Disclaimer:

This document is a draft and has been endorsed by the twentieth session of the GFCM Scientific Advisory Committee on Fisheries (SAC, Tangiers, Morocco, 26-29 June 2018). On this occasion, *"the Committee agreed that the draft handbook for data collection on recreational fisheries be tested through pilot studies and that, on the basis of these outcomes, the next meeting of the Working Group on Recreational Fisheries (WGRF) should consolidate this experience, together with comments on its application, into a revised version of the handbook."*

The first draft of this handbook has been subsequently revised by the experts of the WGRF in 2020 through an online consultation (due to the WGRF meeting being postponed as a result of the COVID-19 emergency), resulting in the present final draft. This draft is currently being edited in view of publication. The final version of the information contained herein is therefore subject to change.

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Food and Agriculture Organization of the United Nations

General Fisheries Commission for the Mediterranean
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HANDBOOK FOR RECREATIONAL FISHERIES DATA COLLECTION IN THE MEDITERRANEAN AND BLACK SEA

(Final Draft Version: July 2020)

Contents

Background

Marine recreational fishing, including sport fishing, is an integral part of Mediterranean and Black Sea coastal life and communities. It is of high cultural importance in the region and represents an important economic component of coastal tourism, which is one of the main maritime sectors in terms of gross value added and employment. Nevertheless, despite the perceived socio-economic benefits, the lack of reliable estimates of catches has resulted in recreational fisheries (RF) being excluded from stock assessments. This can be challenging for assessing stocks which are overexploited by commercial fisheries and for which RF might be an additional component of fishing mortality. Such lack of catch data, coupled with the limited availability of data on the socio-economic impact of RF, impairs proper consideration of this sector in policy-making and undermines the sustainable management of fish stocks (Hyder et al., 2014). The data poor nature of recreational fisheries also undermines the sustainable development of the recreational fishing sector in light of its potential for positive socio-economic contributions to coastal communities (Arlinghaus et al., 2019).

Considering that the main objective of the General Fisheries Commission for the Mediterranean (GFCM) is to ensure the conservation and the sustainable use, at the biological, social, economic and environmental level, of living marine resources as well as the sustainable development of aquaculture in the Mediterranean and in the Black Sea, RF activity needs to be duly considered. Therefore, catch mortality should include all reported or estimated commercial fishing landings, plus landings from RF and subsistence fisheries, and ideally estimates of post release mortality too. Such data has a wide range of existing or potential end users, including national governments, the scientific community, as well as the GFCM.

Improved information on this sector will help to design effective and enforceable control measures and will help to support the development of long-term regional management plans and marine spatial planning. These are crucial issues that should be urgently addressed in order to foster better management of marine living resources in the Mediterranean and Black Sea.

Glossary and abbreviations

ABS	Address-Based Sampling.
Angling	Fishing with hand lines, fishing rods and/or poles using natural and/or artificial baits.
Avidity	The frequency of fishing trips undertaken over a commonly defined period.
Catch	Total number or weight of individuals caught during fishing operations including fish that were caught and released.
Catch-and-release	The process of capturing a fish, usually by angling, and releasing it alive. Catch and-release ranges from legally required, mandatory release of protected sizes and species to voluntary catch-and-release of fish that could have been retained.
CPC	Contracting parties and cooperating non-contracting parties (GFCM).
DCRF	Data Collection Reference Framework (GFCM).
Fishing effort	A measure of resource use by fishers. Typical units of effort are number of trips, fishing time, and/or number of fishing gears used.
GSA	Geographical Subareas established by the GFCM in its area of application (Mediterranean and Black Sea) in order to compile data, monitor fisheries and assess fisheries resources in a georeferenced manner (Annex I).
Harvest	The part of the catch that is kept, not released.
Jurisdiction	Province or territory having the recreational fishing management responsibility.
Logbook survey	Survey of recruited fishers who are asked to record their effort and/or catches in supplied logbooks.
Mail survey	Data collected through questionnaires sent to recipients by post asking for information about previous fishing activity, catch, or expenses.
Non-residents	Someone that fishes in a particular area, but is excluded from the resident sampling frame for surveys in that area.
Offsite sampling	Intercepting respondents away from areas where fishing activity takes place or can be observed, e.g. household and/or over the phone.
Online survey	Questionnaire that can be completed over the internet. Online surveys are usually created as web forms with a database to store the answers and statistical software to provide analytics.
Onsite sampling	Intercepting respondents at principal areas of activity, e.g. fishing sites.
Panel survey	An ongoing survey of a group of fishers who have been enrolled into a panel for a fixed period.
RDD	Random Digit Dialing is a method for selecting people for involvement in telephone statistical surveys by generating telephone numbers at random.

Screening survey	A survey to identify the target population of recreational fishers and their fishing characteristics.
Sport fishing	An organized activity involving free competition between fishers to catch the largest fish of certain species, the largest number of specimens or the largest total weight depending on the rules of each particular competition.
Survey	A survey is a method of gathering information from a number of individuals, known as a sample, in order to learn something about the larger population from which the sample is drawn.

1. Introduction

1.1 Objectives of the handbook

Mediterranean and Black Sea fisheries face serious challenges, with approximately 78 percent of the scientifically assessed stocks considered to be fished outside safe biological limits (FAO, 2018). To take concerted action towards improving this situation, the GFCM developed a programmatic and multiannual mid-term strategy (2017-2020) towards the sustainability of Mediterranean and Black Sea fisheries.

The implementation of the mid-term strategy sought to work towards reversing the trend in the status of commercially exploited stocks by means of a series of targets, outputs and activities. In this context, Output 2.1 of Target 2 "*Robust and timely information on the impacts of small-scale fisheries and recreational fisheries on living marine resources and on their interactions with other human activities in coastal communities*" foresaw the establishment of a permanent working group on recreational fisheries and the assessment of the impacts of recreational fisheries, giving impetus for the development of this handbook. The collection of recreational fishing data is still a recent phenomenon in many countries and there is no clear framework for application of the data for stock assessment or fishery management.

The main goal of this handbook is therefore to provide a clear methodological framework to allow Mediterranean and Black Sea countries to implement suitably harmonized sampling and survey monitoring schemes for recreational fisheries. The information suggested to be collected by this handbook is considered the basic set of information necessary for monitoring recreational fisheries. However, national specificities and data collection needs should be considered when implementing a recreational fisheries monitoring programme, including whether the collection of additional information, such as social data or data on the interactions with vulnerable species, could be necessary.

1.2 Definition of recreational fisheries

In order to understand each other and speak a common language, recreational fishers, managers, politicians and scientists need a proper definition of recreational fisheries for research, management and legal purposes. Past discussions on recreational fisheries within the context of GFCM statutory and technical meetings have primarily focused on the identification of a harmonized definition for recreational fishing. Deliberations from the Transversal Workshop on the Monitoring of Recreational Fisheries in the GFCM Area (GFCM, 2010a) and the eleventh session of the SCESS (GFCM, 2010b) agreed on the following definition for recreational fishing: "Fishing activities exploiting marine living aquatic resources for leisure or sport purposes from which it is prohibited to sell or trade the catches obtained". It was further specified that "leisure purposes" refers to "fishing practiced for pleasure", whereas "sport purposes" refers to "fishing contests practiced within an established institutional framework which sets rules, collects data on catches and informs on the outcomes of the event" (GFCM, 2010a). Building on these discussions, the following definition has been adopted within the following GFCM Recommendations: GFCM/43/2019/2 on a management plan for the sustainable exploitation of blackspot seabream in the Alboran Sea (geographical subareas 1 to 3) and GFCM/42/2018/1 on a multiannual management plan for European eel in the Mediterranean Sea:

"Recreational fishing means a non-commercial fishing activity exploiting marine living resources for recreation, tourism or sport"

The abovementioned definition is considered to be the working definition of the GFCM, absent further decision-making by the GFCM.

It must be noted, however, that there is an array of definitions in the literature and within national legislations pertaining to recreational fishing and its constituent parts and related sectors (Pawson et al., 2008), with subsequent implications for the regulation of these sectors at the national level. For example, in general, there are some discrepancies among national legislations over the term "sport fishing". In some countries, "recreational" and "sport" fishing have different meanings, while in others they are used interchangeably (EAA, 2004). However, as is the case with the GFCM definition, some definitions imply that "sport fishing" is a type of recreational fishing that is more sportive, competition-oriented and technically complex than general recreational or leisure fishing (Pawson et al., 2008).

Furthermore, national definitions differ over the role of subsistence fishing within recreational fisheries. In reality, not all non-commercial fishing can be described as purely recreational. In the Mediterranean and Black Sea region is it common for fishing activity to meet both recreational needs and personal consumption needs, with the catch directly consumed by the fisher or his/her family. The FAO technical guidelines for responsible fisheries touch on this issue by defining recreational fishing as "fishing of aquatic animals (mainly fish) that do not constitute the individual's primary resource to meet basic nutritional needs and are not generally sold or otherwise traded on export, domestic or black markets" (FAO, 2012).

Nevertheless, there is overwhelming consensus among various definitions at the regional level that recreational fishing has a non-commercial, non-profit purpose, expressly excluding the sale of the catch (Hyder et al., 2017).

1.3 Status quo

In the Mediterranean and Black Sea, some countries already collect specific types of data, including estimates of recreational catches and releases for Bluefin tuna (*Thunnus thynnus*), European eel (*Anguilla anguilla*) and elasmobranchs (EU, 2016). However standard and harmonized monitoring programmes for recreational fisheries, with statistically robust sampling designs, are not yet regularly implemented in most countries. Therefore, with a view to moving towards an assessment of RF in the GFCM area of application, the GFCM proposed a roadmap to pilot RF assessments towards the development of a harmonized regional methodology (GFCM, 2017).

As a first step, in 2017, the GFCM circulated a Questionnaire on National Marine Recreational Fisheries among its CPCs. Preliminary information collected within the context of the this questionnaire shows that marine recreational fishing in the Mediterranean and Black Sea involves many different techniques (e.g., rod and line, speargun, traps, longlines, hand-gathering, etc.) (see Annex II) that can be exerted from different locations (i.e., shore, boat, underwater) and that target a broad range of taxa (e.g., finfish, shellfish, crustaceans, etc.).

In the Black Sea, recreational fishers primarily target four taxa: Scombridae, Gobidae, Mugilidae and Pomatomidae (primarily bluefish [*Pomatomus saltatrix*]). In the Mediterranean, however, the catch composition includes a higher number of taxa than in the Black Sea and slight variations in the target species are observed among the four GFCM Mediterranean subregions. The following are targeted in all Mediterranean subregions: Bluefin tuna (*Thunnus thynnus*); small pelagics, particularly Scombridae such as Atlantic mackerel (*Scomber scombrus*) and Atlantic bonito (*Sarda sarda*); large pelagics, particularly Carangidae such as greater amberjack (*Seriola dumerili*) and leerfish (*Lichia amia*); Coryphaenidae, particularly dolphinfish (*Coryphaena hyppurus*); Sparidae, particularly gilthead seabream (*Sparus aurata*) and common dentex (*Dentex dentex*); and Cephalopoda, particularly European squid (*Loligo vulgaris*), common cuttlefish (*Sepia officinalis*) and common octopus (*Octopus vulgaris*).

As noted above, subregional variations occur, for example: Serranidae are mostly represented by different species of grouper, which are targeted along the western coast of the Adriatic Sea and on the rocky bottoms of the western, central and eastern Mediterranean; Mugilidae and bluefish are mainly exploited in the eastern Mediterranean and the Adriatic Sea; and Moronidae, which are represented exclusively by the European seabass *(Dicentrarchus labrax)*, are targeted in all countries bordering the Adriatic, as well as in Egypt, Libya, Spain and Turkey. A summary of the main nekton taxa targeted by recreational fisheries in the GFCM area of application is provided in Figure 1. CPCs for which national license systems for marine recreational fisheries are in place are highlighted in dark gray.

Figure 1. Distribution of the main taxa targeted by recreational fisheries across the GFCM subregions[1]

[1] Source: Responses to the "GFCM Questionnaire on National Marine Recreational Fisheries", 2017

2. Data collection

Choosing how to monitor recreational fishing depends on various factors, including the goal of the survey, its geographical scale, available sampling frames, the spatial distribution of fishing effort and the types of fishing methods used by fishers (Hartill et al., 2012). Multiple methods exist for this task, each one with its advantages and limitations, and various designs are available to obtain representative estimates. As measuring the entire study area is not possible, survey sampling, in its various forms (e.g. catch analysis, questionnaires) is usually the main approach; by collecting a sample of observations, researchers try to obtain a comprehensive representation about the phenomenon of interest.

A good conceptual framework for understanding how to design a survey, and where eventual problems can arise, is the "Total Survey Error" framework (Groves and Lyberg, 2010 – figure 2). This framework can be divided in two components: representation and measurement.

Representation refers to the potential generalizability of the study: how well do the interviewed fishers represent the whole fishing community in the study area? This question identifies two different approaches:

- *Census surveys* collect information from all the statistical units in the target population (e.g. from all the recreational fishers that exist, at a certain time, in the Mediterranean and the Black sea);
- *Sample surveys* collect information from a small group of statistical units from the target population (e.g. from only some of the recreational fishers that exist in the Mediterranean and the Black sea). When certain conditions characterize data collection, findings from sample surveys can be generalized to the whole population of statistical units.

