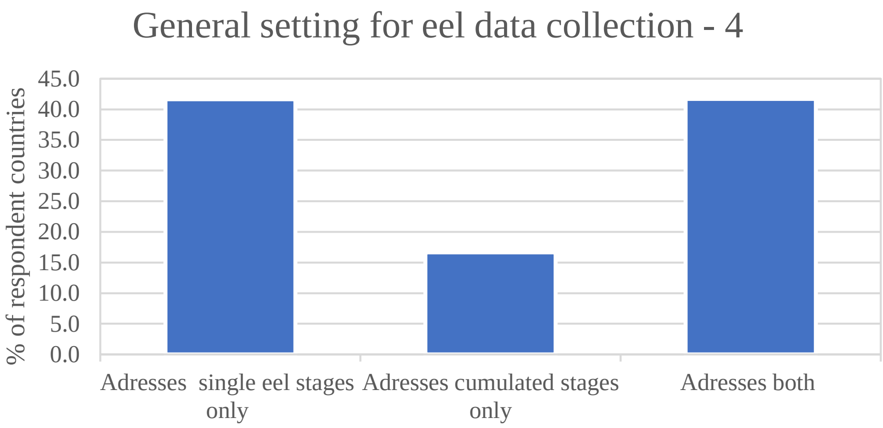

Figure 15.6. Percentage of respondent countries collecting eel data on single and multiple life stages

In 92 percent of countries, eel data collection involved all fishers and companies, whereas only in Italy, samples of fishers were interviewed and then the results were extrapolated to national level (Figure 15.7). In terms of spatial coverage (Figure 15.8), in most cases, the data collection was carried out at the scale of fishing sites and this allowed for reporting habitat type as required by the DCRF, while no country addressed data collection at the catchment level. In many countries the EMUs or the administrative units were also addressed by aggregating data recorded at site level.

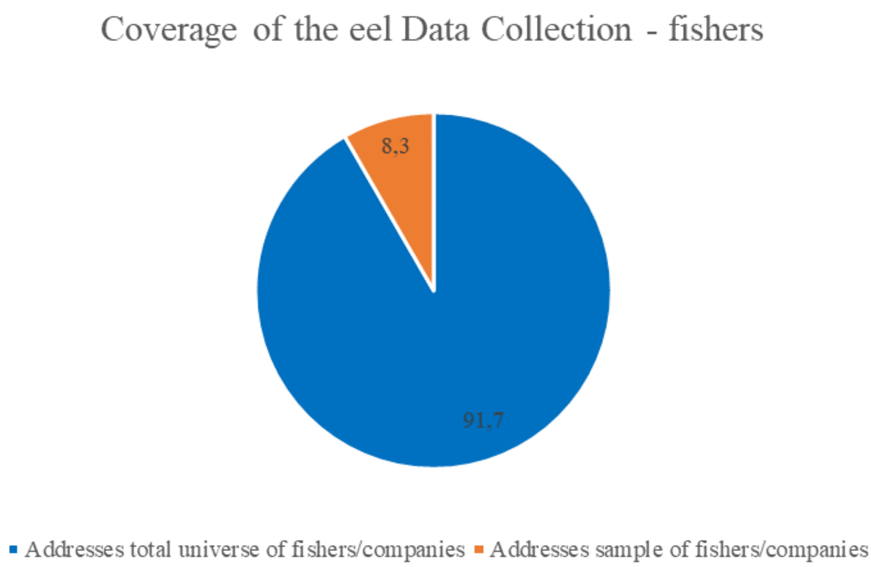

Figure 15.7. Percentage of respondent countries collecting data from all fishers and companies or using a sample-based approach

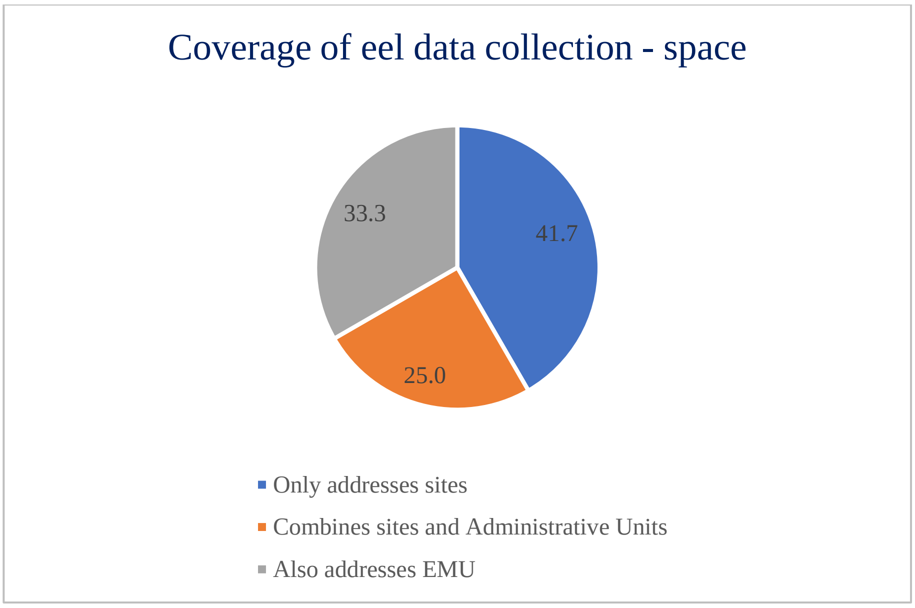

Figure 15.8. Percentage of respondent countries collecting eel data at various spatial scales

As regards the timescale of data collection (Figure 15.9), Albania, Greece and Italy collected data on a yearly basis, while some recorded data on a daily or monthly basis, two used a quarterly data collection system and France used different timeframes, depending on the site.

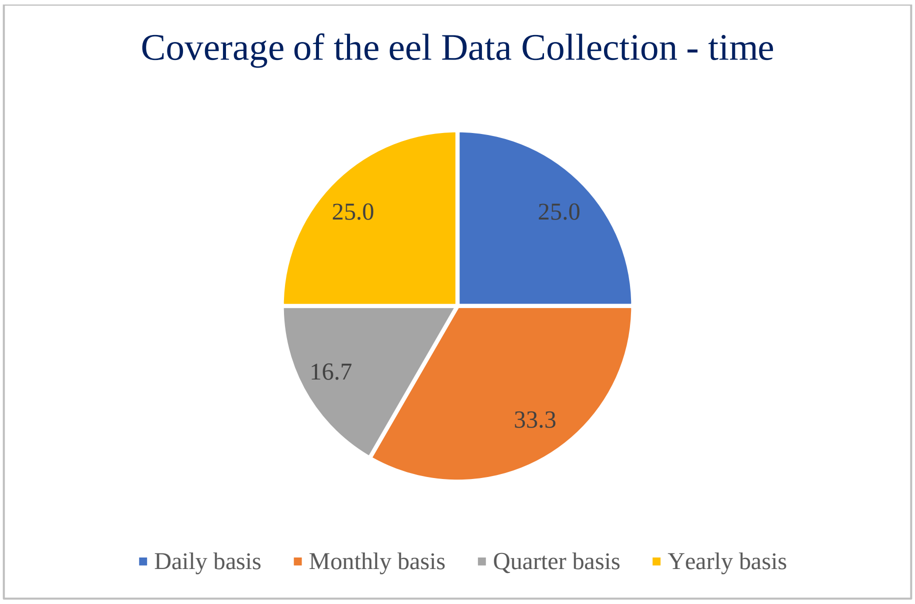

Figure 15.9. Percentage of respondent countries collecting data on various time scales

Most countries (75 percent) collected data on fishing effort (Figure 15.10), taking into account gear type and size, as well the number of gear and installation time (Figure 15.11). Greece, Turkey and

Spain–Valencia did not address fishing effort, although Greece has tentatively started to collect fishing effort data.

Biological sampling of catches was performed by the majority of countries, while only Albania, Turkey and Spain–Catalonia did not have biological sampling schemes. The framework for biological sampling was not specifically related to DCRF requirements but was usually related to the data collection requirements of other frameworks (such as the EU DCF) or national assessment purposes.

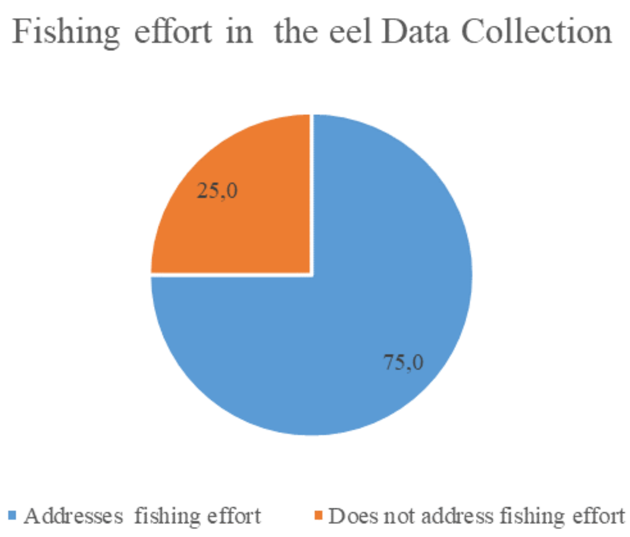

Figure 15.10. Percentage of respondent countries collecting data on fishing effort

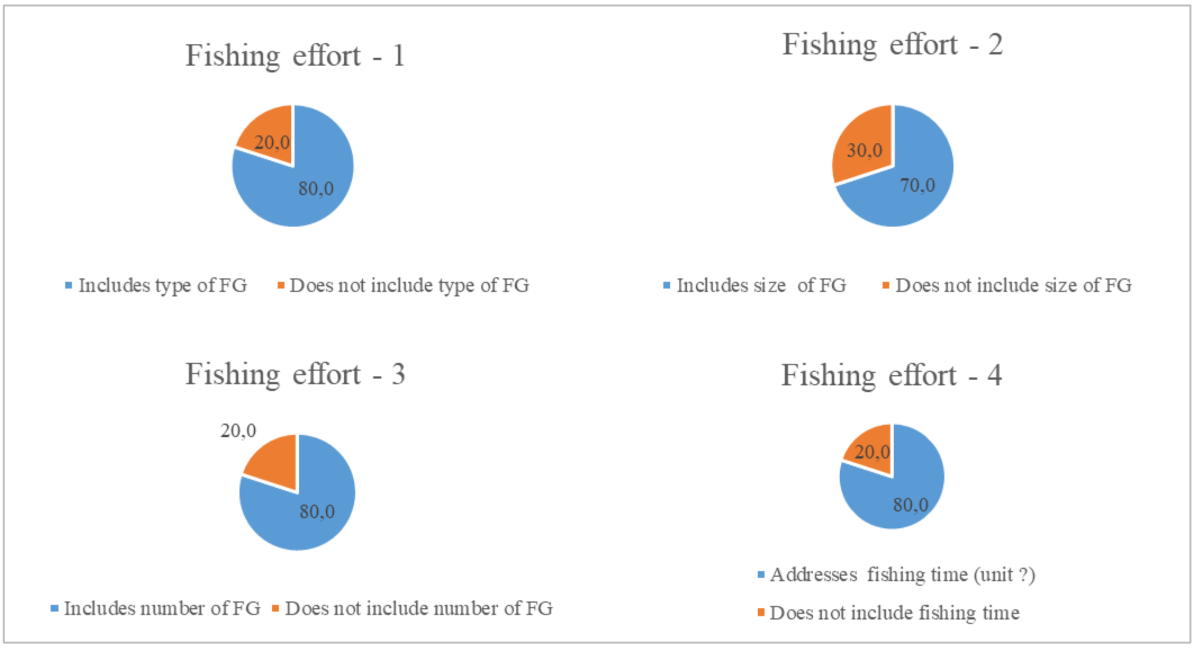

Figure 15.11. Percentage of respondent countries collecting data on specific fishing effort parameters: 1, 2 and 3 – type, size and number of fishing grounds; 4 – fishing time.

Socioeconomic data were not collected in 75 percent of countries. Only Albania and Türkiye collected some socioeconomic information.

In half of the countries, data underwent quality control that mostly addressed the quality of the raw data collected, while in the rest, there was no quality check (Figure 15.12).

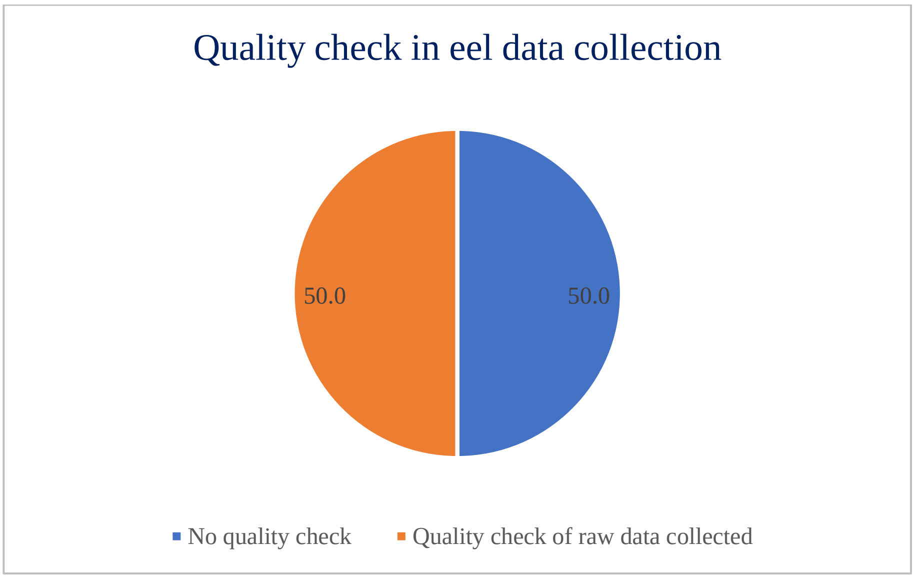

Figure 15.12. Percentage of respondent countries that performed a data quality check

Three countries, Algeria, Egypt and Spain–Valencia did not perform any statistical processing, while five countries performed some processing of catch data (Figure 15.13). Some also processed fishing effort data or biological data.

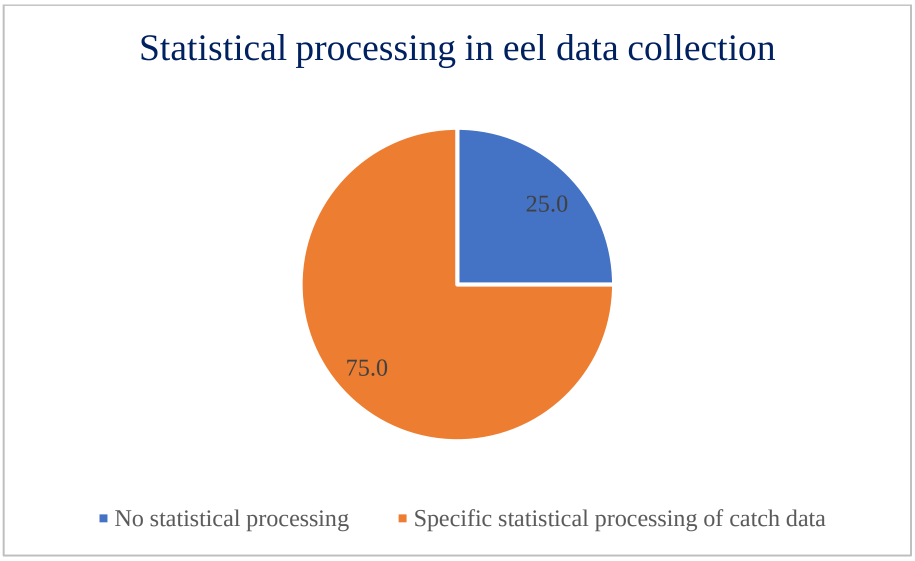

Figure 15.13. Percentage of respondent countries that performed statistical processing of eel data

Nine of the respondent countries stored data electronically, relying in some cases on specific databases located in administration offices or in research institutes who held responsibility for maintenance of the data (Figure 15.14). Meanwhile, in some cases, paper logbooks were also used.