While census surveys always offer a representative picture of a certain phenomenon, sample surveys are far more common, for many different reasons:

- selecting a sample is less time-consuming than selecting every item in the population;
- selecting a sample is less expensive than performing a census;
- census surveys are often unfeasible in practice and sometimes they are unethical;
- sample surveys can be easily repeated in time, to track changes in the phenomena they investigate, while censuses cannot be easily repeated;

On the other hand, the measurement component of the "Total Survey Error" framework (figure 2) refers to our ability to adequately measure the phenomenon we are interested in, in this case recreational fishing effort, catch and economic data. Various methods are available for this task, ranging from in-depth qualitative interviews to simple questionnaires (Vaske, 2008), and these methods will be described in further detail in section 3 of this handbook.

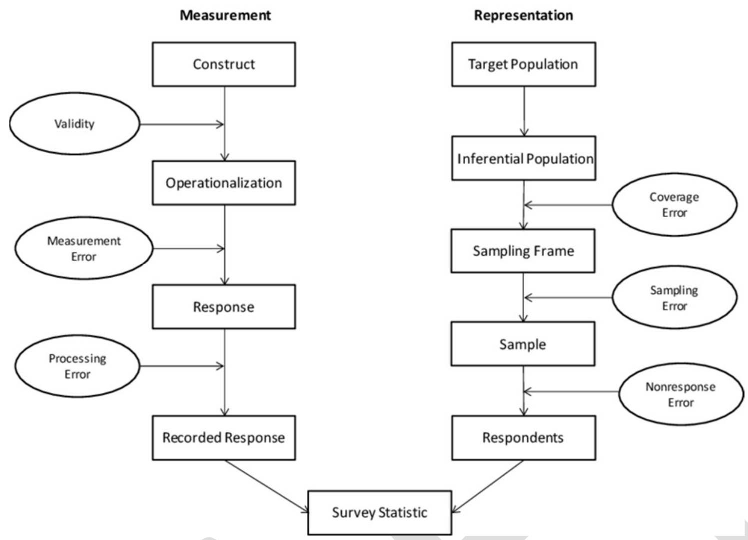

Figure 2. Total survey error components linked to steps in the Measurement and Representational inference process (from Groves et al. 2004).

In recreational fisheries, effort, catch and economic data are frequently collected by means of sample surveys all around the world (Sparrevoh and Storr-Paulsen, 2012; Bellanger and Levrel, 2017), and therefore, this handbook will guide readers through the implementation of such a survey as it is considered the most relevant approach for harmonized data collection by all countries in the Mediterranean and the Black Sea region. It is important to note that in the implementation of a sample survey, errors can be introduced at different stages. As such, it is useful to consider the "Total Survey Error" framework (figure 2) when conceptualizing the survey design in order to minimize error to the extent possible. The combination of multiple data collection methodologies and different sampling approaches can contribute to minimizing the total survey error, while providing researchers with considerable flexibility in monitoring recreational fisheries. To this end, it may be useful to consider complementing a traditional sample survey with onsite data collection and/or any number of new monitoring technologies being used for recreational fisheries, such as mobile applications for data collection (Venturelli et al., 2017) and social media data mining (Sbragaglia et al., 2019).

In the Mediterranean and the Black Sea region, this methodological flexibility is important in order to adapt to the different characteristics and recreational fisheries scenarios found among GFCM CPCs.

Adaptability and Flexibility

During the early years of data collection, it is best to focus on developing a complete understanding of the methodology and being flexible enough to make customizations as required. Setting up a simple but effective method will allow a country to move to more advanced survey techniques in due course.

This handbook presents a harmonized framework for data collection in the Mediterranean and Black Sea region, while also facilitating the necessary flexibility to adapt to the different specificities of the region. The subsequent sections of this handbook will guide readers through the process of defining a sample of recreational fishers to participate in data collection, as outlined in Figure 3, as well as guidance on the data to be collected and analysed.

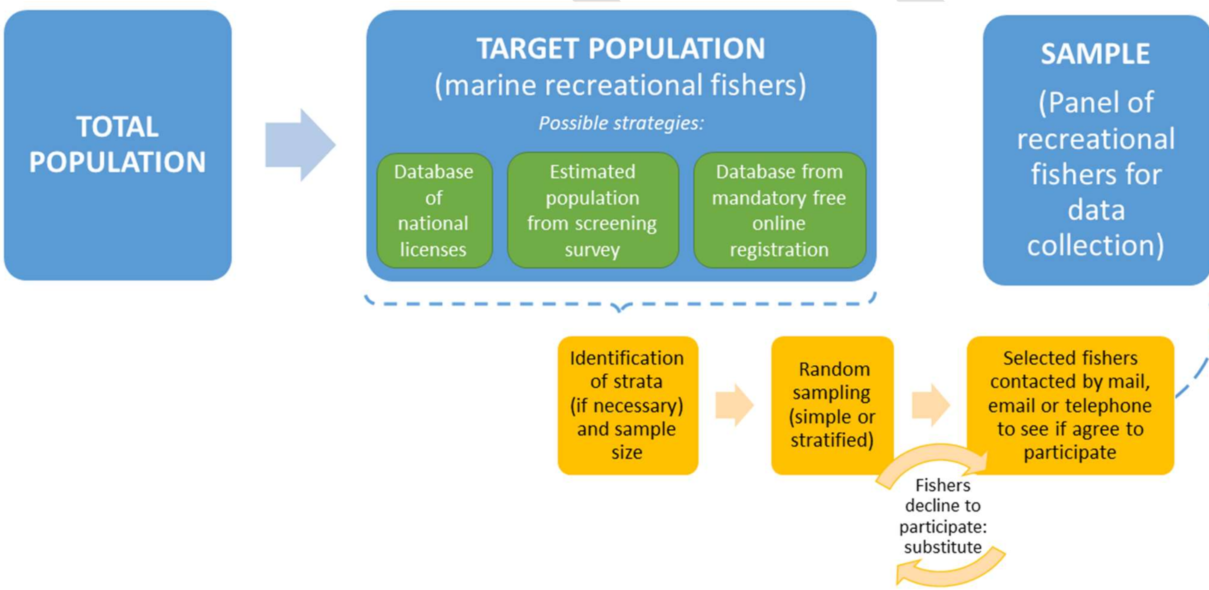

Figure 3. Flow chart for identifying a sample of recreational fishers for data collection based on a national licensing system, a screening survey of the general population or a mandatory free online registration.

2.1 Defining the target population

In order to set up a sample survey, a sample should be selected by extracting some statistical units related to the phenomenon we are interested in from the target population, also known as the statistical universe (Figure 4). The ultimate goal of sampling is to obtain an overall picture about a certain target population, from a subset of units.

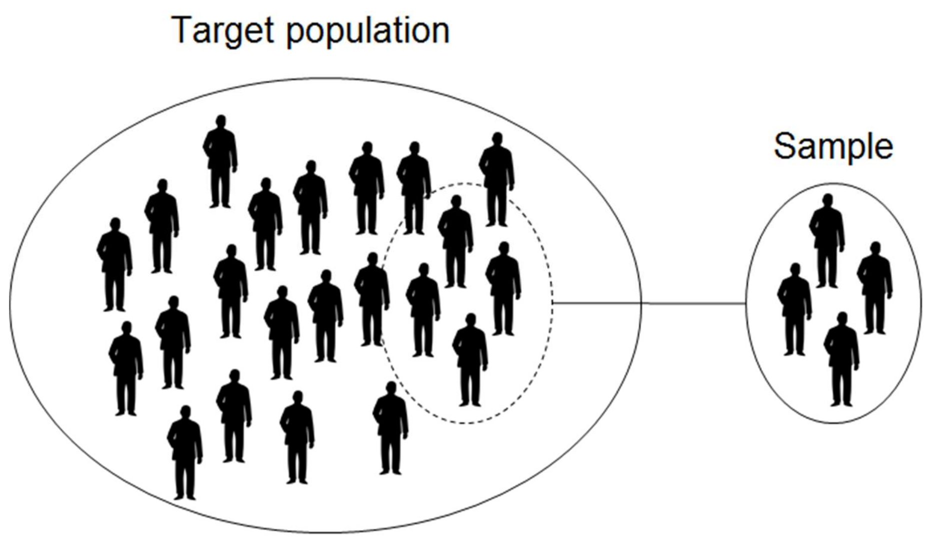

Figure 4. Extraction of a sample from the target population.

The first step of any sampling strategy is therefore the definition of the target population to which the results of the survey are to be generalized. The population is the full list of units for which the survey will be conducted and about which we wish to draw conclusions or describe, in this case, the full population of marine recreational fishers. Sometimes a complete list of all the units composing the population is available, sometimes this is not the case: sampling methods therefore differ between populations with and without lists.

Data sources for the target population may vary across Mediterranean and Black Sea countries and some methods for identifying the target population which may be practical for some countries may not be feasible or cost-effective in others. Many GFCM CPCs do not have license programmes and databases in place that can provide a complete list of all recreational fishers. Indeed, most of the compulsory RF license systems in force either exclude some participants from the obligation to register or do not ensure that all participants actually register or renew their licenses when they expire. Similarly, some countries have active recreational fishing federations or associations which include a high number of fishers. However, the membership of these organizations should only be considered as a complete list of the target population when is membership is obligatory for all recreational fishers. With that said, recreational fishing federations and associations can serve as a valuable partners for engaging stakeholders in data collection (see section 5).

When recreational fishing license programmes do exist, are obligatory and cover all types of recreational fishing, it is still worthwhile to consider the level of compliance with license regulations. If noncompliance is high and fishing without a permit is common, then there may be a need to identify alternative data sources for the target population to account for this higher overall number of fishers. In general, it is important that data collection accounts for the peculiarities of the sector in each country, while at the same time, ensuring that national datasets are organized in a way so as to eventually allow them to be combined at the desired level and in a statistically valid way.

On the other hand, sampling for populations without a list is more complex and less straightforward, as it requires careful design to estimate inclusion probabilities through time-consuming field sampling, such as aerial surveys, point-counts or capture-recapture models (Zischke and Griffiths, 2014). It is therefore suggested that where complete national licensing systems or similar registries do not exist, a simple sampling frame can be adopted such as the general population or all national households for which lists are typically readily available. This approach is seen as being more effective and more easily tailored to the specificities of the Mediterranean and the Black Sea region, as opposed to an approach based on sampling without a list. In this light, the following sections outline three possible strategies which have been identified as appropriate for defining the target population of recreational fishers in Mediterranean and Black Sea countries, each one with its advantages and limitations.

2.1.1 National license system

The identification of the population of fishers is much easier and cost-effective when information can be obtained from national marine recreational fishing license systems and registration databases. Direct list frames of fishers, or fishing vessel operators, could be constructed from fishing license programs, fishing permit programmes or fishing club memberships (when registration with these programmes/clubs is obligatory). Some fishers may participate in more than one list frame, for example by being both a license holder and a fishing club member. It may also be possible that a list frame includes fishers that have not fished during the survey reference period, however, this can be accounted for at later stages in the study. A list frame of fishers should identify license holders, when appropriate, by including the postal mailing address, email address, telephone number, mobile telephone number and, ideally, a national ID or social security number. Ideally, fishing licenses should cover all possible recreational fishing categories and should identify the fishing category(ies) practiced by each license holder, namely fishing from the coast, a boat and/or underwater fishing.

As of 2017, based on the data collected through the GFCM Questionnaire on National Marine Recreational Fisheries, most license systems in force in the Mediterranean and Black Sea were dedicated to boat fishing, while coastal and underwater fishing, in many cases, did not require a license. However, such data sources face potential limitations in the form of national confidentiality protection requirements which might impede the use of contact lists for survey purposes. Researchers should make all attempts to avoid such potential limitations, including by familiarizing oneself with existing legal frameworks for data collection. For countries that do not have a complete license system in place, alternative options are described below. Suggested options including performing a screening survey or a mandatory fee-free online registration. A screening survey could also be valid for those countries that do not have a complete license system in place (e.g. licenses are mandatory only for boat fishing) and need to cover the missing portion of the recreational fisher population (e.g. shore and underwater fishing).

2.1.2 General population screening survey

When a list of recreational fishers from a license system is not available or it is incomplete, it is possible to conduct a screening survey that samples from a broad coverage system like a complete frame of resident households. It may not be necessary to conduct a screening survey every year; every 2-3 years would be sufficient. It is preferable to use a screening survey only as a means of identifying recreational fishers for a more detailed follow-up survey. A flow chart outlining this process is provided below (Figure 5). Therefore, the first contact could be limited to determining if any household residents participate in recreational fishing, collecting their contact information and recruiting them for participation in a more detailed follow-up survey. The survey should collect the minimal data needed to define and profile the fishing population.

A template for the enrollment of fishers for data collection from a screening survey is shown in Annex III. First of all, there is a need to collect information on the gender and age of all members of the household. The second question concerns who went fishing at sea during the last year, and how many times they went, by fishing mode (a rough estimate is sufficient). The last question is one of the most important and concerns the respondent's availability to be enrolled in a panel that will be contacted by phone (mobile phone number would be ideal) every month for data collection. Respondents agreeing to participate in this panel would then be provided with a logbook (Annex V) in order to keep records of requested information (as described in section 3.1.1).