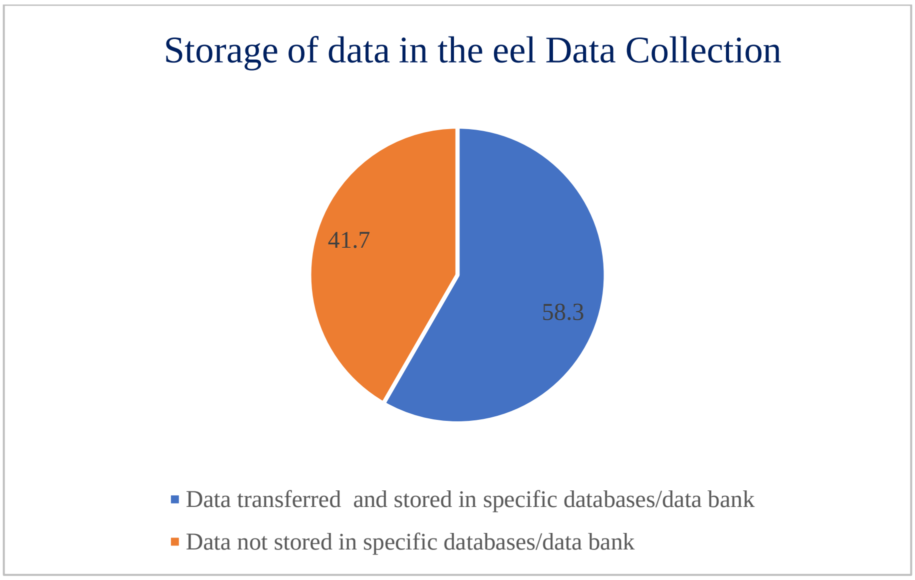

Figure 15.14. Percentage of respondent countries using specific databases for **s**torage of eel fishery-related data

15.3.3. Use of eel fishery-related data

Information on the methods for reporting and transmission of data in compliance with the DCRF Task VII.6 European eel and its annual transmission to the GFCM through the DCRF online platform, was provided by 11 countries (Table 15.1), including the nine countries participating in the RP (Spain answering for the whole country because data transmission is performed centrally) as well as Croatia and Montenegro, among the other CPCs. The results are therefore related to 11 countries, but not all respondents answered all the questions.

Nine countries use the eel fishery-related data for national reporting (Figure 15.15) and upload data regularly on the DCRF online platform (Figure 15.16; Table 15.1). Egypt and Türkiye are still in the process of implementing the DCRF for eel.

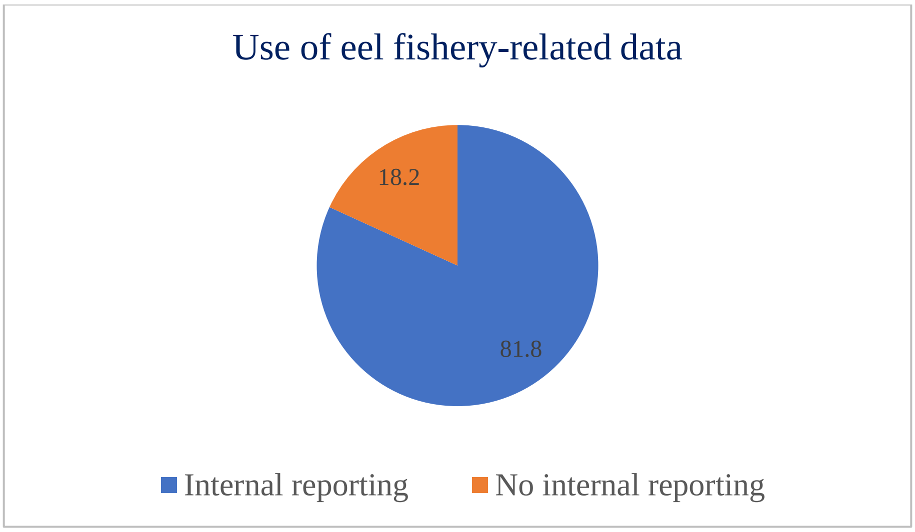

Figure 15.15. Percentage of respondent countries using eel fishery-related data for internal reporting

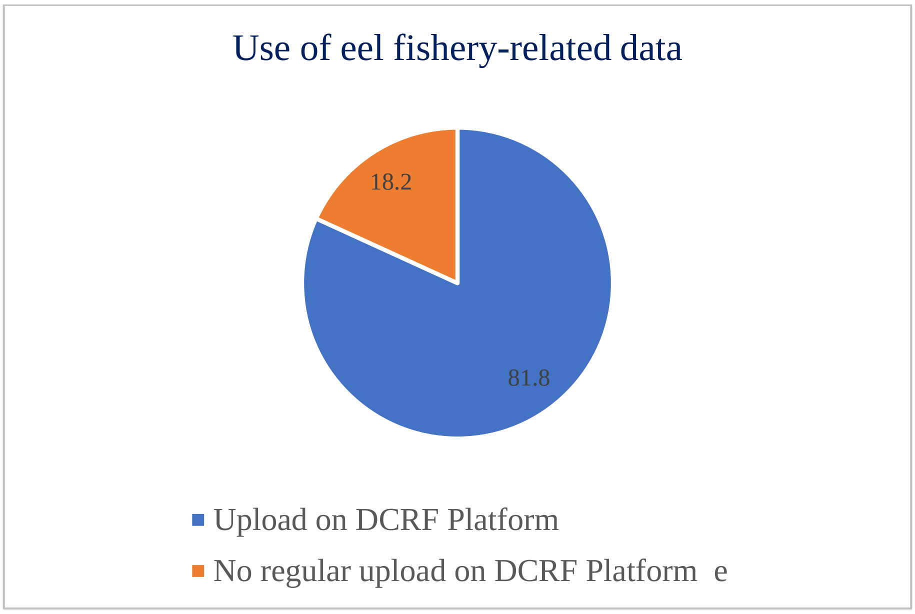

Figure 15.16. Percentage of respondent countries using eel fishery-related data for compliance with uploads to the DCRF platform

Seven countries declared that they also use data for reporting to specific international-level end-users (Figure 15.17). Only France and Tunisia said that they use eel fishery-related data for reporting to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (Figure 15.18), while four countries used it to report for the EU Eel Regulation (Figure 15.19) or for other specific EU requirements (Figure 15.20).

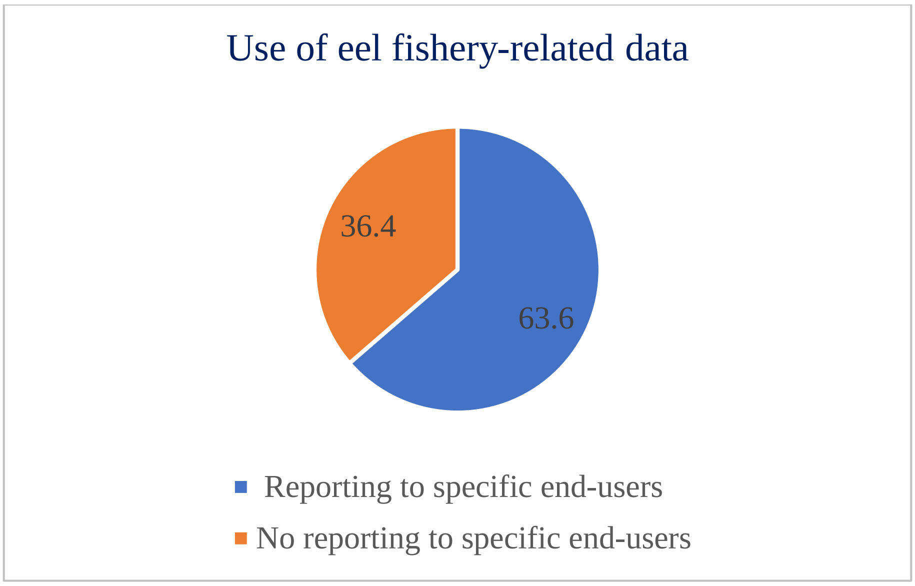

Figure 15.17. Percentage of respondent countries using eel fishery-related data for reporting to specific end-users

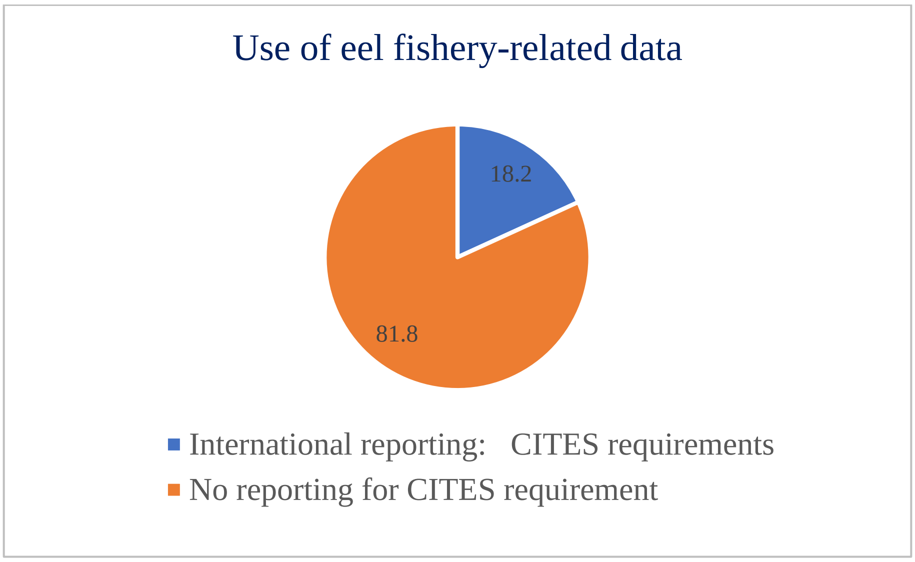

Figure 15.18. Percentage of respondent countries using eel fishery-related data for Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) reporting

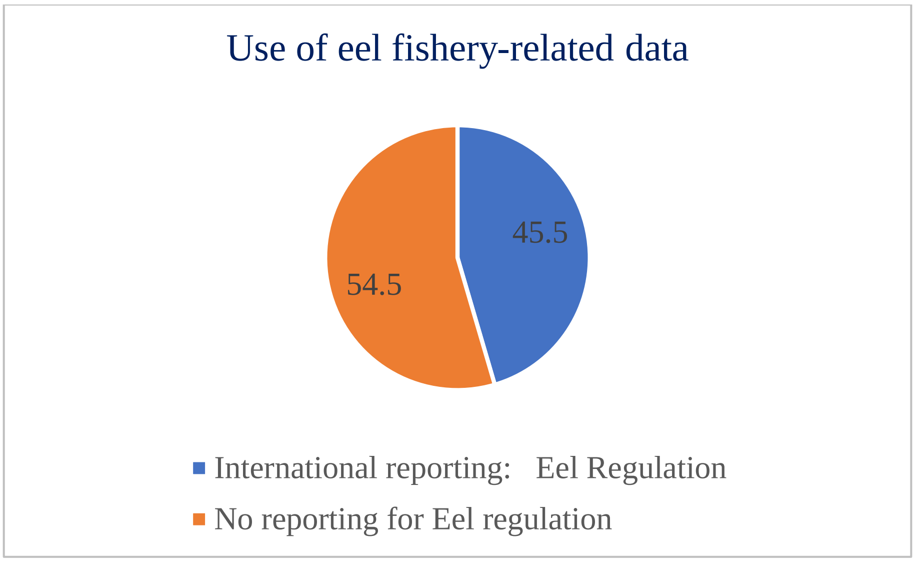

Figure 15.19: Percentage of respondent countries using eel fishery-related data for reporting on the EU Eel Regulation

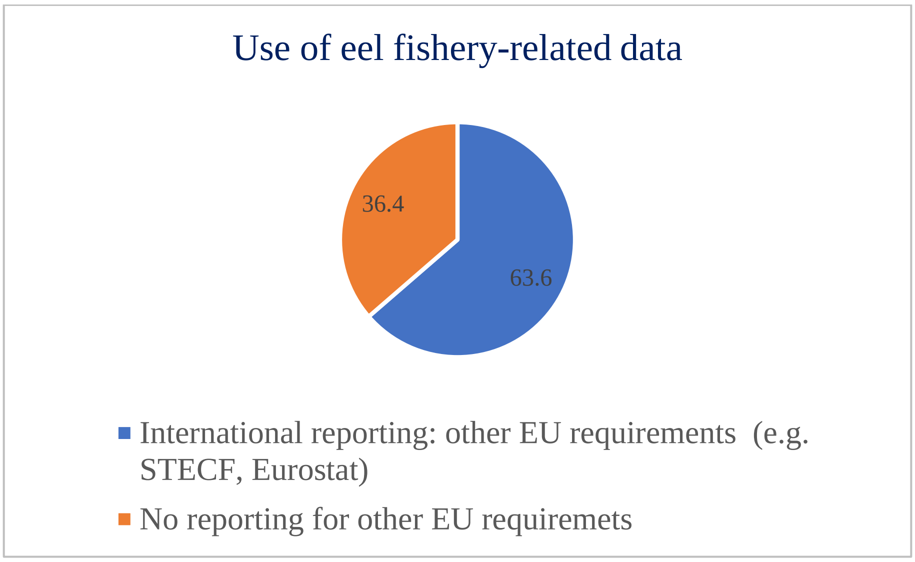

Figure 15.20. Percentage of respondent countries using eel fishery-related data for reporting for other EU requirements

Six countries declared that data were used also for answering international data calls or reporting (Figure 15.21). Seven countries declared that fishery-related data were used to report to the EIFAAC/ICES/GFCM WGEEL (Figure 15.22), but only five countries also used data to answer the related data call (Figure 15.23).

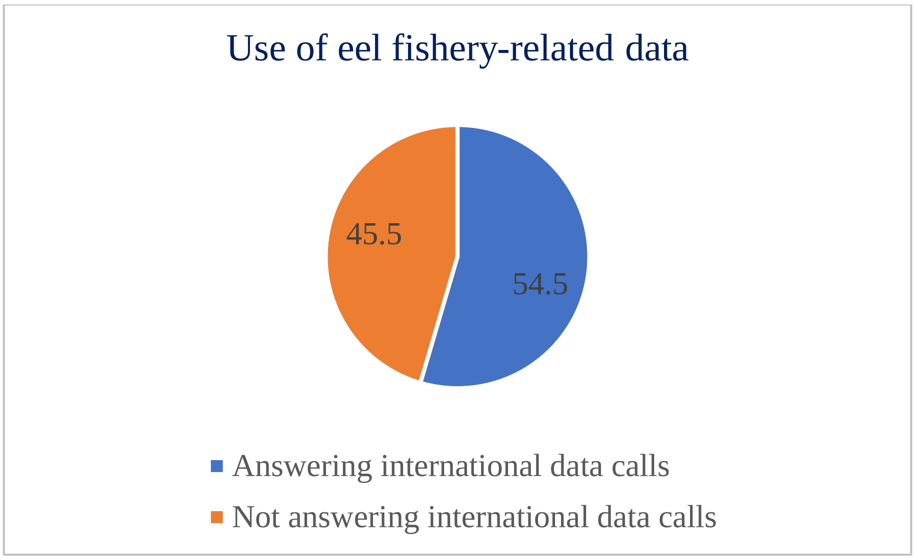

Figure 15.21. Percentage of respondent countries using eel fishery-related data for answering international data calls

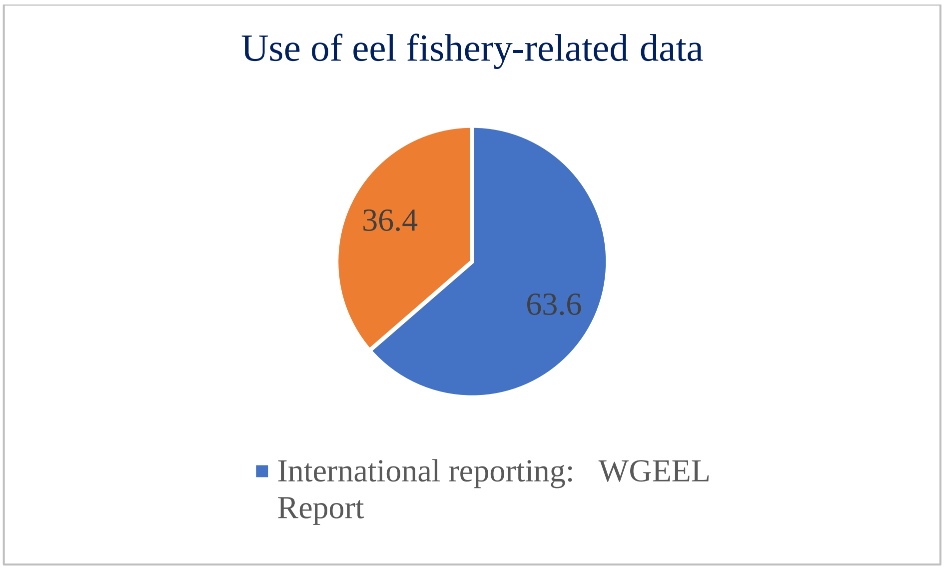

Figure 15.22. Percentage of respondent countries using eel fishery-related data for Working Group on Eels reporting

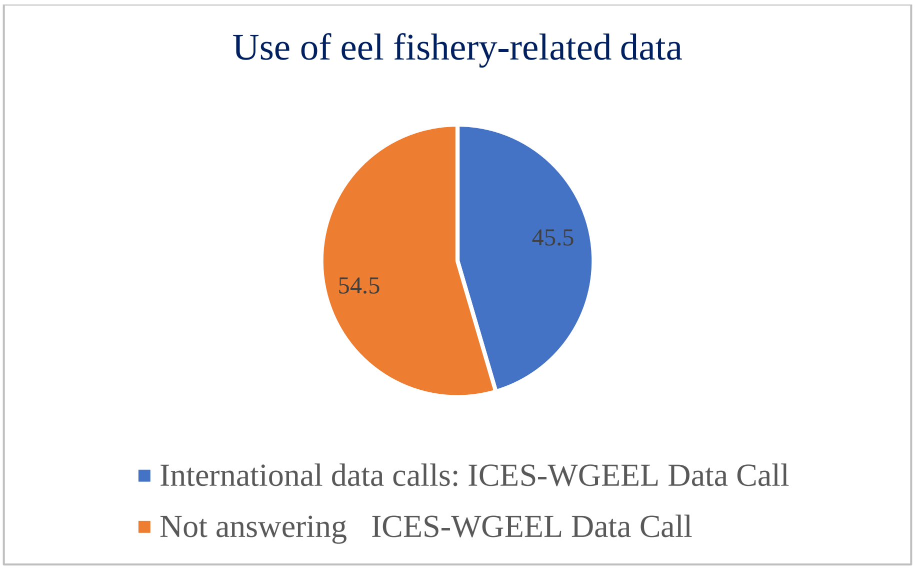

Figure 15.23. Percentage of respondent countries using eel fishery-related data for answering International Council for Exploration of the Sea (ICES) Working Group on Eels data calls (relative percentage of Respondent Countries)

15.3.4. Analysis of data officially reported by contracting parties and cooperating non-contracting parties to the GFCM through the data collection reference framework online platform

Present structure, functioning and data for Task VII.1 European eel

National authorities of CPCs have at their disposal a dedicated section of Task VII.6 European eel data that can be accessed from the homepage of the DCRF online platform (Figure 15.24).

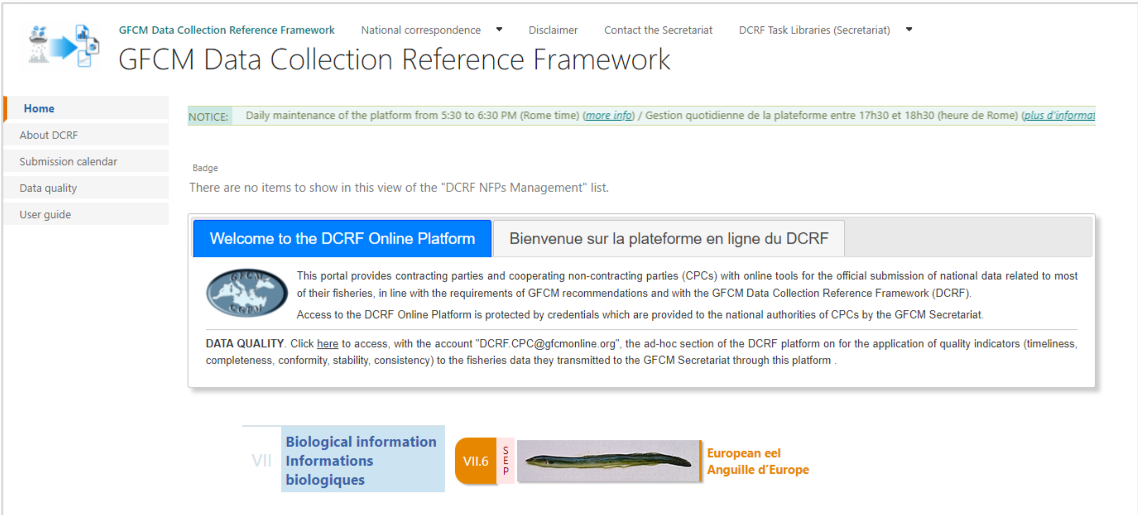

Figure 15.24. GFCM Data Collection Reference Framework online: homepage

Contracting parties and cooperating non-contracting parties can report relevant information under the eel section, in English and French, in the requested data fields as well as in country-specific Excel templates (Figure 15.25). Every year, at the approach of the submission deadline in September, these Excel-based reporting tools are released on the platform and CPC contacts are informed by the GFCM

Secretariat through the GFCM deadline reminder email system that provides CPCs with key information about GFCM data calls.

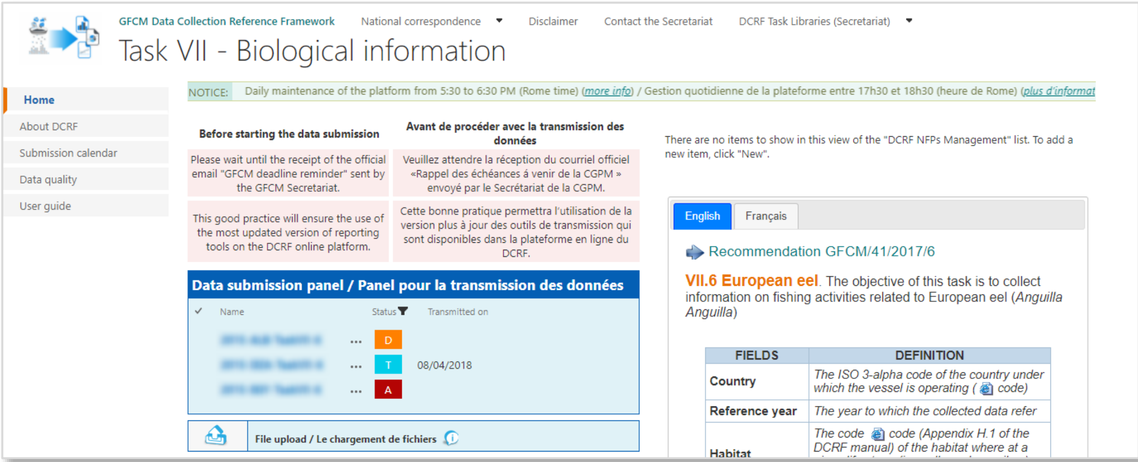

Figure 15.25. Data Collection Reference Framework online platform: Task VII.6 European eel

The DCRF Excel reporting tool for Task VII.1 European eel, in its first worksheet “Data-Données” (Figure 15.26), is structured on the basis of the data fields listed in Recommendation GFCM/41/2017/6 (GFCM, 2017). Contracting parties and cooperating non-contracting parties can work either online or offline by leveraging the features in both the online spreadsheet embedded in the platform and the download or upload commands. The Excel file supports both typed data-entry and copy–paste from external datasets (with the same data structure of the DCRF template), for example, from data exports generated through national information systems.

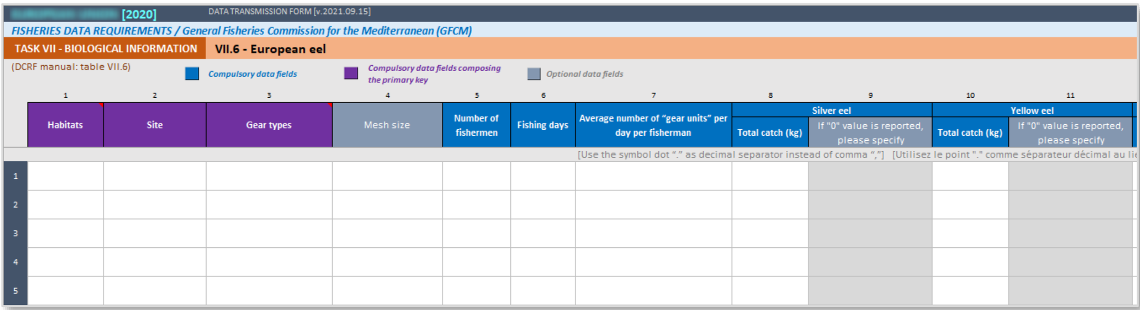

Figure 15.26. Data Collection Reference Framework Task VII.6 European eel reporting tool: worksheet for data entry

Contracting parties and cooperating non-contracting parties can access two dedicated worksheets that provide them with support to assess the status of their data before proceeding with the official submission to the GFCM: “Check-Contrôle” (Figure 15.27), with preliminary quality checks (completeness and conformity) field by field, and “Summary-Résumé” (Figure 15.28) where the data-entry summary is available for a quick review.

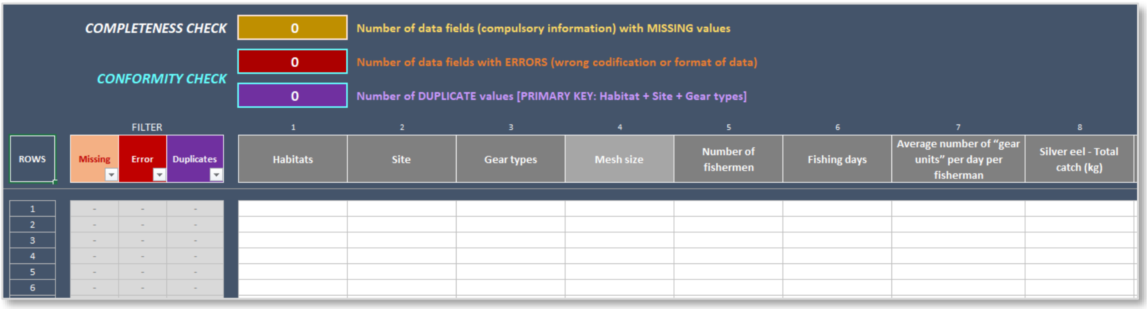

Figure 15.27. Data Collection Reference Framework Task VII.6 European eel reporting tool: worksheet for the data quality check

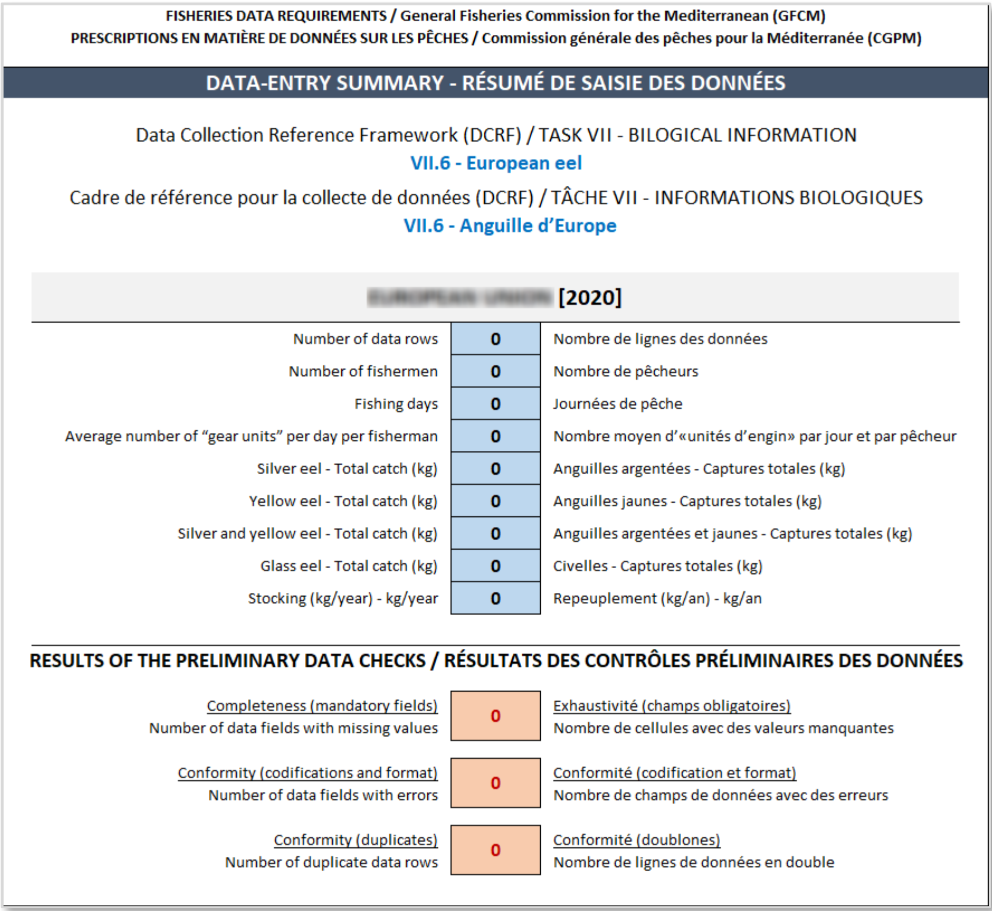

Figure 15.28. Data Collection Reference Framework Task VII.6 European eel reporting tool: data entry summary

Since 2018, data quality routines have started to be implemented on the DCRF online platform on the basis of the DCRF workflow which is composed by seven different steps (Figure 15.29).