Of course a key issue to consider when requesting this information is privacy concerns and so it is recommended to consult national privacy laws prior to initiating this work. Common principles for data sharing and dissemination should always be respected when carrying out data collection, in line with the concept of privacy recognized as a basic human right by the United Nations.[2]

At the global level, both the use of address-based sampling (ABS – complete lists of residential mailing addresses for mail or face-to-face surveys of recreational fishing by residents) and random-digit-dialing (RDD – directory-based telephone surveys that provide access to a majority of their resident fishing population) have been widely used. For more than 30 years, RDD telephone surveys have been the workhorse of the survey research industry (Link et al., 2008). During the past decade, however, participation in most RDD telephone surveys has declined due, most likely, to factors such as the growth of call-screening technologies, heightened privacy concerns in the face of increased telemarketing calls and the proliferation of non-household telephone numbers which are typically non-voice and unassigned numbers (Link et al., 2008). Additionally, RDD frames may exclude households that do not have a landline telephone (e.g. due to increased use of cellular telephones). Increasingly, however, these RDD surveys are conducted using computer-assisted telephone interviewing (CATI) technology or, where georeferenced mobile phone information is available, computer-assisted mobile interviewing (CAMI), thus eliminating the problems associated with fewer and fewer people having landline telephones. Probability sample design alternatives to RDD that are comparable in speed, efficiency, and cost are, however, scarce. ABS is one such alternative which may provide survey researches with a cost-effective alternative to RDD, as the growth of database technology has allowed for the development and maintenance of large, computerized dwelling address databases. In New Zealand, an advanced face-to-face survey from a dwelling list is currently performed, however this is may not be an optimal solution for all Mediterranean and Black Sea countries due to the high budgetary requirements for its implementation.

Should both approaches be possible, ABS and RDD directory frames should be compared and evaluated to determine which provides the most complete coverage for effective screening of resident recreational fishers in each country. Ideally, in order to reduce biases that could result from the under coverage of any one list frame, it would be best to use a dual frame approach. In this way, it is possible to test the coverage of the list frame by comparing recreational fishers occurring in both frames and those appearing only in one. Furthermore, one could consider stratifying coastal and non-coastal municipalities and applying design weights (e.g. 70 percent coastal, 30 percent non-coastal) to

[2] Article 12 of the Universal Declaration of Human Rights (General Assembly of the United Nations, 1948) states "No one shall be subjected to arbitrary interference with his privacy, family, home or correspondence, nor to attacks upon his honour and reputation. Everyone has the right to the protection of the law against such interference or attacks."

oversample coastal municipalities where a higher number of marine recreational fishers are expected to be found.

The screening approach described in this section would therefore provide access to the resident population, excluding non-resident (i.e. tourist) marine fishers. In countries where tourists represent an important component of recreational fishing, it would be necessary to enforce a supplementary survey frame dedicated to non-residents. A possible solution to create a list of non-resident marine recreational fishers could be to enforce a mandatory fee-free online registration as described in the following section. Another potential approach, considering that tourism has a strong seasonal variation, could be to sample outside of the high tourism season in order to measure only resident recreational fishers.

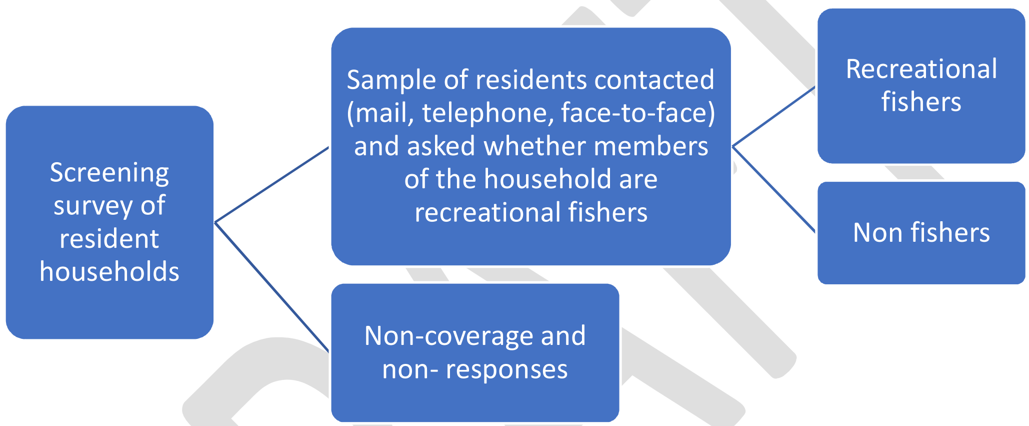

Figure 5. Flow chart for recreational fishing data collection based on a screening of the general population.

2.1.3 Mandatory free online registration

When a complete list of recreational fishers is not available, a list of non-resident fishers does not exist and the screening survey is not feasible, then the third solution would be to enforce the registration of participants through the implementation of an online fee-free registration programme that would collect a valid name, address, e-mail address and telephone number for each participant. This approach has been recently endorsed by the Mediterranean Advisory Council (MEDAC) as a valid method for the assessment of recreational fisheries in the Mediterranean (MEDAC, 2016). Such registration should be mandatory for both residents and tourists, regardless of age, and regardless of whether recreational fishing takes place from the shore, from a boat or underwater. The word "license" should not be used in this case in order to avoid conflict and refusal from the population (ICES, 2010); the word "census" could be suggested instead. The use of an online registration offers many advantages, including ease of access, time saving and efficient data management. However, a possible source of bias could be that the internet may not be user friendly for certain groups of recreational fishers, such as the elderly; although this was not found to be the case in a study in Spain by Gordoa et al. (2019). To avoid such bias, it is recommended that fishing shops assist fishers in online registration, also printing a copy of the document certifying the registration.

The first step of such an approach would be to create a dedicated online platform, which should be endorsed by the national administration in charge of the management of fishing activity (e.g. Ministry). This step implies minor costs, as internet domains are relatively low-cost. Recreational fishers who wish to perform their activity in marine national waters should register online by completing a number of mandatory fields with some general details (e.g. name, email, place and date of birth, nationality etc.). Once the general profile has been filled in, an Identification Number (ID), valid for a lifetime, should be assigned to each fisher. Afterwards, fishers should be required to compile a second form including a list of compulsory supplementary data: type and avidity for every type of recreational fishing practiced and name of an eventual affiliation to a marine recreational fishing association. In some cases, such as the Balearic Islands registration system, users are also required to specify the main areas in which they fish. Once the fishers have completed the compulsory data entry, a certificate should be delivered, either directly through the registration website or sent by email. This certificate should be fee-free, but mandatory to perform any kind of marine fishing in national waters. The fishers should be requested to print this certificate and keep it with them at all times, when carrying out marine recreational fishing activities. A template for a mandatory free online registration is shown in Annex IVa-c. It is desirable that the online registration be linked to a national database, where all information collected is organized and stored.

2.2 Sampling strategy

Once the target population is defined, observations (i.e. recreational fishers) can be sampled according to two criteria: probability and non-probability sampling (Figure 6).

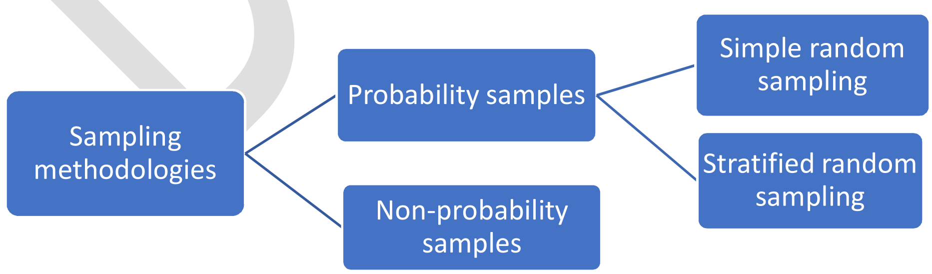

Figure 6. Flow chart for the suggested sampling methodology leading to stratified random sampling with equal probability.

2.2.1 Non-probability sampling

Non-probability sampling, also known as purposive sampling, is a family of sampling techniques (e.g. convenience sampling, haphazard sampling, purposive sampling, expert sampling, diversity sampling, modal instance sampling, quota sampling, etc.) where the odds of any member being selected for a sample cannot be calculated and sampling relies on the subjective judgement of the researcher (Sabatella and Franquesa, 2003). These methods present some advantages, such as convenience, speed and low cost. However, with these surveys it is impossible to know how well the population is represented, as the results cannot be generalized. Plus, a further bias is that confidence intervals and margins of error cannot be calculated, making the results meaningless (Cochran, 1977; Lohr, 1999; Levine et al., 2008). This is the main reason why non-probability sampling should not be considered in the quantification of recreational fisheries in the Mediterranean and the Black Sea. Non-probability sampling should be considered only when some particular conditions apply. For example, the use of mandatory free online registration constitutes a form of non-probability sampling, which does not allow for any formal inference. However, on some occasions where the sampling frame is unavailable, it might be the only feasible approach.

2.2.2 Probability sampling

Within probability sampling, the sample unit selection is based on known probabilities calculated given demographic data collected during the initial screening survey and data provided by the most recent national census. This approach allows the researcher to make mathematically sound, unbiased inferences about the population of interest (Levine et al., 2008). In sampling designs for populations with a list, the two most common forms of probability sampling are simple random sampling and stratified random sampling. These sampling methods have two features in common: i) every element of the population has a known non-zero probability of being sampled and ii) random selection of the sample is applied (Pinello et al., 2017).

Simple random sampling

In simple random sampling all the units from the target populations have the same probability of being extracted. For example, if we had a list of all the recreational anglers that fish in a certain coastal area and we want to know the annual number of sea breams (*Sparus aurata*) that are caught by an angler within a fishing season, we proceed as follows: we extract a random sample of anglers, we ask them about the number of sea breams they landed within the fishing season, we calculate an estimator (Hankin et al., 2019) expressing the total or the average number of sea breams that were landed and we calculate the associated variance of the estimate. Provided our sample is large enough, we can reasonably claim that simple random sampling offers us an adequate picture of the fisheries of sea breams in the coastal area are investigating.

Stratified random sampling

Stratified random sampling, on the other hand, is a suitable choice when our target measurements vary between the units we are sampling. Let's imagine, again, that we have a list of recreational fishers at the national level and that we want to estimate how many people are exclusive sea fishers, who do not go fishing in freshwater. If simple random sampling is adopted, we might have a sample of fishers which contains respondents from inland areas only: this sample is likely to be biased, underestimating the whole number of sea fishers, as sea fishing is almost certainly more common in coastal areas. Therefore, we might divide our respondents on the basis of their geographical provenience, for example by creating two subgroups of respondents from inland and from coastal. Then we can randomly sample fishers from each one of these two groups: our estimates will be correct, as observations are correctly weighted. The two groups of respondents, from inland and coastal ones, are called strata and they have to be mutually exclusive: a fisher cannot be resident, at the same time, in a coastal and in an inner area.

Both simple random sampling and stratified random sampling are correct: this means that, if sampling is designed well, they provide researchers and managers with unbiased estimates of the phenomenon of interest, and that standard error of the estimates can be calculated in a correct way (Hankin et al., 2019). If the variable of interest, let's say the probability of being an exclusive sea fisher, is strongly associated to the strata, then stratified random sampling can provide researchers with more accurate estimates. On the other hand, if there is no strong variation between strata, simple random sampling should be preferred, as inference from stratified random sampling might be inaccurate. The choice of each one of these approaches should be carefully motivated on the basis of evidence at hand.

Statistical weighting of survey data

A final approach is weighting. Weighting offers a way to account for unbalanced sampling, once data are collected. This procedure is particularly useful when simple random sampling is adopted but can also be applied to stratified random sampling schemes. Weights are calculated for target populations for which a list exists, they cannot be calculated for populations without a list. As an example, imagine that we are drawing a random sample of recreational boats where we want to measure the total seasonal catch of common cuttlefish (*Sepia officinalis*). We carry out random sampling, collecting a sample of 410 boats. However, we realize that our sample is unbalanced in terms of fishing activity:

while 40 percent of fishing boats in the study area has an authorization to catch cuttlefish, our sample only contains 10 percent of boats targeting cuttlefish. Recreational boats targeting cuttlefish are therefore underrepresented, while boats targeting other species are overrepresented, with consequent errors in estimated harvests of cuttlefish.

Weights might be estimated as (Vaske, 2008):

$$Weight = \frac{Population\ percentage}{Sample\ percentage}$$

Therefore, weights for boats that target cuttlefish correspond to: 40/10 = 4, while weights for boats that are targeting other species are equal to 60/90 = 0.66. By multiplying reported catches of each boat for its corresponding weights, our estimates are adjusted.

Weighting is a powerful tool to correct estimates, but requires accurate knowledge of the target population and it is not always feasible. Multiple approaches are available, including the use of multiple variables, or the use of weighting to correct non-response bias. Relevant references, including survey method texts, can provide further details (e.g. Vaske 2008; Groves et al., 2009; Dillman et al., 2014).

2.3 Stratifying the population

Once the target population is defined, either through a national license system, a screening survey or a mandatory fee-free online registration, the sample size can be estimated (i.e. number of observations) and the sample of recreational fishers can be selected. However, in case of stratified random sampling, one further step is needed: there is a need to identify the strata. As previously mentioned, an important principle is that strata should be mutually exclusive, as simply illustrated in figure 7.