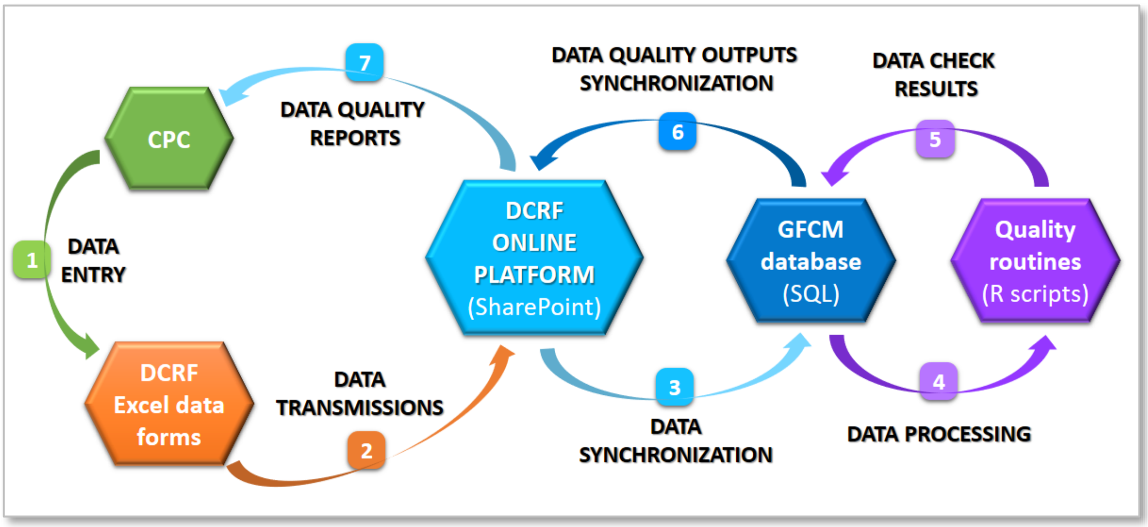

Figure 15.29. The Data Collection Reference Framework workflow: data quality routines

Once a CPC enters their national data (step 1) into the dedicated DCRF Excel-based system and then proceeds with official submission through the DCRF online platform (step 2), the data as received by the GFCM Secretariat are imported into the GFCM database (step 3). At this stage, the data are processed through an R-based package developed by the GFCM Secretariat to specifically address data quality assessments based on the indicators endorsed by the Scientific Advisory Committee on Fisheries and the Commission for the DCRF (step 4). The results of the data check based on the applicable quality routines are then stored in the GFCM database (step 5) and generate a CPC-specific online data quality dashboard, one for each indicator, that is securely stored in a special DCRF online platform repository (step 6). These dynamic data quality reports are finally put at disposal of CPCs with export and printout options (step 7).

Since 2017, when the first GFCM Recommendation on the submission of European eel data entered into force, 77 percent of the expected national datasets have been transmitted by CPCs to the GFCM.

The main reporting issues identified were missing values and wrong catch units (tonnes instead of kilograms) which affected several datasets including France (2017), Greece (2016 and 2017), Italy (2015 and 2017), and Spain (from 2015 to 2018).

Figure 14.30, Figure 14.31 and Figure 14.32 summarize European eel data as officially transmitted by CPCs and then currently stored in the DCRF database.

TOTAL EEL CATCH (Kg)	DATA REFERENCE YEAR						
	2015	2016	2017	2018	2019	2020	TOTAL
Albania		41 000	47 000	60 000	70 000	40 000	218 000
Algeria			17 338	26 860	15 661	22 600	59 859
Croatia		595	499	680	343	387	2 117
France	281 497	424 368	322	491 326	490 590	278 184	1 688 103
Greece		84	67	120 222	40 038	77 814	160 411
Italy	4 582	183 174	3 414	247 761			438 931
Montenegro			40 000	96 000	90 000		226 000
Spain	34	44	43	1 857	36 769	51 321	38 747
Tunisia				166 312	129 252		295 564
Turkey						320 000	
TOTAL	286 113	649 265	108 683	1 211 018	872 653	790 306	

Figure 15.30. Submitted European eel data: total catch volumes by country and year

Row Labels	Avg gear units (n)	Fishermen (n)	Fishing days (n)	Silver eel (Kg)	Yellow eel (Kg)	Silver and yellow eel (Kg)	Glass eel (Kg)	Stocking (Kg/Year)
2015	**836**	**1 083**	**2 266**	**58 813**	**227 230**		**70**	
Algeria								
France				56 833	224 664			
Italy	836	929	1 721	1 954	2 561		67	
Spain		109	545	26	5		3	
Tunisia		45						
2016	**972**	**1 890**	**2 277**	**291 258**	**357 960**		**47**	
Albania		125	115	40 000	1 000			
Algeria								
Croatia	433	12	42	0	595		0	
France				133 703	290 665			
Greece		302	165	84				
Italy	539	1 303	1 575	117 430	65 699		45	
Spain		108	380	41	1		2	
Tunisia		40						
2017	**1 471**	**2 315**	**3 944**	**67 526**	**41 005**		**152**	
Albania		125	115	47 000				
Algeria					17 338			
Croatia	853	13	79	0	499		0	
France				79	243			
Greece		316	165	67				
Italy	603	912	1 953	2 344	924		146	
Montenegro	15	85	340	18 000	22 000			
Spain		823	1 292	36	1		6	
Tunisia		41						
2018	**3 782**	**2 539**	**3 718**	**427 370**	**475 617**	**306 577**	**1 454**	**613**
Albania	4	120	120	0	0	60 000	0	0
Algeria					26 860			
Croatia	403	15	88	0	680	0	0	0
France				119 859	371 467			
Greece	232	307	220	57 963	2 148	60 111	0	0
Italy	488	1 116	1 769	84 086	39 673	123 759	243	0
Montenegro	14	97	385	20 000	28 000	48 000	0	0
Spain	37	738	468	0	646	0	1 211	613
Tunisia	2 604	146	668	145 462	6 143	14 707		
2019	**3 554**	**1 230**	**1 788**	**237 216**	**240 001**	**394 180**	**1 256**	**25 557**
Albania	4	120	120			70 000		
Algeria					15 661			
Croatia	1 283	14	102	0	343	0	0	0
France				57 365	187 975	245 250	0	23 015
Greece	232	258	210	19 605	414	20 019	0	0
Montenegro	12	103	400	20 000	25 000	45 000	0	0
Spain	9	601	894	24 415	6 977	4 121	1 256	2 542
Tunisia	2 014	134	62	115 831	3 631	9 790		
2020	**1 395**	**4 960**	**6 875**	**158 641**	**229 736**	**400 763**	**1 166**	**29 495**
Albania	4	120	120			40 000		
Algeria					22 600			
Croatia	697	35	159	0	0	387	0	0
France				93 851	184 333			28 198
Greece	232	338	196	38 697	210	38 907	0	0
Spain	21	330	992	26 093	22 593	1 469	1 166	1 297
Turkey	441	4 137	5 408	0	0	320 000	0	0
Grand Total	**12 010**	**14 017**	**20 868**	**1 240 824**	**1 571 549**	**1 101 520**	**4 145**	**55 665**

Figure 15.31. Submitted European eel data: fishing effort metrics, catches per life stage and stocking data

		DATA REFERENCE YEAR							
		2015	2016	2017	2018	2019	2020	TOTAL	
	Reporting countries →	5	8	9	9	6	6		
	Fishermen	1 083	1 890	2 315	2 539	1 230	4 960	**14 017**	Number
	Fishing days	2 266	2 277	3 944	3 718	1 788	6 875	**20 868**	Number
Avg of gear units (SUM)	Barrier				5	5	5	**15**	Meters
	Eel longlines			5	2 607	2 005	3	**4 620**	Number of hooks
	Fishing rod		1	1	1	275	222	**500**	Number of rods
	Gillnets		430	850	400	1 010	570	**3 260**	Meters
	Glass eel net								Number of nets
	Shore lift net								Number
	Spear fishing		1	1	1	2	6	**11**	Number
	Traps fyke nets	836	540	614	768	257	589	**3 604**	Number of fyke nets
	Umbrella								Number of umbrellas
	Silver Eel catch	58 813	291 258	67 526	427 370	237 216	158 641	**1 240 824**	Kg
	Yellow Eel catch	227 230	357 960	41 005	475 617	240 001	229 736	**1 571 549**	Kg
	Silver and Yellow Eel catch	n/a	n/a	n/a	306 577	394 180	400 763	**1 101 520**	Kg
	Glass Eel catch	70	47	152	1 454	1 256	1 166	**4 145**	Kg
	Stocking Kg/Year	n/a	n/a	n/a	613	25 557	29 495	**55 665**	Kg

n/a = not applicable (these data have started be requested from ref. year 2018 onwards)

Figure 15.32. Submitted European eel data: summary by year

Modification and sharing of European eel data transmitted to the GFCM

Contracting parties and cooperating non-contracting parties can access both the DCRF Task VII.6 European eel Excel-based reporting template to check their data before submission and the data quality dashboards on the DCRF online platform to check after submission to the GFCM.

Once the data have been officially submitted, they can be accessed by the GFCM Secretariat and remain at the disposal of the CPC that transmitted the data for consultation and download only, without being able to edit.

In line with existing GFCM data submission procedures, CPCs may submit requests for the modification of data already transmitted through the DCRF online platform. Such requests should be sent to DCRF@gfcmonline.org together with a clear justification specifying the rationale and the type of changes to be applied to the data. Upon receipt of the request, the GFCM Secretariat will change the transmission status of the relevant data set(s) from "T" (transmitted) to "D" (draft) and will inform the relevant CPC to proceed with the necessary amendments. Once the changes have been applied, the CPC should set the transmission status of the data set(s) back to "T" (transmitted). The system will then update the transmission date for that dataset automatically.

Contracting parties and cooperating non-contracting parties are responsible for the quality and completeness of the European eel data sent to the GFCM. Once received, data are then stored in the DCRF database and treated by the GFCM Secretariat in accordance with all necessary GFCM security and confidentiality provisions.

In line with the data confidentiality status set in Recommendation GFCM/41/2017/6 (GFCM, 2017), European eel data can be made publicly available to selected audiences, including the GFCM Working Group on the management of European eel (WGMEASURES-EEL) and the joint ICES/EIFAAC/GFCM WGEEL for the sake of facilitating the technical work of participating experts.

Together with other GFCM fisheries data, the European eel data are used in *The State of Mediterranean and Black Sea Fisheries (SoMFi)*, the biennial flagship publication prepared by the GFCM Secretariat based on the data regularly submitted by GFCM member countries.

Comparative analysis of Data Collection Reference Framework eel data and WP3 fisheries data

Within the RP, one of the main tasks was the collection of eel landings and fishing effort data, under WP3. Results have allowed the collection of data on eel landings from all countries, with varying degrees of completion for both temporal and spatial coverage. All the data collected have been verified and checked for reliability and consistency within the work of WP3, bringing together the efforts of scientific partners and national focal points. The resulting analysis is reported in Chapter 10 (eel landings), and data have been used for the assessment carried out within WP4 (Chapter 13: assessment), for the evaluation of potential management scenarios as a basis for discussion of a coordinated management framework for countries in the Mediterranean area.

Parallel to this, there has been a comparative analysis of data collected in WP3 and data officially reported to GFCM Secretariat through the DCRF online platform, in order to verify consistency of data, with the aim of unifying the data collection and storage framework, and to update the data. This comparative analysis also involved a quality check.

From the nine countries partners of the RP, seven countries have officially uploaded data on the DCRF online platform (Table 15.4, Figure 15.33). Türkiye started implementing the DCRF Task VII Eel in 2020, therefore, 2020 data were not yet available for the quality check process of the research programme. Egypt is not yet responding to the DCRF for eel, but the system is being implemented.

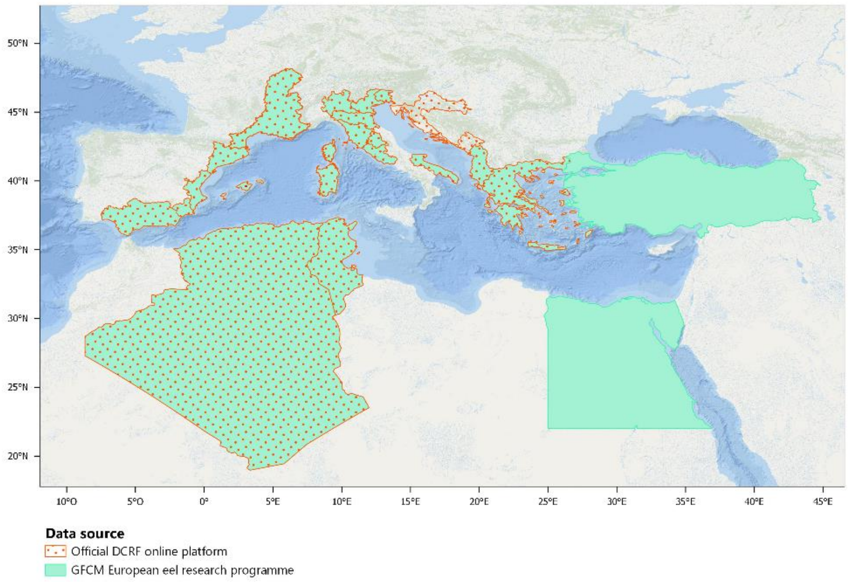

Figure 15.33. Mediterranean countries currently reporting eel fishery-related data to the online Data Collection Reference Framework platform and participating in the GFCM eel research programme.

Note: For Spain and France, data is only for the Mediterranean eel management units. Türkiye and Egypt have started DCRF eel data collection in 2020, but have not yet submitted data through the on-line platform.

Four out of seven countries that have submitted data (France, Spain, Greece and Italy) are reporting at the EMU level. In Italy, data collection and reporting is only for the nine EMUs where eel fisheries are present, as the other 11 regions have already closed their eel fisheries. In Albania, data are aggregated by habitat type, while in Tunisia and Algeria, data are reported at site level.

This heterogeneity in reporting of data is due to differences in the raw data collection methodologies being implemented, which are specific to each country.

A critical issue that emerged during analysis of WP3 data from several sources, was the temporal scale at which fishing data were collected and reported. The WP3 fishery database requested and aggregated fishery data based on the calendar year whereas the DCRF TaskVII.6 European eel table did not specify the temporal scale. This meant that countries were submitting data on the basis of their original data collection methodology, for either the calendar year or the seasonal year which might be based on the escapement or recruitment season for eels, depending on location.

Scientific partners were asked to clarify this aspect and Table 15.4 shows the timescale at which each country was collecting and providing data. The RP collected data based on the calendar year, except for Spain and France which submitted data by seasonal year. From the general point of view, it is possible to compare values within each country except for France, which shows a mismatch in the temporal scales (Table 15.2).

Table 15.4. Eel data collection temporal scales

	WP3 Fishery DB	DCRF Table VII-6
Albania	Calendar year	Calendar year
Algeria	*no information*	*no information*
Egypt	*no information*	*no information*
France	Calendar year	Seasonal year
Greece	Calendar year	Calendar year
Italy	Calendar year	Calendar year
Spain	Seasonal year	Seasonal year
Tunisia	Calendar year	Calendar year
Türkiye	Calendar year	Calendar year

Note: annual data are reported by calendar year (from the 1st January to 31st December) or seasonal year (according to the escapement/recruitment season for eels).

For the five countries with available data, a quality crosscheck was performed (Table 15.1, Table 15.2). Algeria and Greece did not provide the DCRF Task VII.6 European eel tables through their national focal points. The comparison highlighted some critical issues that should be considered in a future revision of DCRF Task VII.6 European eel (Table 15.5, Table 15.6, Table 15.7, Figure 15.34). The nature of the inconsistencies varied between countries and the critical issues varied over the years within each country. This was due to the fact that data collected for DCRF Task VII.6, as well as data submitted through the DCRF online platform, have undergone revisions, which were impossible to trace during quality checks.

Many inconsistencies were due to the data entry sheets being used in official data collection frameworks, which had data entry at different levels of aggregation, by life stage or habitat, and with different classifications of gear and habitats (Table 15.5). The quality check considered these mismatches as common issues.

In other cases (including Italy and Tunisia), in addition to the common issues, catch values were observed that did not match between the two data sources (Table 15.5). This inconsistency was due to the data quality check performed on the WP3 fishery databases (see Chapter 9 – Eel fishing effort and Chapter 10 – Eel Landings), that changed some data, or to the revisions that countries routinely carried out within their national data collection frameworks over time.

Some technical inconsistencies were also observed (Table 15.6), probably due to system problems in the upload and download routines of the online data platform. Table 15.7 and Figure 15.34 show some examples of critical issues related to the data, such as different units and advanced functions of the spreadsheets not working.