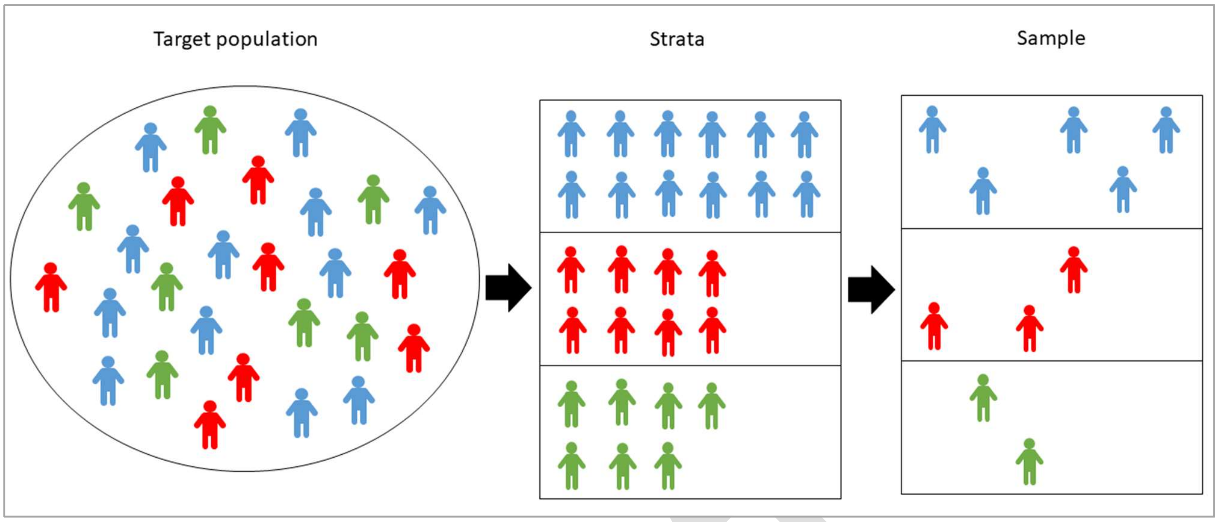

Figure 7. Stratification of the target population

For example, if we divided our respondents equally between residents of coastal and inner areas and we needed a sample of 640 units, we would therefore have to sample 320 respondents (50 percent) at random from the stratum containing fishers from inner areas and 320 respondents (50 percent) from the stratum containing fishers from coastal areas.

Therefore, stratification could be based on the spatial provenience of respondents, such as their area of residence or a specific jurisdiction (e.g. GSA, subnational, region, port, etc.), rather than on the type of fishing habits (e.g. boat fishing, shore fishing or underwater fishing) as the same recreational fisher may engage in different types of fishing habits. Fishing habits might, however, be adopted to weight observations, but it is recommended to motivate this choice by providing: i) a good rationale on why recreationists with different fishing habits might differ and ii) evidence about the soundness of existing dataset about recreational fisheries. Any bias in estimated proportions of recreationists will further affect estimates through weighting.

2.4 Estimating the sample size

The biggest advantage of probabilistic survey sampling lies in its capability of providing accurate depictions of a large population from a small group of units, however, a minimum number of units is required to make inference about the target populations. The minimum number of observations is usually defined on the basis of the desired sampling error, on the size of the target population and on the variability of the trait of interest: a higher number of units is needed to make inference about a large and heterogeneous populations, than for a tiny and homogeneous one. Similarly, to obtain highly accurate estimates, a higher number of units is needed, than to obtain coarser estimates. Hereafter, an example from Salant et al. (1997):

Population Size	±3% Sampling Error 50/50 Split	±3% Sampling Error 80/20 Split	±5% Sampling Error 50/50 Split	±5% Sampling Error 80/20 Split	±10% Sampling Error 50/50 Split	±10% Sampling Error 80/20 Split
100	92	87	80	71	49	38
250	203	183	152	124	70	49
500	341	289	217	165	81	55
750	441	358	254	185	85	57
1,000	516	406	278	198	88	58
2,500	748	537	333	224	93	60
5,000	880	601	357	234	94	61
10,000	964	639	370	240	95	61
25,000	1,023	665	378	234	96	61
50,000	1,045	674	381	245	96	61
100,000	1,056	678	383	245	96	61
1,000,000	1,066	682	384	246	96	61
100,000,000	1,067	683	384	246	96	61

SOURCE: Salant P, Dillman DA. *How to Conduct Your Own Survey.* © Copyright 1997 by John Wiley & Sons, Inc. Reprinted with permission of John Wiley & Sons, Inc.

Sample size for random sampling might be easily estimated, in the case of populations with a list of units. Hereafter, an example of the formula provided by Vaske (2008):

$$Ns = \frac{(Np)\times(p)\times(1-p)}{\left[(Np-1)\times(B/C)^2\right]+\left[(p)\times(1-p)\right]}$$

Where:

Ns = the sample size

Np = the size of the target population (e.g. the number of recreational fishers reported on a list)

p = the prevalence of the target variable (e.g. the number of recreational fishers who are exclusive sea fishers, who do not fish in freshwater)

B = the desired level of sampling error which can be accepted (e.g. 5% = 0.05)

C = the Z statistics associated with the confidence interval (e.g. for a 95% confidence interval, Z = 1.96).

For stratified random sampling, the number of observations for each stratum can be obtained through proportionate stratification. The procedure requires the following steps:

1. Compute the desired sample size (see formula above)
2. Calculate the proportion of each stratum in the target population
3. Assign the number of observational units proportionally to each stratum.

This procedure is called proportionate stratification and it takes the following formula:

$$n_h = \left(\frac{N_h}{N}\right) \cdot n$$

Where:

nh = the number of observations in each stratum of the sample

Nh = the number of observations in each stratum of the population

N = the total number of observations in the population

n = the total number of observations collected with sampling

2.5 Selecting the sample

Once the target population has been defined (see section 2.1) and stratified (see section 2.3) and the sample size determined (see section 2.4), the sample of recreational fishers to be enrolled in subsequent data collection can be selected. To initiate this process, each fisher must have a unique ID, which identifies him or her from all the other fishers. In the case of a licencing system, this unique ID could be the licence number, whereas in the case of screening surveys or mandatory fee-free online registration, each member of the target population should be assigned a unique ID. Following the methodology of random sampling, the basic required condition for the selection of the sample is randomness. To avoid human error this should be carried out by a computerized routine, which ensures that all members of the population have an equal chance of appearing in the sample, thus ensuring randomness. This computerized routine can be carried out simply in Microsoft Excel, following these steps (illustrated in figure 8 below):

1. Enter the complete target population list frame in the excel file, ensuring each fisher is identified by an unique ID;
2. Assign a random number to each ID by means of the "RAND" function in Microsoft Excel by typing =RAND() and hitting enter. A randomly generated number will appear in the cell;

3. To ensure the “RAND” function does not continue to change the value of the randomly generated number, copy and paste all random numbers generated using “paste special – value” to insert the value only in the column with the random number;
4. Sort the list of IDs by their random number, from smallest to largest;
5. According to the chosen sample size (*n*), select the first *n* rows of the list: they constitute the randomly selected sample units.

This simple and straightforward procedure secures the perfect randomness of the sample (Pinello et al., 2017).

	A	B
1	ID	
2	1	
3	2	
4	3	
5	4	
6	5	
7	6	
8	7	
9	8	
10	9	
11	10	
12	11	
13	12	
14	13	
15	14	
16	15	
17	16	
18	17	
19	18	

	A	B
1	ID	Random Numbers
2	1	0.407994121
3	2	0.127159645
4	3	0.728657168
5	4	0.693267446
6	5	0.757092094
7	6	0.437510336
8	7	0.209070448
9	8	0.0468258
10	9	0.568532402
11	10	0.863516298
12	11	0.515697351
13	12	0.127920497
14	13	0.694854633
15	14	0.563546829
16	15	0.787228319
17	16	0.483596731
18	17	0.892700561
19	18	=RAND()

	A	B
1	ID	Random Numbers
2	1	0.407994121
3	2	0.127159645
4	3	0.728657168
5	4	0.693267446
6	5	0.757092094
7	6	0.437510336
8	7	0.209070448
9	8	0.0468258
10	9	0.568532402
11	10	0.863516298
12	11	0.515697351
13	12	0.127920497
14	13	0.694854633
15	14	0.563546829
16	15	0.787228319
17	16	0.483596731
18	17	0.892700561
19	18	0.495818477

	A	B
1	ID	Random Numbers
2	8	0.0468258
3	2	0.127159645
4	12	0.127920497
5	7	0.209070448
6	1	0.407994121
7	6	0.437510336
8	16	0.483596731
9	18	0.495818477
10	11	0.515697351
11	14	0.563546829
12	9	0.568532402
13	4	0.693267446
14	13	0.694854633
15	3	0.728657168
16	5	0.757092094
17	15	0.787228319
18	10	0.863516298
19	17	0.892700561

Figure 8. Example: the total population includes 18 recreational fishers and we want to randomly select 50% of them (9 fishers). With the RAND function we create 18 random numbers, we copy and paste as values these numbers, we sort the fisher ID by random numbers from smallest to largest and we select the first nine fisher IDs (8, 2, 12, 7, 1, 6, 16, 18 and 11). These nine fisher IDs constitute our sample.

Once the sample population has been selected, they should be contacted (e.g. by email or telephone) in order to know if they are willing to participate in the data collection. If they agree to participate in the data collection, then they should be enrolled in the panel survey, whereas fishers who decline to participate shall be substituted by other fishers randomly selected from the database. All attempts should be made to encourage participation and avoid replacement when possible, as replacement could result in a less representative sample. When feasible, it is useful to collect demographic and fishing avidity data from those who refuse to participate, as this can facilitate adjusting statistical weights to account for non-response error.

2.6 Additional considerations

Selecting a sample goes beyond sampling design and the random extraction of statistical units. In practice many other decisions are involved in the process, affecting coverage error, sampling error and non-response error (see Figure 2). Notably:

- The sampling frame might differ from the statistical units of the populations. Some units, given certain sampling mechanisms, might not be covered by our survey, biasing our estimates. A famous case is the use of online surveys: not every person uses the internet, therefore not every person can be recruited in an online survey and therefore online surveys are often biased compared to other survey administration modes (Vaske, 2011). Considering that internet usage can be limited in rural areas, developing countries and among the elderly, estimates from online surveys risk being strongly biased for RF surveys in the Mediterranean and the Black Sea where these three groups make up a significant portion of the target population;
- Sampling error: as discussed in section 2.2, sampling might be biased. For example, simple random sampling might fail to be balanced in terms of relevant groups of units (strata), biasing inference;
- Non-response error: certain mechanisms adopted for selecting units might produce problems connected with people who do not respond to the survey; self-administered surveys, when too time-consuming and cognitively demanding, may be rejected by less motivated respondents, or by respondents with a lower level of literacy. In turn, non-respondents might differ from respondents, in terms of the target variable that researchers want to estimate, and final estimates might be biased. As a simplified example, let's imagine a self-administered mail survey, which is administered to a random sample of fishers, asking them many different questions about seasonal catches. The questionnaire is well-designed and it protects privacy, but it is too long and hard to understand. Therefore, those fishers with low literacy levels (and – for the sake of this simplified example – corresponding lower income levels) do not respond. As a result, responses come from those fishers with higher literacy rates (and corresponding higher income levels). However, owing to this latter group's higher income, they use more expensive and more efficient fishing gear, resulting in overestimation of average seasonal catches.

Defining a sample frame and an administration mode are two practical aspects of survey implementation that might affect the estimation of recreational fishers in the Mediterranean and the Black Sea.

3. Methodology

Independent of the data source (i.e. license system, screening survey or mandatory free online registration), once the sampling frame of recreational fishers is identified, there are a number of different methods for contacting recreationists and collecting effort, catch and economic data.

Each method has its advantages and disadvantages in terms of species and geographical coverage, measurement accuracy and scalability of results (Wynne-Jones et al., 2014). Ideally, data collection procedures should minimize coverage, sampling and nonresponse bias. Moreover, data collection should avoid sensitive questions and should avoid making respondents feel uncomfortable about their answers (Krumpal, 2013). Once these two conditions are met, data collection can provide catch statistics for stocks that are unbiased and sufficiently precise for use in stock assessments and for informing fisheries management.

There are two broad types of approaches to data collection:

- Offsite surveys
- Onsite surveys

Offsite surveys are characterized by researchers drawing observational units without going to the field. This implies that they are inevitably conducted for those target populations whose list is known and that they collect mostly self-reported measures.

Onsite surveys, on the other hand, are based on sampling fishers by going to the field and approaching and interviewing them.

As a general recommendation, both offsite and onsite surveys should aim to ask as few questions as possible in order to minimize the cognitive burden for respondents. Furthermore, sensitive questions should be avoided and all efforts should be made to build a trustworthy relationship with respondents, particularly in the case of economic data collection (see section 3.3.4). Available evidence shows that sharing detailed information about the scope of the questionnaire and providing feedback on the scientific findings to the respondents is useful in promoting trust (Vaske, 2008).

3.1 Offsite surveys

Offsite surveys offer a means of measuring all forms of fishing activity across large spatial scales to produce total harvest estimates. There are certain potential advantages with such methods, particularly in terms of geographical coverage and their ability to reach all the various types of recreational fishers, even those that are harder to recruit in onsite surveys. Respondents can be asked about fishing over defined periods (e.g. day by day or over an extended period), especially when they are enrolled in a panel type survey (Wynne-Jones et al., 2014). However, it is important to note that offsite surveys always provide self-reported information. Offsite surveys can take two forms:

- Logbook surveys
- Recall surveys

3.1.1 Logbook surveys

Logbooks provide a very cost-effective means of collecting both fishing effort, catch and economic data. A template of a logbook is reported in Annex V. The logbook could be delivered to selected recreational fishers as a paper book/diary at the beginning of the survey period. Alternatively, online logbooks or a dedicated app for mobile phones could be developed. As a first step, we suggest delivering paper logbooks as they ensure the maximum coverage. Each page of the logbook should correspond to one fishing trip. Should a fisher engage in multiple fishing modes (e.g. from a boat, from the shore or underwater) within the same day, each fishing mode should be considered a separate fishing trip and a separate logbook should be completed. Fishers should be asked to complete the logbook with:

General information (Annex Va), including:

- Name and surname of the panel participant;
- Whether the logbook information is reported for a single fisher (the panel participant) or multiple fishers (in the case that the panel participant pools his/her catches with other fishers during the fishing trip and it is not possible to determine the panel participant's individual catch). In the case of multiple fishers, the number of fishers (gender disaggregated) and their ages should be reported;
- The location of the fishing ground (e.g. GSA, city, distance from the coast): this can be reported through geographical coordinates (if available through GPS or mobile phone data) and/or by describing the location (e.g. by reporting the basin and the distance from the nearest harbor);
- Total fishing time: the date and time of the start of the fishing trip and the date and time of the end of the fishing trip;
- The fishing mode: whether fishing took place from a boat, from the shore or underwater;
- Information about the fishing effort: fishing gear used, time spent fishing per gear (fishing time), number of units used for each fishing gear (e.g. number of rods, hooks, etc.). In case "Multiple fishers" was selected at the top of the logbook, then the cumulative fishing effort for all fishers should be reported;

- Catches by gear code: in case "Multiple fishers" was selected at the top of the logbook, then the cumulative catches for all fishers should be reported;

Retained species information (Annex Vb), including:

- Biological data of the retained catch, including length, weight and sex (if known);

Released species information (Annex Vc), including:

- Information on the released catch, including the length and post-release status;

Expenditures (Annex Vd), including:

- The value of all expenditures made in relation to the fishing trip, including any expenditures incurred prior to the fishing trip (e.g. the purchase of new equipment) since the last logbook was completed..

Fishing effort will be estimated considering the total fishing time of the trip (ending time minus starting time, including the travel to/from port in the case of boat fishing). In the example shown in Figure 9a, the total fishing time is eight hours. Data on fishing effort must be reported also for each gear/technique used during the trip. The effective fishing (soak) time per gear should be differentiated from total fishing time because catches should be standardized using the effective fishing time. In this example, five hours were dedicated to fishing with hooks (three hooks in total), and three hours for traps (two traps in total). Concerning the hook fishing, it is important to know how many hooks were used, so if, for example, a total of three rods or hand lines were used and each rod/hand line had a tackle with three hooks, then the total number of hooks will be nine.

When more than one person is participating in the fishing trip and the individual effort and/or catch of each person cannot be determined (e.g. when several people are fishing on the same boat, collectively using the same gear and the catch is pooled together), then fishing effort should reflect the cumulative effort of all participants and the total cumulative catch should be reported. During the data analysis phase, the catch and effort of the logbook owner can then be estimated as the mean of the effort and catch of all fishers participating in the fishing trip. For this reason, the number of fishers is requested.

The catch must be recorded by gear typology. A list of gear codes is reported in Annex II as well as in Annex Va and VIa. The gear code is needed to ensure the respondent is referring to the correct gear to facilitate the work of the researcher in order to identify the gear without errors. In the first column the gear code must be reported (see Annex Va, Vb and Vc), while in the column titled "Species" a valid name of the species should be written. The scientific name would be the best way of reporting a catch, but usually recreational fishers do not know the scientific name of each species. Therefore, it would be better to ask for the common name and, in case such a name is ambiguous, then it would be better to contact the fisher and ask for an explanation. Following the example reported in Figure 9b, the first species reported is the common pandora (*Pagellus erythrinus*), one specimen has been kept (total length = 25 cm, corresponding to a weight of 0.3 kg) and one specimen has been released. In the template concerning the released catches (Annex Vc) it would be important to report if the released fish was alive, almost dead, dead or not known, when released into the sea. For example, in Figure 9c, in the case of the horse mackerel (*Trachurus mediterraneus*) under the "catch information" logbook template (Annex Vb), it is noted that three specimens were caught, with the total lengths indicated for each one, followed by the three respective weights. In the case of the abundant catch of the black gobies (*Gogius niger*) reported in Figure 9a, it is sufficient to write the total number of fishes (40) and the total weight (1.2 kg) in the "general information" logbook template (Annex Va). For cephalopods, the mantle length in cm must be recorded in the "catch information" logbook template (Annex Vb), as in the case of the cuttlefish (*Sepia officinalis*) reported in Figue 9. Crustaceans must be measured for carapace length in mm. For other taxa (i.e. Echinoderms) it would be sufficient to report number and total weight in the "general information" logbook template (Annex Va). For further details on measuring catches, see section "3.3.2 Catches".

Logbook and Recall template - general information

Logbook X	**Recall** ☐	Reference month and year ____________

Name and Surname of panel participant Mario Rossi

Information reported for:

Only the panel participant ☐

Multiple fishers (in case the panel participant's catch is pooled with other fishers on the same trip) X

If multiple fishers:

No. Fishers:												
♂	2	age	45	51								
♀	1	age	35									

Fishing location

Geographical SubArea (GSA) 17

City Venice

Distance from the coast (in nm) 3

Fishing time

	Start	End
Date	13-May-19	13-May-19
Hour	06:00	14:00

Fishing mode* Boat X Shore ☐ Underwater ☐

Gear	Gear code	Fishing time per gear (in hours)	Number of units used per gear
Hand implements	MHI		
Harpoons	HAR		
Diving (Speargun)	MDS		
Diving (Hand)	MDH		
Cast nets	FCN		
Boat seines	SV		
Beach seines	SB		
Hooks and lines (not specified)	LX	5	9
Handlines and hand-operated pole and line	LHP	5	3
Traps (not specified)	FIX	3	2
Pots	FPO		
Gillnets and entangling nets (nei)	GEN		
Gillnets	GNS		
Trammel nets	GTR		
Longlines (not specified)	LL		
Lift nets (not specified)	LN		
Scoop nets	MSP		
Gear not known or not specified	NK		
Others**	OTH		

Catches

No.	Gear code	Species	No. Retained	Weight (kg) Retained	No. Released
1	LX LHP	common pandora	1	0.3	1
2	LX LHP	horse mackerel	3	1.1	
3	LX LHP	gilthead seabream	1	1	1
4	LX LHP	black goby	40	1.2	
5	FIX	cuttlefish	2	1.2	
6					
7					
8					
9					
10					

Comments:

** Complete one logbook/recall template per fishing mode*

*** Provide a description of the fishing gear in the comments section*

Figure 9a. Example of how to compile a logbook (general information).

Logbook and Recall template - retained species information

Logbook X Date 13-May-19	**Recall** ☐ Reference month and year ____________

No.	Gear code	Species (retained)	Length*	Weight (kg)	Sex**	Fishing mode***		
						Boat	Shore	Under water
1	LX LHP	common pandora	25	0.3	nd	X		
2	LX LHP	horse mackerel	25	0.3	nd	X		
3	LX LHP	horse mackerel	30	0.4	nd	X		
4	LX LHP	horse mackerel	30	0.4	nd	X		
5	LX LHP	gilthead seabream	40	1	nd	X		
6	FIX	cuttlefish	14	0.5	male	X		
7	FIX	cuttlefish	16	0.7	female	X		
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								

** Total Length for fish (cm), Mantle Length for cephalopods (cm), Carapace Length for crustaceans (mm)*

*** if known (M: Male; F: Female; ND: Not Determined)*

**** Select only one fishing mode (boat, shore, underwater) per row*

Figure 9b. Example of how to compile a logbook (retained species information).

Logbook and Recall template - released species information

Logbook	X	Date	13-May-19	Recall		Reference month and year	

No.	Gear code	Species (released)	Length*	Post-released status**				Fishing mode***		
				Alive	Almost dead	Dead	Not known	Boat	Shore	Under water
1	LX LHP	common pandora	12	X				X		
2	LX LHP	gilthead seabream	15		X			X		
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23										
24										
25										

** Total Length for fish (cm), Mantle Length for cephalopods (cm), Carapace Length for crustaceans (mm)*

*** mark the corresponding cell*

**** Select only one fishing mode (boat, shore, underwater) per row*

Figure 9c. Example of how to compile a logbook (released species information).

Some fishers might not fill their logbooks on a regular basis, which could ultimately bias the study. In this case, follow-up by the researcher would be necessary to find out why fishers did not fill their logbook every month. Regular communication and follow-up with the panel participants could help increase the number of completed logbooks. Another source of bias is the so called “prestige bias”, when fish size or numbers are exaggerated, and hence, deliberately false information is given to manage self-impression to others. On the other hand, certain political or cultural contexts may lead fishers to understate their catches to avoid management implications or due to superstitions about bad luck derived from sharing information about the size of the catch. Both forms of bias might be reduced by emphasizing that data will be reported anonymously, that data will be combined with other means of data collection (e.g. onsite surveys), that honesty is important for the ethics of fishing and that exaggerating data might have negative consequences for the management of fish stocks (Ayal et al., 2015).

It would be useful to train recreational fishers in filling out the logbooks by means of training courses (e.g. online tutorials, seminars, etc.). During such training courses it is important to emphasize that logbooks should be completed on a regular basis, rather than just before they are to be collected by researchers, as this might introduce recall bias and have negative consequences for fisheries management. Logbooks should be collected regularly, for example every month, and data should be stored into a database for subsequent analysis.

Logbook surveys are also an effective way to measure economic expenditures. However, once reliable economic baseline data have been established, it could be foreseen to collect economic data less frequently (e.g. every 2-5 years, rather than annually), in order to simplify data collection and avoid over-burdening respondents. Selected recreational fishers should be asked to register the money they spent to carry out their fishing activity during each fishing trip, including for: fishing equipment (e.g. rods, reels, hooks, lines, swivels, spearguns, underwater accessories, traps, etc.), bait (e.g. natural or artificial bait), travel and accommodation (e.g. train, plane, car, hotels, etc.), boat expenses (e.g. charter, rental, boat ownership expenses such as fuel costs, mooring fees and taxes, boat maintenance, etc.), electronics (GPS, echosounder, radar, etc.) license fees and others. In the case of underwater fishing, boat expenditures should also be included when this type of fishing activity is performed using a boat. A more detailed description of the information to be collected is reported in section 3.3.3 and a template for collecting this information through the logbook can be found in Annex Vd. The monetary value to be inserted in each cell should be indicated in the local currency. To facilitate regional comparison, the survey coordinator should perform a conversion to a common currency, such as EUR or USD, by applying current conversion rates.

3.1.2 Recall surveys

An alternative to logbook survey is the so-called recall survey, which relies on contacting, through email and/or telephone, selected recreational fishers and asking them to recall information about their catches, effort and expenditures over a specific timeframe. Extended timeframes (e.g. one-time surveys with a 6 or 12-month recall period) can significantly over-estimate total recreational fishing effort. Typically, an average catch per trip is memorized and then multiplied with the assumed number of trips. This can potentially lead to a severe overestimation of the harvest, because there is a general tendency for exaggerating the participation rates in recreational events (Tarrant and Manfredo, 1993; Connelly and Brown, 1995; Vaske et al., 2003). However, this is not always the case, as noted in Connelly and Brown, 2011, and as such anglers and recreational fishers should, in general, be treated as a heterogeneous group (Arlinghaus et al., 2008; Johnston et al., 2010). Respondents generally prefer to recall catches in numbers, in which case converting numbers into weight can be problematic. Indeed, a specific problem with recall surveys is that the longer the timeframe respondents have to recall, the more the results tend to be biased (Tarrant and Manfredo, 1993) and, hence, a short recall period would be preferred to minimize possible recall errors. A one to two month recall period is suggested as it is feasible but not too long. At a more advanced stage in implementing recreational fishing monitoring programmes, one could contact more avid fishers more often during the peak season, although that may not be necessary in the early stages of trialing these methods in a country.

As the information required for the recall survey is the same as the information required through the logbook, interviewers can use the same template of the logbook survey for catch and effort data (Annex Va, Vb, Vc), filling in one template per fishing trip. As is the case with the logbook, when a fisher engages in more than one fishing mode (e.g. fishing by boat, shore or underwater) in the same day, each fishing mode should be considered a separate fishing trip and therefore a separate logbook should be completed. In the case of economic expenditures, the information to be collected is identical between the logbook and the recall survey, however, the reference period differs. The logbook (Annex Vd) should include all expenditures made in relation to the specific fishing trip, including any expenditures since the last fishing trip. On the other hand, the recall survey (Annex Ve) should collect information in relation to all expenditures made during the reference period of the recall survey (e.g. the previous 1-2 months). In all cases, it is often helpful to supply the fisher with a copy of the logbook template in advance, so that he or she may keep notes and facilitate jogging their memory at the time of the recall survey interview.

Recall surveys can also be used as a complement to logbook surveys. Selected fishers which are involved in the logbook programme should be contacted on a monthly basis by telephone in order to verify the information reported in the logbook during the previous month. Logbook information that would require verification could include the fishing areas (e.g. wrong or questionable geographical coordinates, doubtful locations, etc.); the number of gears used (e.g. verifying that the number of hooks is reported rather than the number of rods, etc.); the common name of the target species (e.g. in order to associate the right scientific names of the species); eventual peculiar catches in number or weight (e.g. very high number of fishes, wrong correlation between length and weight, etc.), and other eventual anomalies observed in the logbook.

3.2 Onsite survey

Onsite surveys consist of sampling fishers by going directly to the field and interviewing them. Onsite methods potentially offer a more accurate and direct approach because fishery-independent staff members follow randomized probabilistic designs to collect the data, usually soon after any fishing effort has taken place. Detection of and correction for any bias are also potentially more tractable given the direct and verifiable nature of the data collected. Unfortunately, on-site methods tend to be comparatively expensive and logistically onerous, thus limiting the scale at which they can be applied (Hartill et al, 2011). This type of survey could therefore be important as a means of validating and integrating the data acquired through offsite surveys (e.g. logbook, recall) by providing additional data on catch size and species composition. In this way, an offsite logbook or recall-based survey method could provide the primary means of estimating mean catch rates and effort, with onsite sampling with trained interviewers conducted only to validate the self-reported offsite data. The use of onsite surveys to validate offsite surveys can therefore contribute to the detection of discrepancies between self-reported data and data measured in the field.