From a general point of view, for all countries, both scientific partners and national focal points, reported a lack of clarity in the needs and explanations relating to the requirements for filling the DCRF Task VII.6 European eel accurately and for operational procedures during online uploading. For this reason and recalling the importance of the DCRF manual (available online in English and French) to support CPCs in their data reporting duties to the GFCM, it could be useful to integrate the reference material and organize information webinars. An interaction between national focal points and eel scientists within CPCs could also guarantee more efficient compliance in both data collection and its transmission. In this sense, it would be advisable to create within the GFCM a network of eel scientists who can coordinate the actions related to eel, on both the national and international side.

Table 15.5. Countries reporting eel landing data on the Data Collection Reference Framework online platform; data years available and performance of the quality check

Country	DCRF country	Online platform data available on June 2021	Quality check
Albania	Yes	2016–2019[a]	Yes
Algeria	Yes	2015–2019[a]	Not complete: official data not reported through the national focal point
Egypt	No	no data	No
France	Yes	2015–2019[a]	Yes
Greece	Yes	2016–2019[a]	Not complete: official data not reported through the national focal point
Italy	Yes	2015–2019[a]	Yes
Spain	Yes	2015–2019[a]	Yes
Tunisia	Yes	2015–2019[a]	Yes
Turkey	Yes	no data[b]	np

Notes: [a] Data 2020 not yet uploaded (deadline 30 September 2021).
[b] Country's first year of data collection: 2020; data not yet uploaded (deadline 30 September 2021).

Table 15.6. Issues encountered in the quality check between the data collected in the Work Package 3 databases and the data officially transmitted through the DCRF online platform

Common issues:
Mismatch of landing values: revised values or technical issues
Catches reported at a different level of aggregation: sites, eel management unit, region
Mismatch of catches per life stage
Mismatch of catches per gear type
Mismatch of catches per habitat type
Mismatch of fishing effort values

Table 15.7. Technical issues identified in the current Data Collection Reference Framework Table VII.6 European eel template

Technical Issues:
Unit of measurement not explicit (tonnes vs kg)
Advanced functions not working
Temporal framework not explicit: e.g. "calender year" vs "eel season year"
Table requirements not explicit, issues encountered changing “within country” data over time

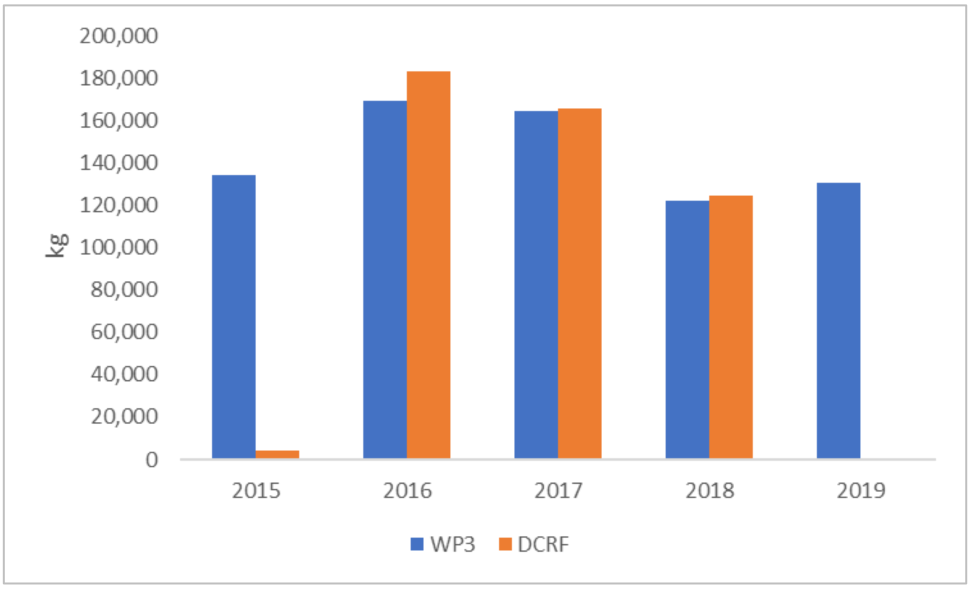

Figure 15.34. Comparison between total landings as reported within Work Package 3 and the official landings reported on the Data Collection Reference Framework online platform, over the period, 2015–2019

Note: Issues encountered in the quality check included mismatch of values due to a revision by the country and internal technical issues in the DCRF online platform.

Table 15.8. Examples of technical issues: Data Collection Reference Framework Task VII.6 European eel Table "Summary_résumé spreadsheet" with the advanced functions not working

DCRF summary-résumé sheet_check Italy (2018)			WP3 – WP5 quality check - comment
Number of data rows	**22**	Nombre de lignes des données	**OK**
Number of fishers	**972**	Nombre de pêcheurs	**OK, SUM**
Fishing days	**1 497**	Journées de pêche	**OK SUM, BUT if annual data: 1497 days of fishing over 365 days/year?**
Average number of "gear units" per day per fisher	**69 063**	Nombre moyen d'«unités d'engin» par jour et par pêcheur	**NO - it is not the average of "gear units", but the sum of S**
Silver eel – total catch (kg)	**69 063**	Anguilles argentées – captures totales (kg)	**OK**
Yellow eel – total catch (kg)	**169 727**	Anguilles jaunes – captures totales (kg)	**NO - it is not the sum of Y, but of Y + YS**
Silver and yellow eel – total catch (kg)	**119 638**	Anguilles argentées et jaunes – captures totales (kg)	**NO - it is the sum of Y + S + G**
Glass eel – total catch (kg)	**243**	Civelles – captures totales (kg)	**OK**

Inputs from Work Package 3 - fishing gear and fishing effort

Collection of data on fishing methods and fishing effort was also carried out under WP3 to complement quality checking of landings data. Detailed results are reported in Chapters 8 and 9 and these suggest factors that need to be considered, in particular relating to the recording of fishing effort and its possible use, within the DCRF TaskVII.6 European eel framework.

Table 15.9 shows the list of fishing gear in use in partner countries, based on WP3 work, along with the list given in Appendix H of DCRF TaskVII.6 European eel (GFCM, 2018). The first issue is inconsistency in the list of gear types. One of the main gear is the eel fence, used by fishers in seven of the nine partner countries but not present in the DCRF list, as well as pond nets and eel pots that are used in a few countries. Other gear included in the DCRF list for commercial fisheries, have been reported and described by partners as only being used for recreational fisheries. There are also possible mismatches for other gear such as gillnets and non-specific nets, as well as umbrella and snigging. Therefore, a final agreement on the complete list of gears should be made, to be implemented in Appendix H.

Table 15.9. List of gear (names and codes) in use for eel in partner countries, their use in commercial (Com) and Recreational (Rec) fisheries, and gear listed in Appendix H to Data Collection Reference Framework TaskVII.6 European eel

Gear type	Code	Albania	Algeria	Egypt	France	Greece	Italy	Spain	Tunisia	Türkiye	DCRF gear list
Glass eel net	GEG /GEN						Com	Com			Yes
Fyke net	FYK		Com		Com	Com	Com	Com	Com	Com	Yes
Fence	FEN		Com		Com	Com	Com	Com	Com	Com	No
Eel longline	ELL	Com		Com	Com	Com	Com	Com	Com	Com/Rec	Yes
Barrier	BAR	Com				Com	Com	Com	Com	Com	Yes
Pots and traps	EPO				Com/Rec		Com			Com	No
Pound net	PON							Com			No
Non-specific net	NTS	Com					Com		Com		No
Other	OTH								Com		No
Fishing rod	FRD				Rec		Rec	Rec		Rec	Yes
Shore lift net	SNL /SLN						Rec				Yes
Snigging	SNI						Rec				No
Spear fishing	SPF						Rec				Yes
Gillnets	GLN										Yes
Umbrella	UMB										Yes

Appendix H of DCRF TaskVII.6 European eel (GFCM, 2018) also indicates the gear units for reporting, either dimensions (meters) or numbers (number of hooks, rods, nets). The descriptive analysis of fishing methodologies given in Chapter 8 (eel fishery), highlights that within each gear type, there is great variability in shapes, materials, structures and mesh sizes, depending also on the habitat type, specific features of the fishing sites and on local fishing traditions. At this stage, the analysis of fishing methodologies did not allow a review of the classification and categorization of gear based on characteristics and dimensions. To do this, it would also be necessary to analyse the actual ranges of variability and also to verify whether further classification is actually necessary.

As highlighted in this chapter, the great variability in methodologies involved in fishery-related data collection also entails that data relating to fishing effort are being addressed differently between partner countries. This is also clear from the results reported in Chapter 9 that attempted the quantification of the fishing effort for both commercial and recreational eel fisheries. Reliable and exhaustive data on the number of fishers, number of licences, number of gear and fishing time (measured in months, days, and hours) were difficult to assess. Data provided by RP partners were disparate, scattered and of varying quality because of the differences in methodologies for collection of effort data, while the units used were not always consistent. Nevertheless, a first descriptive overview was obtained, that will also make it possible to address data relating to fishing effort in the future.

For the moment, the subgroup working on eel fishing gear and fishing effort recommend the collection of detailed information on habitat and life stage, as well as the following parameters from all sites where eel is caught, either as a target or as a bycatch species:

- Longlines: total number of hooks used per licence, distance between two hooks, hook size, soak time per fishing operation, number of fishing operations per day, number of fishing days per trip, number of licences and landings per trip.
- Eel pots: total number of pots used per licence, distance between two pots, mesh size, soak time per fishing operation, number of fishing operations per day, number of fishing days per trip, number of licences and landings per trip.
- Fyke nets and fences: minimum mesh opening, number of pockets (codends) per gear, pocket dimensions (diameter, length), number of gear per licence, total gear dimensions, landing per effective fishing operation, soak time, number of licences.
- Barriers: number of chambers or rooms, chamber or room dimension, minimum mesh size, landings per fishing operation, effective number of fishing days.

Considering the importance of recording and estimating fishing effort towards the aim of evaluating changes in eel catches, effort and catch-per-unit effort (CPUE) over time, as highlighted by the work of WP4 (Chapter 13 – Assessment), and hence key information to develop and implement a management plan for eel, it is proposed that the collection of data on these parameters should be integrated into the workplan of Task VII.6 European eel.

Additional data to collect for purposes of assessment: scientific monitoring surveys

The DCRF Task VII.6 European eel should be implemented with a dedicated system for assessment-related input of data. This recommendation comes from the overall discussion of the needs for data collection on eel, as well as the outcomes of WP2 (Chapter 14 – Eel monitoring) and WP4 (Chapter 13 – Assessment). It also takes into account the criteria for selection of stocks that should be subject to annual assessments as European eel fulfils most of the needs to include some stocks or species in Subtask VII.1 Stock assessment input data of the DCRF.

The need for fishery-independent monitoring surveys in the Mediterranean region to correctly assess the eel stock on a long-term basis is crucial. Additional data are needed, both concerning biological variables, collected on a consistent basis with standardized methodologies, and specific indicators of glass eel recruitment, as well as yellow eel standing stock and silver eel escapement. It is recommended that each country carries out the following programme:

- Collect eel information annually, in at least one site per eel habitat type: lagoon, river or lake (lakes only if it represents an important habitat for eels in that country), on glass eel recruitment, yellow eel standing stock and silver eel escapement (number or weight per unit of effort, including time, gear, volume or surface area of water).
- Record biological data for each eel stage based on a representative sample. For glass eels: body length and weight, pigmentation stage. For yellow and silver eels: body length and weight, and when possible, for eel greater than 30 cm, horizontal and vertical diameters of the left eye and length of the left pectoral fin.
- Considering the need to limit the sacrifice of animals, sampling and measurements should be carried out using anaesthesia (individuals will be released once recovered in the same site) and imaging techniques (use of photography and image processing software). For a representative sample of yellow and silver eels: data on age and sex will be provided (in addition to the biometric data) every year for fishery-dependent sampling and every three years for fishery-independent sampling. When animals are sacrificed, age readings will be integrated with analyses for evaluation of the prevalence of the parasite *Anguillicola crassus*, muscle lipid levels and pollutant concentrations.
- Where possible, the three eel stages (glass, yellow, silver eel) will be monitored at the same site. When not possible, they will be monitored at different sites, but information should be provided for the three stages.
- Within each country, the selected sites should be, as much as possible, representative of the habitat category selected.
- The description of the site and the protocol used for the collection of these data will be provided.

The final plan for collection of standardized fishery-independent data for specific indicators shall be agreed and coordinated at national and sub-national (EMU, administrative region, local) levels with relevant parties, including national administrations, eel experts and scientists in the country, taking into account the following:

- The selection of the sites will give priority to sites where long-term or mid-term monitoring are already in place with standardized methodologies (see WP2, Chapter 14 – Eel Monitoring).
- Implementation of fishery-independent monitoring will ensure a long-term perspective, for example, the possibility of monitoring for at least ten years to evaluate the trends.
- Standardized methods will be used, based on the review performed in the RP (WP2, Chapter 14 – Eel Monitoring). The final protocols shall be chosen based on resources, but they will be selected in order to be adapted to habitat type and local conditions, to reliably represent glass eel recruitment, yellow standing stock and silver eel escapement at the site. Standardized methods will also consider a suitable time scale, adapted to the seasonality of eel presence and migration of life stages, and the need to collect data over the same season with the same effort every year.
- A minimum sampling scheme will be planned by each country (three sites, one for each habitat type, and separately for each stage, for a total of nine surveys per year), but possibly enforcing implementation of additional monitoring to include more sites, especially for lagoon habitats (the most important eel habitat in the Mediterranean region), depending on resources and on-going research.
- This task is addressed to all countries operating in the GFCM area of application.
- Results from this additional data collection should be transmitted by countries annually via the DCRF online platform and by experts via email to the GFCM Secretariat.
- Data will be transmitted pertaining to year n-1, one month in advance of any meeting or data call on eel, such as the annual joint ICES/EIFAC/GFCM WGEEL meeting and related data calls for annual evaluation of the eel stock through its whole distribution area, as well as any

other relevant events. This means that the data transmission date may differ from year to year according to the scheduling of these meetings.

- Information transmitted by countries through the DCRF online platform will be made available to experts participating in the joint ICES/EIFAC/GFCM WGEEL and to any other eel-related working group.
- Data collection and data transmission of all eel-related data, both fishery-dependent and fishery-independent, will be facilitated by the establishment of a GFCM network (as an internal GFCM working group: the GFCM Working Group on Mediterranean Eel [WGME]", composed of eel expert scientists working on eel in the GFCM area), that shall interact with national administrations, national focal points and the GFCM Secretariat.

15.4. DISCUSSION AND CONCLUSIONS

The results of this chapter and of the RP, provide the basis to discuss a revision of DCRF Task VII.6 European eel and its implementation, to fulfil the needs of European eel assessment and management in the Mediterranean, in coordination with other frameworks and end-users, including the WGEEL.

Most partner countries, as well as some other CPCs not participating in the RP, perform eel fishery-related data collection and these countries include those where there are important eel fisheries. Eel fishery-related data collection stems from many different data collection frameworks, such as national statistical systems and EU data collection frameworks. As a result, methodologies have been extremely variable between countries. Therefore, a standardization of fishery-related data collection is recommended, taking into account the following:

- Address all fishers or fisher cooperatives specifically authorised to fish for eel or practicing eel fisheries under any regulatory framework (national, regional, in marine transitional and inland waters).
- Cover all eel sites in all eel habitats (lagoons, rivers including river estuaries and lakes).
- Rely on mandatory logbooks or exhaustive declarations by fishers. The definitive structure of logbooks is to be prepared by a network of eel scientists in collaboration with national focal points and national administrations.
- Data collection should be implemented on a monthly or quarterly basis (to be agreed), in order to allow aggregation of data at any time scale (year, season), at the site level in order to have the prospect of long-term time series and to allow aggregation at any level (habitat, EMU, country)
- The data to be collected should include total landings per month or quarter (to be agreed), separately for each life stage and disaggregated by fishing gear (making reference to the revised list of gear) as well as detailed information on fishing effort including detailed gear characteristics, dimensions, mesh size, mean number of gear per day for each month or quarter, number of fishing operations (trips) per day or quarter and total number of fishing days in the month or quarter. For barriers, information should detail total dimensions, number of chambers or rooms, the dimensions of chambers or rooms, minimum grid size, landings per fishing operation, effective number of fishing days per month, number of days of opening per month.
- A quality check of raw data prior to uploading should be carried out, as well as a revision of internal quality check routines, supported by eel scientists at the national level, interacting with national administrations. National eel experts shall also participate in the GFCM network of experts, to facilitate coordination between countries.

The possible integration of the DCRF Task VII.6 European eel with a dedicated system for assessment-related input data is suggested, as described above. To correctly assess the eel stock on a long-term basis, there is a need for fishery-independent monitoring surveys to be implemented in the Mediterranean Region. This will provide additional data on biological variables, collected on a consistent basis with standardized methodologies, as well as specific indicators of recruitment, yellow eel standing stock and silver eel escapement. The resulting data will allow CPCs to contribute to eel stock assessment at the global level.

Therefore, it is recommended that European eel should be included in Subtask VII-I Stock assessment input data of the DCRF. The additional data required for the assessment should be collected through scientific monitoring surveys, as already detailed. Possible implementation frameworks should be discussed, also as a requirement of Eel management plans at the Mediterranean level,.

Most RP partner countries (and other CPCs) submit eel fishery-related data to the GFCM online platform, even if compliance is not yet complete in terms of years and coverage. Quality checks have highlighted discrepancies in most countries between the available fishery data and the data submitted to the online platform. Based on the GFCM data submission procedures, it is recommended that:

- All partner countries submit requests for modification of data already transmitted through the DCRF online platform, specifying that the rationale behind the request is the quality check and data revision performed within a specific task of the eel programme.
- Following the enabling by the GFCM Secretariat of the transmission of amendments, the definitive data set should be uploaded.
- Partner countries that are not fully compliant, as well as other CPCs, should proceed to a quality check and transmission of the definitive data.
- Quality checking, revision and transmission of amendments should be facilitated by interactions between the network of GFCM eel scientists and national administrations, national focal points and the GFCM Secretariat.

The use of fishery-related data currently addresses needs at the national and international level, as well as answering specific eel data calls by ICES, the GFCM and the European Union. Dates of data transmission to the GFCM are presently non-specific and submissions to eel data calls, especially to joint ICES/EIFAAC/GFCMWGEEL data calls for non-European Union countries, are dealt with independently by eel scientists involved in the joint ICES/EIFAAC/GFCM WGEEL. A higher level of consistency, awareness and coordination is needed, involving both European Union and non-European Union countries. It is therefore recommended that:

- Data transmission deadlines for eel-related data be revised, in order to be coordinated with the existing data calls, and eventually adapted from year to year depending on additional or alternative requests by end-users. The transmission of eel-related data, both fishery-related and from scientific surveys, in answer to data calls, should be performed by CPCs directly involving eel national experts for checking and compilation of tables and annexes that will eventually be needed.
- The definitive format of tables related to DCRF Task VII.6 European eel should be revised, to be more consistent with the format of annexes, tables and metadata information of the on-going data calls, in order to facilitate information exchange. Specific work in this sense should be planned, based on the data checks performed within the GFCM RP, and specific consultations should be held immediately after the end of the programme.

A general lack of clarity was highlighted both by scientific partners and focal points, on how to fulfil the reporting requirements of eel fishery-related data collection. It is therefore recommended that:

- Informative seminars and webinars be organized, addressed to national focal points and eel scientists in CPCs.
- A GFCM network of eel scientists is established to coordinate the actions related to eel in both national and international programmes.

The work carried out under the WP5 RP has highlighted the need for changes to the present structure of DCRF Task VII.6, both to improve the fishery-related data collection and to widen its scope. The need for data collection and data transmission of all eel-related data (both fishery-related and monitoring data) will be facilitated by the establishment of a GFCM network (as an internal GFCM Working Group: GFCM WGME, composed of eel expert scientists working in the GFCM area), that shall interact with national administrations, national focal points and the GFCM Secretariat.

The review of the current GFCM data requirements for European eel under the DCRF carried out in this task comprises the first step towards discussing a revision of DCRF Task VII.6. This will fulfil the need to assess and manage European eel in the Mediterranean, in coordination with other frameworks and end-users, including the joint ICES/EIFAAC/GFCM WGEEL. Some of the proposed changes, based on the discussions of the 2022 GFCM Working Group on the management of European eel (WGMEASURES-EEL) are aimed at amending Recommendation GFCM/41/2017/6 on the submission of data on fishing activities in the GFCM area of application in its data fields list for European eel (Table 15.10), whereas other proposals address both the list of gear types (Table 15.11) and the fishing effort parameters in the DCRF manual (Table 15.12).

The proposed amendments to Annex 1 of Recommendation GFCM/41/2017/6 include adding two new data fields, “quarter” and “fishing effort”, as well as more closely defining reporting requirements for several fields, and deleting the data fields “mesh size”, “fishing days”, “average number of gear units per day per fisher” and “total catch of silver and yellow eels” (Table 15.10).

Table 15.10. Proposed amendments to Annex 1 of Recommendation GFCM/41/2017/6 on the submission of data on fishing activities in the GFCM area of application (new fields in green, deleted fields in red)

DCRF DATA FIELDS (Biological information - European eel)	MANDATORY (X)	DATA CONFIDENTIALITY STATUS[a]
Quarter	X	P
Habitat	X	P
Site	X	P
Number of fishers (by site)	X	S
Gear type	X	P
~~Mesh size~~		~~S~~
~~Fishing days~~	~~X~~	~~S~~
~~Average number of “gear units” per day per fisherman~~	~~X~~	~~S~~
Total catch of silver eel (by gear type)	X	P
Total catch of yellow eel (by gear type)	X	P
~~Total catch of silver and yellow eels~~	~~X~~	~~P~~
Total catch of glass eel (by gear type)	X	P
Stocking lifestage	X	P
Stocking (kg/year)	X	P
Fishing effort	X	S

Note: [a] “Chapter 9 – Data confidentiality and access policy” of the DCRF manual

The proposed amendments to Appendix H.2 – Gear types for the European eel fishery of the DCRF manual add several additional gear types and codes, including “fence”, “non-specific net”, “pots and traps”, “pound net”, “snigging” and "other" (Table 15.11)

Table 15.11. Proposed amendments to Appendix H.2 – Gear types for the European eel fishery of the Data Collection Reference Framework manual (changes in green)

Gear types	Gear code
Barrier	BAR
Eel longlines	ELL
Fence	FEN
Fishing rod	FRD
Glass eel net	GEN
Gillnets	GLN
Non-specific net	NTS
Pots and traps	EPO
Pound net	PON
Shore lift net	SLN
Snigging	SNI
Spear fishing	SPF
Traps fyke nets	FYK
Umbrella	UMB
Other	OTH

A new proposed field “fishing effort” will imply the addition to the DCRF manual of a new reference table (Table x) providing details about the fishing effort by eel fishing gear type.

Table 15.12. New reference table to be added to the DCRF manual

Gear type	Fishing effort parameters
Barrier	Total dimensions
	Number of rooms
	Rooms dimension
	Minimum grid size
	Landing/fishing operation
	Effective number of fishing days/month
	Number of days of opening/month
Eel pot	Total number of used pots/license
	Distance between two pots
	Mesh size
	Soak time per fishing operation
	Number of fishing operation/day
	Number of fishing days/trip
	Number of licenses
	Landing/trip
Fyke nets + Fences	Minimum mesh opening
	Number of pockets (codends)/gear
	Pockets dimensions (diameter, length)
	Number of gear/licences
	Total gears dimensions
	Landing/effective fishing operation
	Soak time
	Number of licenses
Longline	Total number of used hooks/licences
	Distance between two hooks
	Hook size
	Soak time per fishing operation
	Number of fishing operation/day
	Number of fishing days/trip
	Number of licences
	Landing/trip

European eel should be included in DCRF Task VII.1 Stock assessment input data. Given the relevance of the European eel species to the Mediterranean region, the implementation of the DCRF Task VII with a dedicated system for European eel assessment-related input data (DCRF Task VII.1 Stock assessment input data) is proposed. This system should rely on specific monitoring surveys to provide additional data both concerning biological variables, collected on a consistent basis with standardized methodologies, and specific indicators of recruitment, yellow eel standing stock and escapement.

A GFCM working group on Eel in the Mediterranean should be established. A network composed of eel expert scientists in the GFCM area is proposed as an internal GFCM working group, the GFCM WGEM. By interacting with national administrations, national focal points and the GFCM Secretariat, this working group will address the need for coordination of data collection and data transmission for all eel-related data (both fishery-related and monitoring data), while also facilitating interactions between and among CPCs and the joint ICES/EIFAAC/GFCM WGEEL.

15.5. REFERENCES

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Supplementary Material on the Methodology Part I – Exploratory questionnaire on fishery-related data collection submitted to national focal points

Research programme on European eel: towards coordination of European eel stock management and recovery in the Mediterranean

Work Package 5 – GFCM-DCRF Task VII.6 European eel

Exploratory Questionnaire on FISHERY-RELATED DATA COLLECTION

The purpose of Questionnaire is to have first exploratory overview and gathering information on the Administrations involved in the DCRF within Countries, and of Scientific Institutions dealing with eel data collection specifically.

NATIONAL INSTITUTIONAL FRAMEWORK à General for fisheries at the national level

1. Institution officially responsible for the overall fishery data collection in your country (thereafter named "Fishery Data Collection Office")

a. Name

b. Contact details

2. Does the fishery data collection office directly collect the data related to European eel fisheries ?

YES ☐ NO ☐

a. If no, please specify name and contact details of the Institution officially in charge to collect data on European eel

3. Is there any national or local (regions, fishery organizations etc) framework/programme for data collection on European eel fisheries in place?

YES ☐ NO ☐

a. If yes, please provide general information (name and objectives) about such framework or programme/s for data collection on European eel, also indicating in which year it started.

b. If yes, is there a coordination framework for these programmes ? Specify which (for example: National coordination of local/regional/fishery organisations within Eel Management Plans etc.)

5. Is your country a member of or participating in any regional or sub-regional project/programme/organization dealing with data and/or information systems on European eel fisheries ?

YES ☐ NO ☐

a. If yes, please provide the name of the project/programme/organization.

6. Does your country regularly report data on European eel to regional/international organizations?

YES ☐ NO ☐

a. If yes, please provide

- the name of the regional/international organizations
- the frequency of the data transmissions (biennial, annual, etc.)
- the month of the year of the data transmissions

NATIONAL INSTITUTIONAL FRAMEWORK à DCRF Specific

1. Institution officially responsible for the DCRF in your country

a. Name

b Contact details

2. Does the Institution officially responsible for the DCRF in your country directly collect data or is the Institution only responsible for data compilation and transmission ?

Direct collection ☐ Only compilation and transmission ☐

3. If the Institution only transmits data, which is/are the Institution/Institutions responsible for DCRF eel data collection ?

a. Name

b. Contact details

4. Is there a coordination between DCRF and the National eel data collection system ?

YES ☐ NO ☐

If yes, specify the coordination framework and mechanism:

Supplementary Material on the Methodology Part II – First questionnaire on eel fishery-related data collection submitted to national focal points

Research programme on European eel: towards coordination of European eel stock management and recovery in the Mediterranean

Work Package 5 – GFCM-DCRF Task VII.6 European eel

Questionnaire 1 - EEL FISHERY-RELATED DATA COLLECTION

The purpose of the present Questionnaire is to collect information on the methods for collecting eel fishing data at the National level, also in compliance to the GFCM-DCRF **Task VII.6 European eel**. The Questionnaire is addressed to the Officers/Scientists actually carrying out technical activities for eel fishery-related data collection, processing and transmission to National Authorities.

COUNTRY: ___________________________

REGION/ADMINISTRATIVE UNIT/MANAGEMENT UNIT: ______________________________

COMPILER: Name ________________________ Institution _______________________________

e-mail ________________________ Telephone _______________________________

Section A - GENERAL PURPOSE OF THE EEL FISHERY DATA COLLECTION IN PLACE

Please tick the box of interest. If necessary, tick several boxes

☐ Specifically for GFCM-DCRF

☐ For National purposes à ☐ National statistical system

☐ Local statistical system, specify ________________________

☐ Other, specify ____

☐ For EU frameworks à ☐ EU-Map

☐ Eel Regulation

☐ WFD

☐ Other, specify ______________________________________

☐ For other frameworks, specify ____

Section B - *GENERAL METHODOLOGY FOR THE COLLECTION OF RAW DATA*

Please tick the box of interest. If necessary, tick several boxes

- Is there a protocol / standard operating procedure? ☐ Yes ☐ No

If Yes: ☐ The procedure was established on purpose for eel fisheries

☐ The procedure was adapted from protocol in place for other fisheries

(specify: ____)

- Is the system ☐ Fishery-dependent ☐ Fishery-independent

B1 *For fishery-dependent systems, raw data are collected based on:*

Please tick the box of interest. If necessary, tick several boxes

☐ Registrations à in this case: ☐ fishers ☐companies ☐vessels

☐ Logbooks à in this case: ☐ catch reports ☐ specifically designed logbooks

☐ Questionnaires à ☐ filled by respondents à ☐ posted ☐ handed ☐ sent by mail

à Is there a check for errors or no response? ☐ Yes ☐No

☐ filled by a interviewer

☐ Interviews à ☐ structured interview ☐ open interviews

à ☐ individual interview ☐ panel interview with a group of fishers

à Who carries out the interview? Specify _______________________________

☐ Direct observations of à ☐ landings ☐ markets ☐ catch samples

à Who carries out observations? Specify _______________________

☐ Other, specify ____

B2 *Coverage of the surveys*

Please tick the box of interest. If necessary, tick several boxes

- Collection of raw data targets:

☐ all fishers ☐all companies ☐fleets

☐ samples of fishers à how is the sample extracted? Specify ___________________________

- Participation of fishers to the survey is ☐ mandatory ☐ voluntary

- Collection of raw data is carried out in:

☐ all fishing sites

☐ specific sites à how are the sites chosen? Specify ______________________________

- Collection of fishery data addresses:

Eel by life stage: ☐ Glass eel ☐Yellow eel ☐Silver eel

Cumulated life stages: ☐all stages ☐Glass eel + yellow eel ☐Yellow eel + Silver eel

- Time scale of the surveys

☐ day ☐ week ☐ month

☐ several months: specify: two-months, quarter, semester, other _______________

☐ annual

- Spatial scale of the survey

☐ Fishing site ☐ Catchment: river/river stretch/lake/lagoon

☐ Management Unit (MU) à ☐ MU established for eel ☐ MU established for other purposes

(specify:__________________________)

☐ Administrative Region

☐ Other administrative unit: specify ____

** If possible, provide list or map*

B4 Methodology for fishing effort

Please tick the box of interest. If necessary, tick several boxes

- Does the survey address recording of fishing effort? ☐ Yes ☐ No

- If Yes, which are the data recorded:

☐ Type of fishing gear à is there a reference list of fishing techniques? ☐ Yes ☐ No

Eventually specify _______________________, *possibly provide the list*

☐ Size of the gear ☐ Material ☐ Mesh ☐ Other, specify __________________________

☐ Number of each type of fishing gear

- Is the fishing time addressed? ☐ Yes ☐ No

- If Yes, which are the data recorded:

☐ Length of time of installation/functioning of the gear

☐ Fishing days ☐ Fishing hours

☐ Other: specify ____

B5 For fishery-independent systems

Please tick the box of interest. If necessary, tick several boxes

Are these methods used: ☐ regularly for GFCM-DCRF ☐ Occasionally

specify purpose ____________________

☐ regularly for other frameworks (specify:______________________________)

☐ never used

- What raw data are collected:

☐ Abundance à ☐ Numbers ☐ Biomass

(specify unit:_____________________________)

☐ Biological data: specify ___________________________________

☐ Other: specify: ____

- What methods are used:

☐ Electrofishing

☐ mark-recapture

☐ new technologies (acoustic cameras, sensors, etc: specify _____________________________)

☐ Other (specify:____________________________________)

Additional details: ____

B6 Collection of other data

Please tick the box of interest. If necessary, tick several boxes

- Are data on eel local stocks collected? ☐ Yes ☐ No

If Yes à which data are collected: specify ____

- What is the use of data on local stocks?