In some countries, such as those with limited coastlines or a limited number of access sites, it may be feasible to use onsite surveys as the primary means of collecting fishing effort and length data directly from fishers, in view of estimating catch per unit of effort (see section 3.3.1). In other countries this may not be a feasible or cost-effective option.

Whether using an onsite survey as the primary means of data collection or to validate offsite surveys, the main purpose of an onsite survey is to collect data on as many recreational catches as possible, for as many species as possible. Engaging recreational fisheries stakeholders through Federations and Associations is one way to reach a high number of fishers (see section 5. “Stakeholder engagement”). Interviews can be carried out at harbors, beaches, ramp sites, slip ways, etc. The locations can vary and hence it is important to include all specific locations with fishing participants in the sample frame. The catch data to be collected should include the species of fish, the number of fish caught of that species, the number of fish kept and the number of fish released. In addition, the interviewers should attempt to obtain length and weight measurements on a random sample of the kept fish that the angler is willing to make available.

Biases might arise within the onsite survey when fishers are selected for sampling based on accessibility or convenience (e.g. by sampling only vessels that arrive in port within certain hours). This selection would not constitute a random sample of the population because the probability of selection would be unknown, thus invalidating the interpretation of the data (Grafton et al., 2006).

The probability of sampling at different times of day should be controlled using expert knowledge of fishing patterns in different areas and seasons. See section 3.2.1 for information on other onsite data collection methods, beyond this traditional approach.

The way the interviewer introduces him or herself to the fisher is one of the most important considerations, which can frequently determine the success of the interview. It is important to establish a relationship of trust with the interviewee, as this this promotes honest responses. It is therefore suggested to use the following approach when introducing oneself to a potential interviewee onsite:

> *"Hello, my name is ---- and I am doing a recreational fishing scientific research survey for ------ (Institution) on behalf of ------- (e.g. Ministry of Fisheries). Can I ask you a few questions about your fishing today?"*

If the fishers want to know the objective of the study, it should be clearly explained that the main aim of the survey is to collect information on the local recreational fisheries in order to foster its sustainable management and that the anonymity of the participant is ensured.

The following information should be annotated during in the interview:

General information (Annex VIa):

- Date of interview;
- Whether information is being reported for a single fisher or a group of fishers (in the case that gear/catches are pooled and it is not possible to determine one fisher's individual catch). In this latter case, the number of fishers (gender disaggregated) and their ages should be reported.
- Fishing location – the location of the fishing ground should be requested in following manner: "Roughly, where did you fish today? Could you please estimate the distance from the coast?" It can indeed be useful to bring a map and to ask fishers to indicate directly on the map where the fishing ground is located. In case fishers are particularly collaborative, they could be asked to provide the exact fishing location by geographic coordinates (Latitude and Longitude);
- Total fishing time – this refers to the time spent during the whole fishing session. For example, in the case of a boat trip this includes also the navigation time. The time should be clearly written in order to understand if it refers to before (a.m.) or after (p.m.) noon. The date should be reported for both starting and ending time of the boat trip to avoid errors when the fishing session takes place over multiple calendar days;

- Fishing time and number of gears – for each gear used, it is necessary to ask the fishing time (how long the gear was in the water) and the number of gears (e.g. number of rods and total number of hooks);
- Number and weight of retained species, as well as the number of released species, by gear. Each species must be recorded using the local name or the scientific name (if possible). In case of doubts about the correct identification, it is advisable to take a picture, using the timestamp on the photo to associate the pictures with the interviews. For each species, register the number of specimens and their total weight, as well as the number of released individuals;
- Fishing trips performed during the previous year – in order to have a rough estimation of the avidity of the fisher, the fisher should be asked to estimate how many fishing trips they performed during the previous year. This can sometimes be a very difficult question for a fisher to answer and it may be necessary to prompt the fisher with potential responses (e.g. "was it 5, 20 or 50 times?"). This question should be asked to all fishers of the party and should refer to the fishing mode (boat, shore or underwater fishing);
- Willingness to participate in a panel survey – it would be important to collect contacts for subsequent diary/logbook or recall surveys, so when interviewing fishers, they should be asked if they are willing to be contacted in the future. If the answer is positive, then contact information, including name and mobile phone number (which is preferable to a landline phone number) should be collected. This information should be requested at the end of the interview, once fish have been measured and a rapport has been established with a fisher who has been willing to answer most questions;
- Comments – Any comments the interviewer may have on the interview should be noted here. This can help to understand eventual oddities that emerged during the survey, for example, the bait used or whether each fisher is listed in the national list of household telephone numbers could be useful information to annotate;

Retained species information (Annex VIb):

- Total length, weight (and sex if possible) of retained species by gear – To facilitate this task, it is useful to ask: "can I please measure your fish?" and, if the fisher agrees, then every retained species must be measured at the lowest 0.5 cm for Total Length (TL). Although useful, weight and sex are not mandatory, as weight can be estimated subsequently by means of the length/weight relationship, whereas it is usually required to open the belly of the fish in order to understand the sex;

Released species information (Annex VIc):

- The length of each released specimen should be asked, including information on the post-released status (e.g. alive, almost dead, dead, not known).

3.2.1 Other onsite methods

In countries where more extensive onsite data collection could be considered feasible (e.g. in countries with limited coastlines), in addition to the traditional onsite data collection approach described above, two alternative survey methods could be considered to estimate catch and effort: the bus route method and aerial-access surveys.

Bus route method

Robson and Jones (1989) developed a procedure for collecting RF catch and effort which is analogous to a "bus route" and which allows for a limited number of interviewers to sample a high number of access sites. Instead of visiting just one or two access sites a day (the traditional approach), each interviewer makes a complete circuit of all access sites each sampling day (Jones et al, 1990). The agent has a precise schedule to follow each day and arrives and departs from each site on a predetermined timetable. Because the starting point along the circuit is chosen randomly each day, each site is visited randomly throughout the day over the survey period. This method is particularly appropriate when there are many access sites to be sampled. For example, if the study area consisted of 12 access sites, it would be unreasonable to spend a full day at only one of so many access sites as each site would then be sampled infrequently within the survey period. With the "bus route" method, one interviewer (or one crew of interviewers) would cover all 12 sites within a single day. With a traditional approach, the same number of interviewers would visit only one to two sites per day.

Aerial-access surveys

The use of observers in aircraft flying at low altitudes (150-300 m, depending on the minimum-permissible altitude under civil aviation regulations) is an additional method that could be used to count recreational fishing vessels or fishers from the shore. There are two forms of aerial-access design: the random-count design (described by Pollock et al. 1994 and used by English et al. 1986, 2002; Coutin et al. 1995; and Soupir et al. 2006) and the less commonly reported maximum-count design (Parker 1956; Dauk 2000; Dauk and Schwarz 2001; Lockwood et al. 2001).

With the random-count design, the day is divided up into two or more time bins and flights are scheduled to take place at a random time within one or more diurnal strata on each survey day. The estimated number of hours fished in a given time bin is the product of the number of hours occurring within that time bin and the aerial count. This estimate of the number of hours fished within a time bin is then combined with a catch rate estimate for the same period to provide a catch estimate for this time interval (Hartill et al., 2011). Flights can be scheduled to take place during all time bins within a day, and the estimates of catch and effort obtained for each time bin can then be combined to provide total estimates for that day. Estimates from a random subsample of available days can then be averaged and expanded to provide catch end effort estimates for a larger temporal stratum, such as a summer season. Alternatively, time bins can be randomly sampled at a lower intensity across all survey days within a larger temporal stratum. Care must be taken, however, to ensure that at least one time bin is selected from each survey day and that sufficient replicates are sampled from each time bin across all surveyed days. Regardless of which random-count design is used, the number of flights required to adequately estimate the total level of effort occurring on a sample day and across all sample days is potentially prohibitive yet unavoidable because these flights offer the sole means of estimating levels of effort when this design is used (Hartill et al., 2011).

Maximum-count aerial-access designs, such as that described in Hartill et al (2011), are more cost effective because only a single flight is required per survey day. A count of fishing vessels made during this flight is used in conjunction with creel survey data to describe the distribution of effort throughout the day. The substantial reduction in the cost of the hours flown is to some extent offset by the need to station creel survey clerks at selected access points throughout the day. However, results from this study suggest that catch rates vary throughout the day, and the best means of correctly accounting for this change is to interview fishers throughout the day. The same study evidenced that it would be preferable to combine aerial count and fisher interview data together at the level of the primary sampling unit, the day. Estimates of total effort and catch were calculated for each randomly selected survey day, which were then averaged within their respective temporal strata. Hartill et al. (2011) observed that the advantages of linking data from the aerial survey and fisher interviews on each survey day to estimate levels of effort are twofold: (1) fewer flights are required to assess levels of effort, which can significantly reduce aircraft operating costs; and (2) a relationship between these two data sources can be used to estimate levels of effort on those days when flights are cancelled, which is a common problem with aerial-access surveys.

Both the above-mentioned forms of aerial-access surveys are, however, rather high-cost data collection methods. With the rapid advances and decreasing prices of remotely piloted aircraft systems (RPAS) – colloquially known as drones – researchers have a potentially innovative and cost-effective tool for implementing this kind of survey. In addition to improved cost-efficiency over existing techniques, highly replicable flight routes and the potential to access remote or inaccessible locations, RPAS also have the potential added benefit of being able to produce high-resolution mapping and capture footage beyond the visible spectrum, as well as provide non-invasive survey techniques for marine fauna. However, this technology also has several limitations including range, logistical considerations when operating over water, regulatory requirements and battery life (Desfosses et al., 2019). Furthermore, it must be noted that, to-date, limited studies have evaluated the suitability of RPAS as a recreational fisheries data collection tool (Desfosses et al., 2019). While these tools have a number of potential benefits, it is important that they be adequately evaluated in order to provide researches with a more complete understanding of the potential biases they may introduce (Beckmann et al., 2019) and their eventual suitability for the sustainable management of fish resources (Desfosses et al., 2019).

3.3 Type of information to be collected

Independent of the survey method (logbook, recall or onsite), in order to define the relationship between the sample and the statistical universe, it is necessary to collect basic personal data, such as gender, age and residence. The place of residence is needed in order to spatially allocate the fisher within the sampled population. For offsite surveys (logbook and recall) it is also recommended to collect the name and the mobile phone numbers. Other personal information are not relevant for the specific aims of this study (e.g. profession, education), unless the study has specific socio-economic objectives.

3.3.1 Fishing effort

Fishing effort is a measure of the amount of fishing activity deployed by a certain fishing segment and can be useful to calculate Catch Per Unit Effort (CPUE), which is needed to analyze changes in the amount of catch. This information is crucial for developing multiannual management plans.

Fishing effort can be calculated through a combination of inputs related to capacity, gear and time.

In particular, it is useful to collect the following data:

- Number of fishing trips: the number of fishing trips conducted during the interview period. The fishing trip is defined as a single fishing session, either performed from the shore, from a boat or underwater (i.e. starting from the shore or from a boat);
- Total fishing time (hours): the total duration (in hours) of a fishing trip (including navigation in case of boat);
- Fishing time (hours): the number of hours that a specific gear has been used (e.g. for set nets, longlines and traps it is the time from setting to pulling in, for hooks and spearguns it is the fishing time, etc.);

- Number of gears used: the number of nets (e.g. scoop net, cast net, beach seine, etc.). This also refers to the number of panels for gill nets (or length of total set nets used), the number of hooks used with rods or hand lines and the number of traps.

3.3.2 Guidance on how to measure fishing effort by fishing gear is provided in Annex VII. Catches

The objective of collecting catch data is to monitor and investigate the population dynamics of the most important species in area of study. Knowledge of the biomass removed by species from the ecosystem by fishing operations is fundamental for monitoring the status of stocks, as well as the impact of fishing on fish populations, gear selectivity, as well as catch-at-age.

In particular, it is useful to collect the following data:

- Species caught: identify the valid common name in order to define the scientific name of each species caught.
- Number of specimens kept: the number of specimens caught and retained by species (including all taxa, such as Molluscs, Crustaceans, Echinoderms, etc.).
- Number of specimens released and their post-release status: the number of specimens caught and released by species (including all taxa, such as Molluscs, Crustaceans, Echinoderms, etc.).
- Status of specimens after releasing: a) “alive” - strong body movements and nor or only minor injuries; b) “almost dead” – weak body movements and major injuries; c) “dead”; and d) “not known” – when the status was not observed.
- Length (cm): Length measures are easy to make, but require a well-defined and standardized way of being collected, in order to allow for comparison of results. The length measurements to be taken depend on the group of species under study. The length of fish and cephalopods, whenever possible, should be generally measured with graduated fish measuring instruments, called “ichthyometers”, while calipers are used for crustaceans (see below).
- Weight (kg): the weight of each single individual. If it is not possible to collect this information, it is possible to transform length into weight by using the length-weight relationship.
- Sex: determining the sex of caught individuals can either be easy or extremely difficult. For most fish it would be necessary to open the belly and check the gonads, and this should be authorized by the recreational fisher. Macroscopic observations can distinguish four sex categories: Male (M), Female (F), Undetermined (U – when, after dissection, it was not possible to determine the species’ sex with the naked eye) and Not Determined (ND – individual that has not been examined). For some fish taxa (e.g. some gobies, elasmobranchs,

etc.) it is possible to determine the sex by observing some external morphological features (e.g. fins, claspers, etc.).