☐ for GFCM-DCRF: specify ____

☐ for assessment

☐ for other uses: specify ______________________________________

- Are socio-economic data recorded? ☐ Yes ☐ No

If Yes à which data are collected: specify ____

Section C - STORAGE, SYNTHESIS AND ANALYSIS OF EEL FISHERY DATA COLLECTED FOR GFCM-DCRF TASK VII.6 EUROPEAN EEL

Please tick the box of interest. If necessary, tick several boxes

- How are data archived? ☐ Paper logbooks ☐ Electronic database ☐ On-line system

☐ Other archive, specify ___________________________________

- Where are data actually stored? specify

____

- Who is responsible for data keeping?

____

- Is there a quality check of raw data collected? ☐ Yes ☐ No

If Yes à specify ____

- Are the data statistically processed? ☐ Yes ☐ No

If Yes à Who performs the statistical processing? Specify __________________________

If Yes à What is the purpose of data processing?

☐ Compliance to GFCM-DCRF online submission

☐ National statistics ☐ Other statistical systems

☐ National reporting or assessment, specify __________________________

☐ International reporting, specify __________________________

☐ Other, specify __________________________

If Yes à Which data are processed ?

☐ Catch ☐ Fishing effort ☐ Biological data, specify ______________________

____

☐ Socio-economic data

If Yes à What is the type of processing ?

☐ Aggregation ☐ Expansion

☐ Other statistics, specify ____

If Yes à What is the level of processing ?

☐ By spatial units, specify __________________________

☐ By time units, specify __________________________

☐ By habitat typology, specify __________________________

☐ By fishing typology, specify ______________________________

☐ By eel life stages, specify ______________________________

☐ Other, specify ______________________________

Section D- ***DIFFICULTIES, PROBLEMS, BOTTLENECKS (IF ANY) ENCOUNTERED FOR THE COLLECTION OF EEL FISHERY_RELATED DATA***

Please indicate here eventual problems arising in the work related to the GFCM-DCRF eel fishery data collection when complying with Table VII.6 European eel, concerning methodologies and implementation, on any aspect: raw data collection, data processing, data storage and transmission, compliance with Data Calls, ...

Supplementary Material on the Methodology Part III – Second questionnaire on fishery-related data management submitted to national focal points

Research programme on European eel: towards coordination of European eel stock management and recovery in the Mediterranean

Work Package 5 – GFCM-DCRF Task VII.6 European eel

Questionnaire 2 - EEL FISHERY-RELATED DATA MANAGEMENT

The purpose of the present section of the Questionnaire is to collect information on the methods for reporting and transmission of data in compliance to the GFCM-DCRF **Task VII.6 European eel,** and its annual transmission to the GFCM through the DCRF online platform. The Questionnaire is addressed to the Officers/Scientists actually carrying out data management, reporting and transmission.

COUNTRY: ____________________________

COMPILER: Name _________________________ Institution ________________________________

e-mail _________________________ Telephone ________________________________

Section A - **REPORTING AND TRANSMISSION OF EEL FISHERY DATA COLLECTED FOR GFCM-DCRF TASK VII.6 EUROPEAN EEL**

Please tick the box of interest. If necessary, tick several boxes

- Who are end-users of data?

☐ National Institutions ☐ GFCM

☐ European Commission ☐ ICES

☐ Other International organizations, specify ___________________

☐ Any other applicant, specify ________________________________

- Who is responsible for data reporting and transmission? Specify ________________________________

- Who actually reports and transmits data? Specify____

- Are data uploaded regularly on the GFCM-DCRF online platform? ☐ Yes ☐ No

à If No, why? Specify ____

- What are, if any, the main problems met when uploading data? Specify ______________________________

____

____

____

- Are data used for internal reporting? ☐ Yes ☐ No

If Yes à specify ____

- Are data used for International reporting? ☐ Yes ☐ No

If Yes à ☐ Eel Regulation needs

☐ Other EU Calls, specify ________________________________

☐ EIFAAC/ICES/GFCM Working Group on Eel

☐ ICES Annual Data Call

☐ Other ICES Data Calls, specify ________________________________

☐ Other requests (NGOs, Commissions, etc) specify ________________________________

☐ Other, specify ____

Section B- DIFFICULTIES, PROBLEMS, BOTTLENECKS (IF ANY) ENCOUNTERED FOR GFCM-DCRF TASK VII.6 EUROPEAN EEL

Please indicate here eventual problems arising in the work related to the GFCM-DCRF eel fishery data collection when complying with Table VII.6 European eel, concerning methodologies and implementation, on any aspect: raw data collection, data processing, data storage and transmission, compliance with Data Calls, ...

CONCLUSION

BACKGROUND

The overall results of the GFCM Research Programme on European Eel in the Mediterranean (RP) made it possible to draw a number of relevant conclusions on Mediterranean stocks of eel, their habitats, typical methods of exploitation and more generally on eel recruitment in the region. This was based on considerable in-depth data collection and analysis, indicating long-term trends, inter-annual dynamics and the seasonality of both recruitment and escapement. However, the data collection is far from complete because information on countries not participating in the RP was missing while some partner countries could not achieve a complete overview and collect detailed data on some issues. Partner countries already involved in eel management under the EU Eel Regulation (Reg. 1100/2007) framework, benefitted from their access to a large amount of information and data as well as an established network of relevant contacts. Meanwhile other partners found themselves undertaking a task that was new in some respects, but which nevertheless benefited from data already available, as well as scientific results, thanks to the interest of all countries in eel-related issues. From this point of view, an important result was the prospect of developing a common methodology for the collection of data and their storage, in databases that can be further enriched and updated in the future. The joint work of the network of scientists within the RP, sharing interest and experience, will contribute to this, by bringing forward the work in collaboration with National Focal Points, who also participated in the project by providing support for data collection and showing participation and involvement at national level. This synergy of expertise will make it possible to devise and implement a management strategy, with the support of GFCM Secretariat, and through interaction with the joint EIFAAC/ICES/GFCM Working Group on Eel (WGEEL) and the European Community, with the common goal of sustainable exploitation of eel resources and restoration and conservation of the stock at the global level.

A general conceptual scheme for the RP is outlined in Figure C.1. The sequence started from the quantitative and qualitative exploration of eel habitats in their various components (Chapters 1–4), and continued with the study of recruitment (Chapter 5) and the characterisation of local stocks from the point of view of their biology and quality (Chapters 6 and 7). The qualitative and quantitative description of the exploitation methods employed by fisheries and aquaculture followed in Chapters 8–11, while Chapter 12 provided the results of a thorough review of all management measures relevant for eel in the context of the different frameworks, both within eel-specific management plans, or relevant to eel within fishery regulations and habitat protection frameworks.

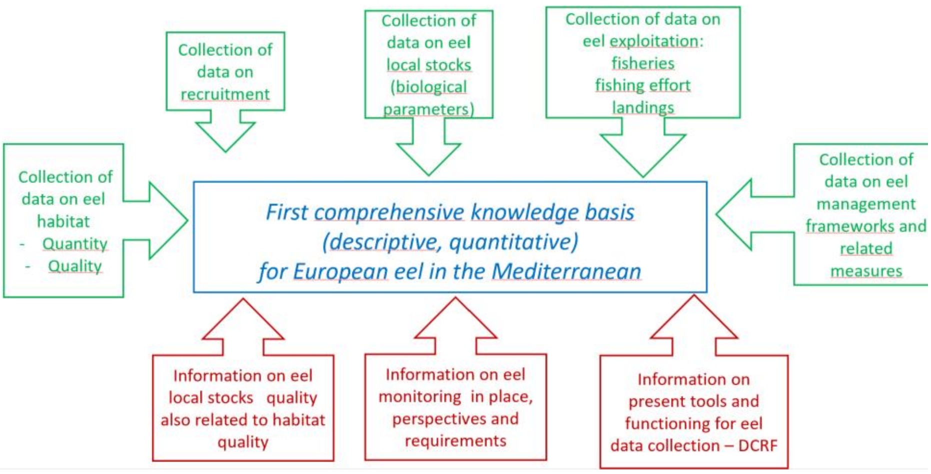

Figure C.1. Summary of the aims and outcomes of the GFCM European eel Research Programme

MANAGEMENT-RELATED RESULTS AND CONCLUSIONS

Eel habitat

The RP found that lagoons provided the most important habitat type for eels while lagoon fisheries and their typical management model also contributed to habitat quality. This means there is a need to maintain lagoon fisheries, focusing on management for long-term, habitat enhancement.

In lakes and lagoons, the main impacts comprised anthropogenic mortality associated with fishing pressure and pollution by heavy metals and pesticides, leading to a recommendation to reduce fishing mortality in these habitats.

In rivers and estuaries, the main impacts were the result of anthropomorphic development of river basins related to the presence of invasive alien species, changed land use, habitat loss and poor water quality leading to frequent hyper-eutrophication, as well as pollution by pesticides and heavy metals.

The need to establish habitat enhancement programmes was highlighted, especially by improving water quality and connectivity. In this sense, the eel becomes an umbrella species under whose protection many other aquatic species would be improved. Actions should be performed in coordination with other habitat-related frameworks such as the EU Water Framework Directive, the EU Habitat Directive and other non-EU frameworks. In addition, there is a need for further research on habitat quality for eel and its evaluation as well as on potential habitat enhancement measures.

Recruitment

Recruitment of glass eels was documented in 80 sites across the Mediterranean, including in transitional habitats mostly in north-western parts of the region. Past recruitment abundance, from the early 1900s until the 1980s, showed a decreasing trend consistent with the ICES trend observed elsewhere in Europe, and recruitment was found to currently be at the lowest levels recorded. Many scattered recruitment fisheries were described in some rivers, in Italy and Spain, and some closed fisheries were identified.

Most countries were found to already have a glass eel fisheries ban in place, but illegal fisheries and illegal trafficking were found to still be present, and even enhanced. The proposal of the RP was to give total protection to recruitment with a total ban on glass eel exploitation, the reinforcement of controls, an appraisal and enhancement of habitat quality in recruitment sites and the establishment of specific habitat-related measures, such as assisted migration, only in case of documented specific impacts.

Local stocks

A review of all biological parameters useful for stock assessment was compiled including information on sizes, sex-ratios, growth rates and age structures varying across the Mediterranean, by habitat and in local sites. A need for further work was identified for silvering of eel and escapement of silver eel.

The RP suggested that there was a need to implementation regular data collection of biological parameters, under the Data Collection Reference Framework (DCRF) Task VII Eel. Some work was carried out to gather information on the quality of local eel stocks but this was not exhaustive.

Contamination levels with POPS and heavy metals were found to be generally low or medium (at 80 percent of sites), while the parasite, *Anguillicola crassus* was found to be present in eels from all partner countries and only a few sites were found to be free from infection. Given the importance of eel quality for successful migration and spawning, the RP suggested eel transfers between sites should be avoided and encouraged countries to carry out regular monitoring of contaminants and pathogens, especially for silver eels.

Seasonal patterns of migration

The seasonal migration patterns of both migrating stages, during glass eel recruitment and silver eel escapement were analysed. Glass eel ascent was found to coincide with the winter months, but the season may extend to June for pigmented elvers. Silver eel escapement was found to be best documented in lagoons, where the migration period extended from October to March.

When considering the three-consecutive month time closures established by most countries based on Recommendation GFCM/42/2018/1 and Council Regulation (EU) 2019/124, as well as at other levels, the RP recommended checking the consistency of implemented time closures with effective migration periods to better align the closure timing with observed seasonality.

Fisheries

An analysis of the gear used to catch eel revealed eight prevailing gear-types in commercial fisheries and two in recreational fishing. Effort levels were found to vary at different levels and were deemed not currently quantifiable. Most catches came from fyke-nets and fences specific for eels and from barriers which are not specific for eel. Most catches came from lagoons as average catches from this habitat over the past five years accounted for one third of stock-wide catches of yellow and silver eel. One third of Mediterranean catches came from Egypt.

The role of recreational fishing was found to be uncertain but probably higher than documented and overlapping with illegal, unreported and unregulated fishing. The RP suggested the closure of recreational fisheries, as well as the revision of regulations and gears to reduce catches and effort, while there should also be improvements to the implementation of closure periods and a reduction of fishing effort and catches by specific gears. Finally, the RP suggested the implementation of fishery-related data collection, with a special focus on fishing effort data and recreational fisheries.

Aquaculture

Aquaculture in the Mediterranean was found to be capture-based and dependent on wild seed. It has developed as a traditional activity, linked to lagoon management, for example in the north Adriatic, where an extensive system called *valliculture* is practiced. Aquaculture production expanded over the years, 1970–2000, with the development of recirculation-based aquaculture systems.

The main producers in the Mediterranean were found to be Italy and Greece, with Egypt as a new entrant to the industry. The decline in recruitment of eel is considered to be a limiting factor because of seed shortages. Small yellow eels are also used to start aquaculture cycles and stock the northern Italian *valli* but their origin, which may be from France, is uncertain. The RP suggested that it is necessary to improve traceability and revise the data collection system for eel aquaculture.

Management

A review was carried out of all management actions, measures and plans in the Mediterranean under different frameworks, including at national, eel management unit and local levels. Many measures were found to be in place, particularly fishery-related measures such as those related to mesh size, gear-type and minimum landing sizes but there was no harmonisation and they were rarely found to be sufficiently aligned to the local situation.

Some measures considered were found to not be really useful for eel, such as regulations from other fisheries. Countries were found to implementing eel life stage-related measures including restocking, which was only happening occasionally, often at unsuitable restocking sites and with no evidence of effective contribution to escapement, and release programme performed by some countries and in some cases consistently (for example by Greece and France), making an effective contribution to escapement.

No eel-specific habitat-related measures were found, other than the establishment of many protected sites (most lagoons, many rivers and lakes). The RP agreed on the need for coordinated, simple, feasible management schemes with, when possible, harmonised fishery-related measures. Restocking using glass eels was not considered a suitable or effective option, but silver eel releases were considered as effective.

All the information, collected at the highest possible resolution (site level), and analysed at different levels (site, EMU or local level, country, habitat typology, regional), provided the basis for a model-based evaluation of alternative management strategies, reported in Chapter 15. The conceptual scheme for this step is shown in Figure C.2.