Data on catches can be combined with effort data to estimate the CPUE, which is a relative measure of fish stock abundance. CPUE can be used to estimate absolute abundance and it could be an indicator of fishing efficiency (GFCM, 2018). In its basic form, the CPUE could be expressed as the captured biomass for each unit of effort applied to species/stock (e.g. total catch of a species divided by the total fishing: kg/number of fish per longline hook days, or numbers retained or caught by trip). Declining trends of this estimator could indicate overexploitation, while unchanging value could indicate sustainable fishing.

Further consideration must also be made for the role of catch-and-release – where fish are unhooked or set free from a trap or net and returned into the water alive – as a considerable portion of fish caught by recreational fisheries can be released (Ferter et al., 2013). The rates of released specimens, including the species and fishery-specific catch-and-release mortality rates, are unknown for most of recreational hook fisheries and therefore there is a need to estimate these mortality rates for use in stock assessments. A mixture of desk-based study and experimental work is therefore needed to compile data on the mortality of hook and line-caught fish and to underpin the evidence base in order to account for survival. Such studies should consist of reviewing existing literature, assessing the potential for extrapolation between species and fisheries, setting up generic mortality profiles, and conducting species-specific mortality studies to fill existing data gaps (ICES, 2014). This information is absent for most target species in the Mediterranean and Black Sea region and, until such information becomes available, a precautionary approach could be adopted, assuming a zero survival rate for those released species with no survival estimate.

How to measure fish, crustaceans and cephalopods

Bony fish and Elasmobranchs – For bony fish, sharks, skates and rays, the length should be considered as the total length (TL). The fish is measured to the lower half centimeter, from the tip of the snout to the end of the caudal fin (Figure 10).

The length classes should be reported in centimeters (as a whole number, or half cm, e.g. 0.5, 1.0, 1.5 etc.).

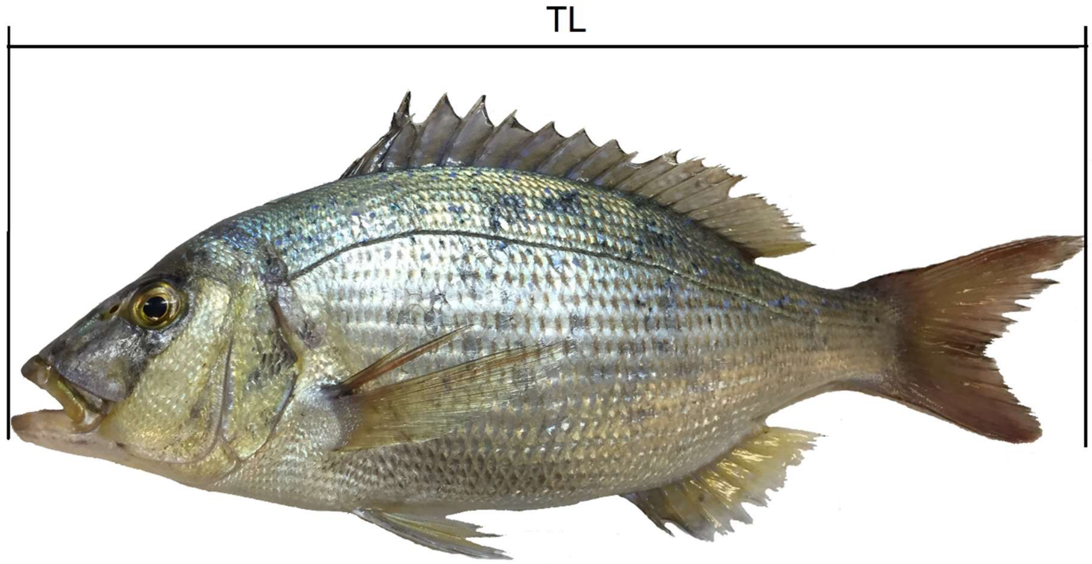

Figure 10. Illustration showing the measurement of total length (TL in bony fish. (photo by Lucchetti A.).

Crustaceans – For crustaceans (lobsters, crawfish, shrimps, prawns, stomatopods), the standard measurement is the minimum length of the carapace length (CL). The length classes should be reported in millimetres (as a whole number, e.g. 1, 2, 3, 4 etc.). The crustacean is measured, to the lower millimetre (mm), from the back border of the eye orbit (inside of the eye socket) to the posterior margin of the carapace (Figure 11). All measurements are taken with calipers.

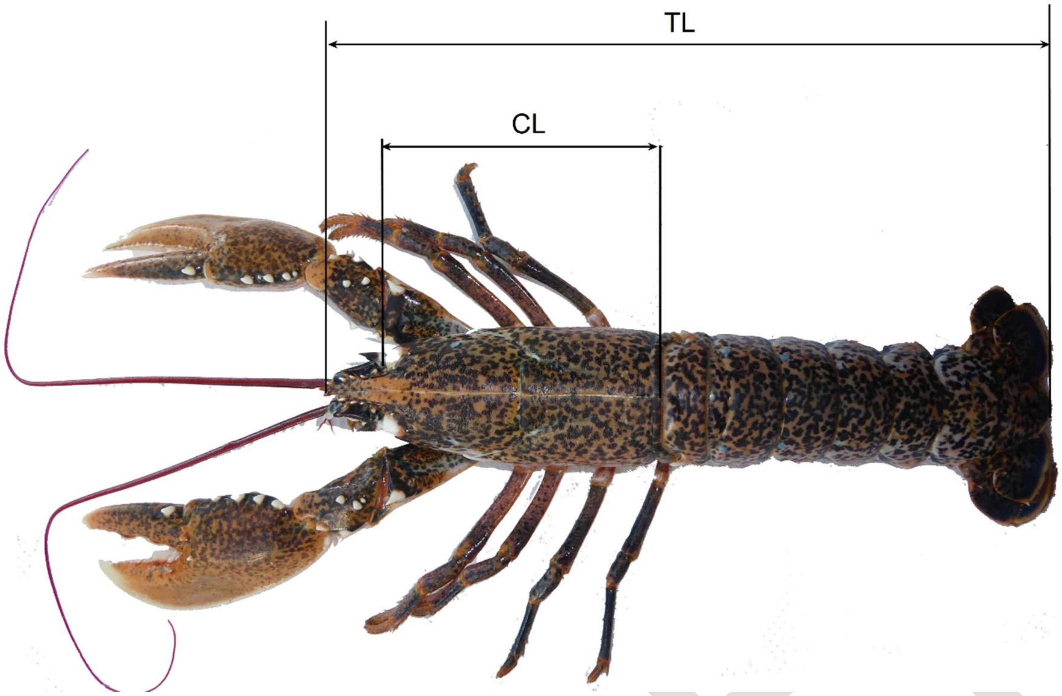

Figure 11. Illustration showing the measurement of total length (TL) carapace length (CL) for crustacean's decapoda (photo by Lucchetti A.).

Cephalopods – For cephalopods, the length is the dorsal mantle length (ML). The length classes should be reported in centimetres (cm). The cephalopod is measured to the nearest lower half centimetre. The size should be reported in centimetres (as a whole number, or half cm, e.g. 0.5, 1.0, 1.5 etc.). For Decapoda, measurement is made along the dorsal midline from the mantle margin to the posterior tip of the body, excluding long tails (Figure 12).

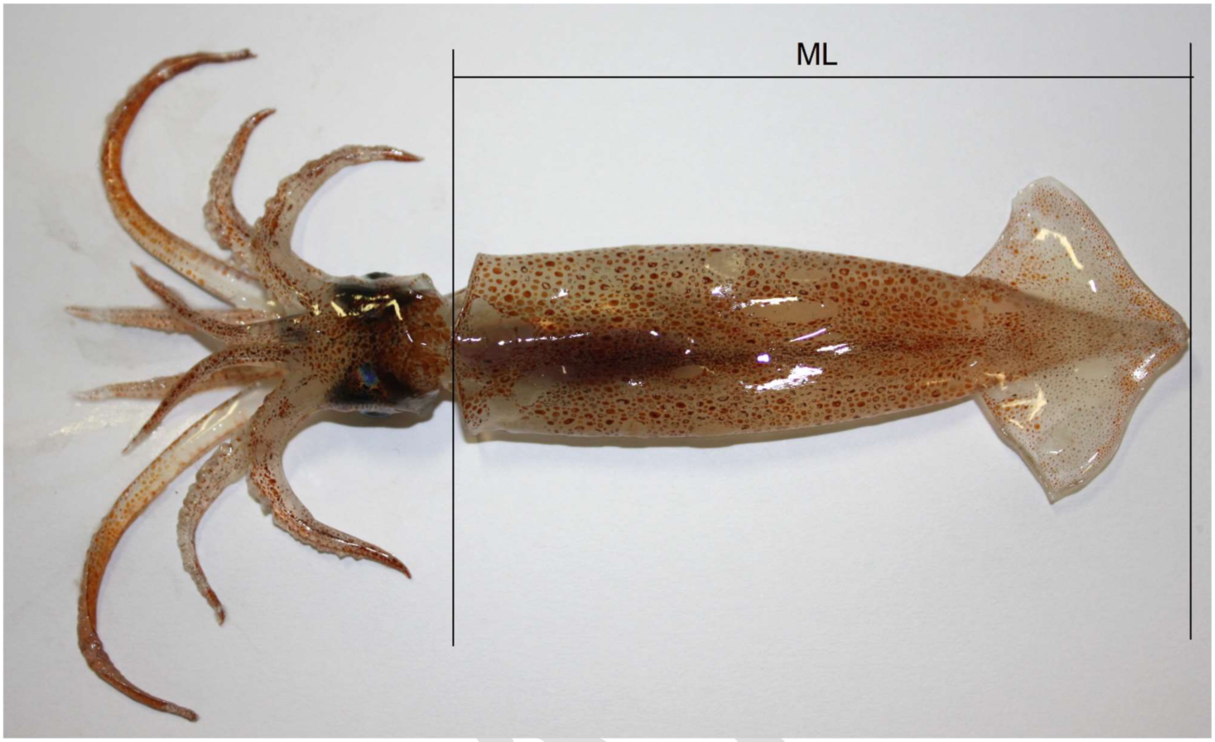

Figure 12. Illustration showing the measurement of dorsal mantle length (ML) on cephalopods (photo by Lucchetti A.).

3.3.3 Economic data

Although recreational fisheries do not generate a direct commercial output, it has been shown that these fisheries generate significant economic value, for example, through their contribution to the tourism sector (Gaudin & De Young, 2007). For this reason, the assessment of the economic impact of this sector is essential and economic data are an important component of any recreational fisheries data collection programme. Considering that recreational fisheries are, by definition, "non-commercial", meaning that it is prohibited to sell or trade the catches obtained, non-market valuation techniques therefore need to be applied. Both revealed and stated preference methods can be used to assess the value of recreational fisheries, however, revealed preference methods, such as the travel cost method and the hedonic pricing method, are most commonly used. These methods assess expenditures made as a proxy for economic value. Data on costs recreational fishers incur help to explain their behavior and are useful in understanding the wider economic impact of this fishing activity. A simple method for calculating recreational fishing expenditures is through a logbook or recall survey, by asking recreational fishers to report or recall the expenses incurred to carry out their leisure activity over the reference period. In the case of a logbook, fishers should include all expenditures in relation to the current fishing trip, as well as any expenditures made since their last fishing trip (e.g. purchase of a new rod, etc.). In the case of a recall survey, all expenditures within the recall period should be reported. Templates are provided in Annex Vd for logbooks and Annex Ve for recall surveys. A description of the variables to be collected for which expenditures should be calculated is listed below:

- Equipment: costs incurred for the purchase of equipment. For shore fishing and boat fishing these may include the purchase of rods, hooks, reels, cast nets, etc., whereas for underwater fishing these may include the purchase of a: speargun, fins, mask, wetsuit, etc.
- Bait: expenditures for both artificial baits (jigs, lures, spinner baits, etc.) and natural baits (worms, sardines, anchovies, shrimps, etc.) should be considered.
- Travel and accommodation: travel costs to/from the fishing site should be considered. These may include the cost of staying in a hotel (for the days spent fishing), round trip expenses to/from the fishing site, such as train or airplane tickets or expenses for travel by car (fuel costs, highway and parking fees, rental car expenses, etc.).
- Fishing license fees: it should be indicated whether the license is an annual, semi-annual, quarterly, monthly, weekly or daily license.
- Boat expenses: These may include, the purchase of a boat, boat rental or charter fishing fees, fuel costs (including two strokes lubrication oil), boat taxes (mooring, ramp, etc.), boat maintenance costs (engine maintenance, antifouling, etc.), as well as electronics (echosounder, GPS, radar, etc.).

4. Data analysis

4.1 Quality check of data

Once data are collected, they should be analysed and raised to the total population. However, before this can be done, a critical step is to carry out a data quality check and necessary data treatments. The accuracy of a survey estimate refers to the closeness of the estimate to the true population value and the difference between the two is referred to as the error of the survey estimate. This value – the error − is a fundamental component in the following steps for making estimations. Unfortunately, in practice, we can never obtain a true measure of sampling error, but only an estimate of it (Pinello et al., 2017).

Sampling errors refer to those errors which are encountered in the estimate of a parameter of the universe because of the fact that not all the population, but only a subset of it (the sample), is the object of observation.