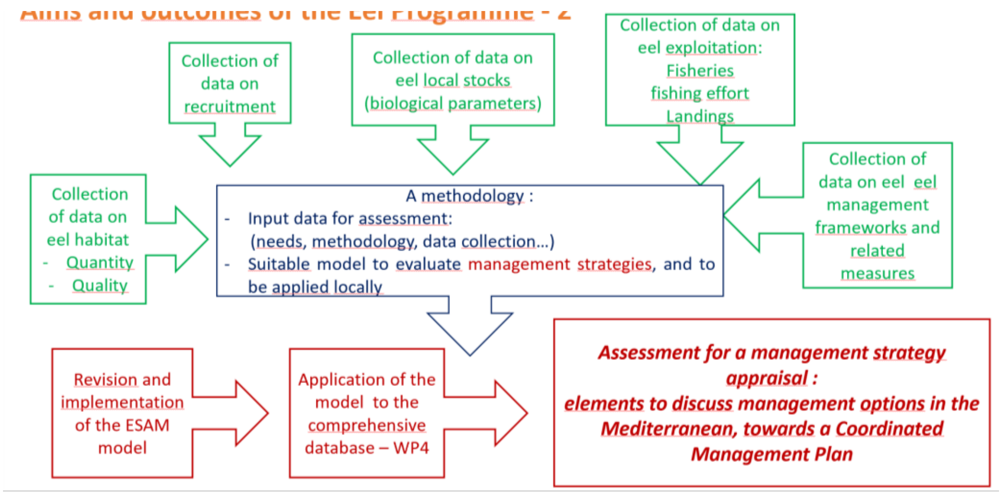

Figure C.2. Conceptual scheme for the use of collected data and for application of the model for appraisal of management options

Based on the management measures that all Mediterranean countries have established and implemented, some that are shared between countries under current management frameworks and others that are purely theoretical, a set of potential scenarios for establishing a common approach in the Mediterranean was chosen during the RP. These measures were used for a model-based appraisal to evaluate their possible effectiveness based on the escapement of spawners, as well as on landings of eels.

The model-based appraisal was carried out at the single site scale, for which a calibration was obtained because a wide set of input data were available from data rich sites. These results at site level were extended to other sites, according to similarity criteria, such as habitat typology (rivers, lakes or lagoons) and site characteristics, as well as proximity. The results are presented here are for the whole of the Mediterranean region. The time horizon for the appraisal was set at 2030, thus considering the effects after seven years of implementation of management plans starting from 2023, and results are expressed in terms of relative (percent) increases or decreases of landings and escapement with respect to current management measures. For scenarios targeting the reduction of fishing effort, the model assessment did not include socio-economic aspects, due to time and data limitations, and assumed that measures were implemented efficiently.

The proposed measures (B–K), which were evaluated against a baseline scenario foreseeing the maintenance of status quo management measures (A), were:

B: No time closures (without the three months requested by GFCM/42/2018/1 and EU Reg. 2019/124), a reference scenario considered to evaluate the effects of the current measures in place including those under the GFCM Recommendation 2018/42 (also considering that in some countries they might not be fully implemented, or not fully consistent with the seasonality of species migration).

C: Abolition of current minimum landing size (where present) was explored to assess the effectiveness of a common measure established in many countries (EU and non-EU), with extreme variability in actual size choices (ranging from 20 cm to 70 cm), notwithstanding that the effectiveness of such a measure beyond the pure increase of escapement biomass is in doubt for a semelparous (breeding once in its lifetime) species.

D: Full fishery closure, based on the awareness that the eel is an endangered species and fisheries targeting eels are presently considered unsustainable, as well as taking into consideration the 2021 ICES Advice.

E: Reduction by half of fishing efforts at barriers. This measure was explored considering that in some countries, eel fishing is performed using barriers on the tidal channel connecting lagoons to the sea, therefore mostly targeting escaping silver eels. By reducing the fishing effort by 50 percent (that is, barriers operating for half as many days compared to current use), there is a direct increase in the escapement provided that free migration is ensured (by modifying the barrier grid), or by directly releasing catches.

F: Reduction by half of fishing effort of all nets. This scenario was explored based on the fact that in most countries, eel fisheries are performed with various types of nets in different habitats, but mostly fyke-nets and fences in addition to fish barriers. By reducing the fishing effort by 50 percent (that is, half the number of the currently operating nets or the same number of nets but operating for half as many days per year), this entails a potential increase in escapement.

G: Reduction by half of fishing effort of all other gears (hooks) This scenario was explored based on the fact that in some countries, eel fisheries are performed also with other gears besides barriers and fyke-nets and fences, such as eel pots and longlines.

H: Reduction by half of ALL fishing effort. This scenario was explored as a conciliatory measure to equally share the burden of fishing effort reduction.

I: River connectivity restoration (both upstream and downstream). This scenario was explored considering that one of the factors that has impacted the abundance of the species is the loss of habitat due to loss of longitudinal connectivity that hinders colonisation to eel further upstream in the rivers, as well as their downstream movement. This scenario is tested as a theoretical measure, but the data to explore this scenario as collected by the RP are less reliable, and data on carrying capacity in higher stretches of rivers are also not available.

J: Restocking in all sites at a rate of one g/ha. This was a theoretical measure, based on the hypothesis that all the quantities of glass eels actually caught by official fisheries were used exclusively for restocking purposes, to identify the theoretical maximum effects of restocking. Other considerations should be taken into account, such as the origin of the seed (local or not, that is, assisted migration or not), the suitability of restocking sites, the increased mortality linked to restocking, the possible transfer of pathogens, and the effective contribution to escapement.

K: Full fishery closure in protected sites (including, RAMSAR and Natura 2000). This was also a theoretical scenario explored in order to start the discussion on the potential role of FRAs. No specific criteria for choice have been considered here, but only general frameworks for habitat protection in specific sites all over the region.

The results of the model-based appraisal, globally for the Mediterranean region, are shown in Table C.1. These comprise a main outcome of the RP in terms of addressing the main choices to be potentially included in a Mediterranean Management Plan, specifically tuned to the Mediterranean eel situation. They constitute the basis for discussion with different stakeholders, including national administrations, fishers and fisher organizations, managers of protected areas and conservation organisations.

Table C.1. Results of the ten simulated management scenarios emerging from the model-based appraisal. (Percent increase in green, decrease in red, compared to baseline scenario A)

2030 SCENARIOS		LANDINGS	SILVER EEL ESCAPEMENT
B	NO TIME CLOSURES (without 3 months requested by GFCM/42/2018/1 & EU Reg. 2019/124)	+4,1%	-5,7%
C	ABOLITION OF CURRENT MINIMUM LANDING SIZE (where present)	+0,7%	-1,5%
D	FULL FISHERY CLOSURE	-100,0%	+109,7%
E	REDUCTION BY HALF OF FISHING EFFORTS AT BARRIERS	-15,5%	+19,2%
F	REDUCTION BY HALF OF FISHING EFFORTS OF ALL NETS	-10,2%	+11,8%
G	REDUCTION BY HALF OF FISHING EFFORTS OF OTHER GEARS (hooks)	+0,0%	+0,0%
H	REDUCTION BY HALF OF ALL FISHING EFFORT	-25,9%	+31,4%
I	RIVER CONNECTIVITY RESTORATION (both upstream and downstream)	+0,0%	+0,4%
J	RESTOCKING IN ALL SITES (1g/ha)	+0,3%	+3,2%
K	FULL FISHERY CLOSURE IN PROTECTED SITES (RAMSAR, Regional parks, etc.)	-65,5%	+64,3%

COLLECTION OF DATA AND MONITORING

Context

The last important task of the RP dealt with an in-depth analysis of the current tools used for the collection of data on eel stocks, arising from the current monitoring in place in the different countries under different frameworks (including research, assessment, EU obligations and national requirements) and on eel fishery- related data collection under the GFCM DCRF VII Eel. The wider analysis was achieved by an extensive investigation carried out involving scientific partners supported by the National Focal Points, within WP2. Meanwhile the DCRF analysis was carried out in collaboration with the GFCM Secretariat, within the tasks of WP5, interacting with the scientific partners for quality checking data by comparing DCRF-derived data with the fishery-related data collected in WP3. The results are given in Chapters 14 and 15, and are summarised below, along with resultant recommendations.

Eel monitoring

Information on all monitoring (glass eel recruitment, silver eel escapement and yellow eel stock) for eel in the Mediterranean was collected, with reference to site location, methodologies and timeframes. This task aimed at developing a coordinated network in the future to evaluate the status of the Mediterranean eel stock on a long-term basis. It was found that most of the monitoring is localised in the northern part of the Mediterranean, performed by EU countries, while an important gap was observed in the south-eastern part of the Mediterranean, even if future monitoring is planned in additional countries in all the types of habitats (lagoon, river, lake), which could help to reduce the regional monitoring gap. The locations and their characteristics provided indications to identify relevant key sites for each habitat typology in all partner countries, and methods that could be selected and used for the long-term monitoring of each eel stage. The maintenance of monitoring in sites that already provide data, and the implementation of a Mediterranean-wide coordinated network was recommended. The choice of sites and methodologies needs to take into consideration local specificities, as well as the possibility of adequate support.

Revision of DCRF-Table VII Eel

The revision of the current structure of Task VII.6 European eel under the GFCM DCRF provided a review of the current state of fisheries data collection for eel as performed by contracting and non-contracting parties of the GFCM. Most partner countries participating in the RP, as well as some others not included in the RP, submit eel fishery-related data via the DCRF online platform However, an uneven situation of data coverage, by year, among countries was revealed. Eel fishery-related data collection used for submission to the GFCM stems from many different data collection frameworks, such as national statistical systems and EU data collection frameworks, consequently the methodologies used were extremely variable between countries. A quality check of the submitted data was conducted, comparing DCRF data to fisheries data (landings, fishing effort) collected within WP3. The quality check highlighted discrepancies in most countries between available fishery data and data submitted via the on-line platform. The RP proposed a revision of the DCRF Table VII Eel, by amending Recommendation GFCM/41/2017/6 on the submission of data on fishing activities in the GFCM area of application and amending the DCRF manual. The revision should include a standardised methodology for fishery-related data collection and the implementation of the collection of fishing-related effort data as well as the inclusion of biological variables.

The RP also proposed the implementation of fishery-independent monitoring using standardised methodologies for monitoring glass eel recruitment, yellow eel standing stock and silver eel escapement, employing suitable gears, timeframes, habitats and establishing a network of key-sites, as highlighted by WP2. This should be done by including European eel in DCRF Task VII.I stock assessment input data, relying on existing monitoring systems, and by coordinating and optimizing the numerous available schemes already in place under different frameworks. The RP also proposed the establishment of a GFCM Working Group on Eel in the Mediterranean, composed of expert scientists working on eel in the GFCM area.

SCIENTIFIC MANAGEMENT PROPOSALS PUT FORWARD BY THE SCIENTIFIC PARTNERS OF THE RESEARCH PROGRAMME

Background

As highlighted in previous years by the WGEEL and reiterated in 2021, the status of European eel remains critical in its entire distribution range, including the Mediterranean Sea, with the lowest recruitment levels ever recorded in 2020. Since 2008, European eel has been listed, as critically endangered in the red list of the International Union for Conservation of Nature (IUCN) and this listing was confirmed in 2018.

Proposals for management

Based on the outcomes of the extensive work done under the remit of the GFCM RP, priorities were identified, from a scientific point of view, for future management of European eel in the Mediterranean. The priority of implementing habitat-related measures was discussed as highlighted widely in the report, but discussion and choices will need the involvement of many different actors and proper frameworks for coordination.

A number of fishery-related management choices were discussed, based also on the results of the appraisal of different scenarios performed within the tasks of WP4, and reported in Chapter 13. Among the main management scenarios tested, special attention was given to the effectiveness of temporal closures and to the possibility of better alignment of such closures to ensure escapement of silver eels. The discussion led to the conclusion that a three consecutive months closure in the appropriate period during winter would entail a total closure of most fisheries that deal with silver eel. The lack of robust fishing effort data also hampers the application of other management measures, such as quotas. The application of a TAC system was also discussed in depth, but it was agreed that this would require detailed investigations and suitable data reporting. Given the current level of recruitment, a sustainable management system, from a scientific standpoint, could not be based on quotas.

Based on the precautionary principle and in light of the present status of the stock and the alarming decline in eel recruitment, the scientific partners agreed that a total closure of fisheries would be the only reasonable scientific advice. While acknowledging the importance of continuing to explore instruments to minimise the impacts of fishing closures on the livelihoods of fishers, socio-economic considerations alone cannot take priority over the urgent need to minimise fishing mortality, given the alarming situation of the stock.

Despite acknowledging that socio-economic issues were not a priority when providing scientific advice, the scientific partners agreed to propose two management options, one that advised a total closure, while still involving the fishers in the process of monitoring, and a second leaving some fisheries, in consideration of socio-economic issues. Considering that the stock is critically endangered in the whole of the distribution area, measures should apply to the whole distribution range.

Considerations on eel habitats in the Mediterranean

The RP confirmed that the largest remaining area for eel in the Mediterranean corresponds to lagoon habitats which comprise about 755 000 ha, compared to lakes and rivers that account for 81 589 ha and 135 000 ha, respectively. Lagoons are present in all countries participating in the RP. In the Mediterranean, lagoons are subjected to anthropogenic mortality associated with fishing pressure. Despite this, the traditional management models employed for lagoons have also been contributing towards maintaining these important habitats that tend to be ephemeral from the ecological point of view. Meanwhile, lagoons are also significantly affected by pollution with heavy metals and pesticides.

Management proposals

These proposals should apply to all eel habitats (freshwater, brackish and marine).

Firstly, the RP advises immediate actions targeting habitat-related measures for habitat improvement and maintenance as well as a reduction of anthropogenic mortality not related to fisheries.

Secondly, specifically for fisheries, two alternative avenues for management are described below in order of preference:

I. Pilot phase of zero-catches for three years and a recruitment assessment over one season

The proposal entails a complete closure of all eel fisheries for three years and rests on a number of conditions:

- All countries in the entire distribution range of European eel should adhere to the management measure, not only Mediterranean countries.
- During this three-year period, the closure should be accompanied by a compensation scheme. Funds should be provided to cover incomes of fishers and persons involved in the eel fishery at a coordinated international level.
- Fishers should be included in monitoring of the three life-stages of eel, in coordination with scientists.
- In addition to monitoring, a socioeconomic study should be carried out to understand the effects on fishers in the Mediterranean and the value chain (see second phase of the

RP below) and evaluate how the eel fishery activity could resume in a sustainable manner after the three year period if the research results show it is possible. Based on this, the closure should be re-evaluated and a second stage of this proposal could then foresee the implementation of different measures, for example, TACs.

II. Close the silver eel fishery for three years as well as a total ban for both recreational and glass eel fisheries for three years and a recruitment assessment over one season

This proposal entails three main management actions to be undertaken together, and rests on a number of conditions:

- Close the silver eel fishery for three years:
    - All countries in the entire distribution range of European eel should adhere to the management measure, not only Mediterranean countries.
    - During this three-year period, the closure should be accompanied by a compensation scheme. Funds should be provided to cover incomes of fishers and persons involved in the eel fishery at a coordinated international level.
    - Fishers should be included in monitoring of the three life-stages of eel, in coordination with scientists.
    - Report in detail the fishing effort and catches of yellow eels.
    - In addition to monitoring, a socio economic study should be carried out to understand the effects on fishers in the Mediterranean and the value chain (see second phase of the RP below) and evaluate how the eel fishery activity could resume in a sustainable manner after the three year period if the research results show it is possible. Based on this, the closure should be re-evaluated
- Implement a complete ban on recreational fisheries
- Implement a complete ban on glass eel fisheries

Proposal for the second phase of the research programme

The scientific partners agreed on, and proposed, the following basic elements for a second phase of the GFCM research programme on European eel in the Mediterranean:

- Based on the consistent amount of information gathered by the RP, postulating that Mediterranean lagoons are the most important habitat for eel, the second stage of the research programme should aim at validating the data collected in the first phase and improving some aspects to better understand the drivers of the population, by doing field work on the three stages of the life cycle at specific key sites, with the involvement of fishers:
    - Identify and select key habitats and sites to be sampled as part of the second phase of the research programme.
    - Develop and implement a common monitoring scheme for each life stage or alternative schemes to be evaluated on a comparative basis, developing a standardised procedure for this field work and future monitoring, also taking into account the efforts being done in the ICES area.
    - Carry out work in the field in selected key sites to gather data for the validation of statistical and management models.
    - Analyse emerging information towards identifying potential future management strategies, for example, TACs.
- Perform a socioeconomic study on eel fisheries in the Mediterranean