Non-sampling errors can be simply defined as all of the other errors in the estimate arising during the course of all survey activities other than sampling (e.g. the way you run the survey). Unlike sampling errors, they can be present in both sample surveys and censuses and are extremely difficult, if not impossible, to measure mathematically. With this in mind, both survey designers and data quality evaluators have to ensure that non-sampling error is avoided as far as possible, or at least randomly distributed in order to eliminate its effect on the calculation of population estimates or brought under statistical control.

The most common non-sampling errors result from poor coverage and selection bias, low response rates, non-responses, interviewer errors and data entry errors. Non-sampling errors are systematic errors that tend to accumulate over the entire sample and these types of errors often lead to a bias in the final results. While sampling errors diminish with an increase in sample size (annulling themselves for census) this will not, in general, be true for the non-sampling error.

It is worth noting that, even for well-designed and well-implemented surveys, non-response represents a serious threat to the validity of estimates. It is fundamental to ensure that non-respondents do not belong to a specific segment of the target population, otherwise this would limit the validity of our inference. This point is of utmost importance and non-responses must be investigated to ensure that they have the same characteristics as the responses. The likely reason for non-response should be recorded for each respondent, so that appropriate weighting and calibration methods are applied to correct for non-response.

Prior to producing estimates for end-users, a certain amount of data checking and monitoring must be performed with the purpose of ascertaining the state of completeness and the quality of primary data (FAO, 2002). Such control functions involve:

- <u>Monitoring</u> - providing summary lists and reports will give quick indications as to the availability of samples on boat activities and catches in each estimation context.
- <u>Data range checking</u> - providing lists showing "extreme" values (the range of values) for catch, sample effort and prices. Too high or low values should be verified.
- <u>Sample size checking</u> - providing lists showing expected sample size and accuracy level for boat activities and landings.

To ensure quality assurance of recreational catch estimates from national surveys and document bias in data collection the ICES WGRFS have developed a quality assurance toolkit (QAT) for evaluation (ICES, 2013). The aim of this evaluation is to provide statements of quality of recreational data for end-users, including stock assessment scientists, and identify potential improvements to survey design. QAT consists of three modules: sampling designs, implementation and data analysis, leading to minimum bias and an accurate estimate of precision, making the most efficient use of sampling resources.

4.2 Response and completion rates

Rates are obtained by dividing integers by totals. In a simple random-sampling survey estimating the number of households containing recreational fishers, this value is obtained by dividing the number of households with recreationists over the total number of households that are interviewed. In simple random sampling, rates remain constant between samples and the overall populations. In the case of our survey estimating the number of fishers, if households are drawn at random and 20 percent of household components are found to be recreational fishers, we are confident that 20 percent will be the expected participation rate. The variance of estimated rates will vary based on the sampling design, the estimator and the distribution of the target variable. However a simple random sampling or a stratified random sampling survey will always be centered on this value (Hankin et al., 2019). This point will be further discussed when talking about estimators.

Among the most important rates lies the so-called "response rate". When data are collected through a nationwide screening survey, the first step of data analysis is to identify the fraction of recreational fishers from the total population who responded to the survey. The percentage of this active fraction is the response rate (Arlinghaus et al., 2014; Hyder et al., 2017). For self-administered surveys, like mail surveys, a response rate can be calculated by dividing the number of fishers who took part to the survey to the total number of fishers who were contacted. The rate can then be converted to a percentage, by multiplying it by 100. For example, when 200 persons answer to a telephone survey obtained from a sample of 1,000 individuals the response rate is 0.2 (i.e. 20 percent). The response rate can be increased through multiple reminders, especially if units are surveyed through self-administered questionnaires. In this case, it is important to record rates for each wave of reminders, to obtain a more nuanced overview about the survey effectiveness. For example, a survey might have a 0.8 response rate in the first wave, a 0.6 rate in the second wave after the first reminder, a 0.3 rate in the third wave after the second reminder and so on. Response rates generally decrease through time, wave after wave, and reminders might absorb a considerable proportion of the budget. It is highly recommended to account for reminders, when planning the financial resources for a survey.

When response rate is below one, non-response has occurred. Non-response can be easily imagined, in self-administered questionnaires as fishers who received a questionnaire and never sent it back. Non-response can be a severe bias affecting estimates. Dealing with non-response is complex and four different approaches are available: i) resampling, ii) data imputation or iii) calibration and iv) weighting (Fox, 2015):

- Resampling tackles non-response by replacing non-respondents with a corresponding number of randomly re-sampled units and, in stratified random sampling, replacements are taken from the same strata of missing observations.
- Data imputation is based on model fitting and it “fills” missing observations with predicted data from a model, but only when observations are missing completely at random, which is rarely the case in practice.
- Calibration includes information from auxiliary variables associated with non-response into estimators.
- Finally, weighting assign different importance to collected observations on the basis of the proportion of non-respondents in the sample. Weighting is particularly common in survey studies (Vaske, 2008) and it deserves a short explanation. Let’s imagine that we surveyed 1 000 households with a self-administered mail survey, asking for the presence of recreational fishers in the house and collecting data about seasonal catches. Our response rate is 30 percent only and we find that 80 percent of households contain at least one recreational fisher. However, we carry out a non-response check, knocking at the door of 90 percent of non-respondents: in our non-response check only 40 percent of households host recreationists. This finding suggests that the likelihood of answering the questionnaire was probably associated with the presence of recreational fishers within households, as they were motivated and interested in our survey. For example, a previous census revealed that only 50 percent of households contain recreational fishers. So, our sample probably includes too many households containing recreationists. We might therefore weight observations on the basis of pre-existing information about the statistical population. Weights can be expressed as:

$$Weight = Population\ percentage / Sample\ percentage$$

In this case, catches from households containing fishers would be weighted by a factor of 0.63 (50 percent : 80 percent = 0.63), while catches from households which do not contain fishers would be weighted by a factor of 2.5 (50 percent : 20 percent% = 2.5). The possibility of weighting the data to adjust for non-response makes clear the importance of non-response checks, to appreciate differences from respondents and non-respondents. It is important to understand that strata which are represented and under-represented should be identified carefully, just like when weighting observations: weighting for strata which are not relevant will further bias findings. Moreover, we encourage researchers to pay attention to the quality and the sample size of non-response checks.

Another fundamental rate is the "completion rate". In most quantitative surveys, respondents answer to structured questionnaires, each one containing a fixed number of questions. The completion rate represents the proportion of respondents who completed each question, and might be calculated as a geometric mean for all the questions in the survey. Low completion rates usually indicate that a questionnaire is too cognitively demanding for respondents, that perceived privacy protection is low or reporting burden is too high on the fishers. Piloting might provide researchers with valuable insights which can contribute to increase completion rates. Completion rate should be calculated for each question as the ratio between the number of questionnaires where the question was completed and the total number of questionnaires that were administered. Moreover, multiple completion rates might be averaged by calculating their geometric mean, which summarizes the extent to which questionnaires were completed.

Let's imagine that we designed a questionnaire to measure three common forms of non-compliance affecting recreational fisheries, each one with a different level of sensitivity and with different potential sanctions: throwing away leftover fishing lines into the sea (low sanctions), catching undersized fish (medium sanctions) and fishing within a commercial harbour, which is often forbidden for safety reasons but also common (high sanctions). Not surprisingly, in over 1 000 questionnaires that we collect, we discover that 896 respondents answered the first question, 451 the second question and that 86 respondents only answered the third question. Completion rates for the three questions are, respectively, 0.89, 0.45 and 0.09.

$$Geometric\ mean = \sqrt[n]{X_1 \ * X_2 \ * \ldots * X_n}$$

In our case, the average completion rate is 0.32. Of course, completion rates are usually equal to 1.0, when surveys do not include self-reported information, but when they simply measure some traits of the observational units. In a field survey where technicians count fishing boats there is no such a thing as a response rate. But response rate is a common issue in self-administered surveys, like mail, online or telephone surveys.

4.3 Measuring central tendency and data dispersion within our sample

Once data are collected it is fundamental to characterize our sample in terms of its centrality measures and in terms of its variability.

Centrality measures provide values around which observations are organized. The most famous measure is the arithmetic mean, known as the sum of all measurements divided by the number of observations in the data set:

$$\overline{x_a} = \frac{1}{n} \cdot \sum_{i=1}^{n} x_i$$

The arithmetic mean can also be calculated for a quantitative character *X*, divided into *K* classes, as:

$$\bar{x_a} = \frac{1}{n} \cdot \sum_{j=1}^{K} c_j \cdot n_j$$

Where *K* is the number of classes in the frequency distribution, *cj* is the central value of each class and *n* is the absolute frequency of the character in the class. This procedure correctly estimates the mean if each central value of a class corresponds to the mean of the values of each class. This situation occurs when the character is equally distributed among classes.

In case it is desirable to assign different weights to the various observations, it is possible to compute the weighted arithmetic mean:

$$\bar{x_a} = \frac{\sum_{i=1}^{n} x_i \cdot p_i}{\sum_{i=1}^{n} p_i}$$

In this case, *xi* represents values of the character within each class and *pi* the weights we want to assign to each class. For example, let's imagine that we survey three groups of fishers which might buy fishing licenses to go fishing around a protected area: exclusive recreational shore angler (n = 1 200), exclusive recreational spearfishers (n = 500) and exclusive boat anglers (n = 100). Each one of these three groups pays three different amounts of money for a seasonal fishing license: 20€, 50€ and 100€ respectively. If we want to estimate average expenditures, we have to account for the different number of people over the various classes: (20€ * 1,200 + 50€ * 500 + 100€ * 100) / (1,200 + 500+ 100) = 32.7 €.

Two alternative measures of central tendency are:

- the mode, the value of the distribution which appears with the highest frequency;
- the median, the middle value that splits the distribution our measures into two equal halves.

It is worth noticing, that the median and the mode are the only measures of central tendency that can be used for ordered variables, where values are ranked relative to each other but not measured absolutely.

For a series of quantitative measures, with an uneven number of elements, the median can be calculated as (n + 1) / 2, where n is the number of observations. On the other hand, the median for a series with an even number of elements can be calculated as the semi-sum of the two central units, n/2 and (n + 1)/2. The median is far more robust than the arithmetic mean against extreme values. If your sample of recreational fishers is highly heterogeneous, with few respondents having extremely high/low catches, using the median will provide a more accurate measure of your data centrality, compared to the arithmetic mean.

Variability indexes, on the other hand, represent the tendency of observational units to take different values of the same measure. Typically, variability indexes have two characteristics:

- their minimum value occurs when all observations have the same value of a certain measure;
- they increase the more diverse the observations in the sample are;

The most common indexes are based on differences between values of the observational units and the arithmetic mean. The variance, for example, can be expressed as the average squared difference between units and the mean:

$$Variance = \frac{1}{n} \cdot \sum_{i=1}^{n} (x_i - \bar{x})^2$$

The variance is always positive, and it can be converted to the original scale, by a square root. This procedure generates another measure of variability: the standard deviation. Being obtained through a square root, the standard deviation can be either positive and negative: if our sample of seasonal fish catches has a standard deviation of 40 kg, this means that measured fish catches are distributed within 40 kg above or below the arithmetic mean. Being on the same measurement scale as the mean, standard deviation is usually preferred to the variance. We can also measure the variability of our observations in terms of percentage, through the coefficient of variation (CV):

$$CV = \frac{Standard\ deviation}{Arithmetic\ mean} \cdot 100$$

The coefficient of variation represents the ratio of the standard deviation to the mean, and it is useful for comparing the degree of variation between two or more distributions, even if the means are drastically different from one another. For example, if a distribution has a coefficient of variation of 37.3 and another distribution has a coefficient of 61.3, the second distribution is more heterogeneous than the first one.

It is a common feature of recreational catches that a few people catch most of the fish, and that other catch no fish at all, and consequently catch distributions are generally highly positively skewed. The sampling distribution of mean catch rate estimated from such a distribution becomes more normal with increasing sample size, and when the sample size is large enough, the standard error can be used to define the confidence interval around the estimated parameter. However, in many surveys, sample sizes are too small for normality to be assumed. In these situations the bootstrapping technique provides an appropriate alternative to parametric methods (Efron & Tibshirani 1993). The basic idea of bootstrapping is that inference about a population from sample data can be modelled by resampling the sample data and performing inference about a sample from resampled data. As the population is unknown, the true error in a sample statistic against its population value is unknown. In bootstrap-resamples, the 'population' is in fact the sample, and this is known; hence the quality of inference of the 'true' sample from resampled data is measurable. A comparison of bootstrapping methods for calculating confidence intervals on catch estimates from recreational fishing survey is explained in further detail in Hoyle and Cameron (2003).

4.4 Estimators: estimating population mean, totals and variance.

For most applications, researchers and practitioners need minimum adjustments to adopt the information contained in their samples. Two routine operations that are performed in every form of survey research, are the estimation of participation rates, which should always be reported, and the use of the raising factors, to shift from sample totals to population totals. Calculating these two forms of information is straightforward and does not pose any particular problem to practitioners and researchers.

4.4.1 Simple estimations

Participation rate

In case the data source comes from a nationwide screening survey, the first step of data analysis is to identify the fraction of recreational fishers from the total population. The percentage of the active fraction is called "participation rate" (Arlinghaus et al., 2014; Hyder et al., 2017). You calculate the participation rate by dividing the number of active recreational fishers by the total number of people constituting the population. You can then multiply the resulting quotient by 100 to get the percentage.

Example: if by means of a telephone survey we randomly contact 1,000 people and we obtain that 200 of them perform marine recreational fishing, then the participation rate is 20%.

Raising factor

The raising factor is the factor by which the numbers in the sample have to be multiplied to give the total numbers in the population sampled (FAO, 1966). This is a vital step in combining and analyzing sample data.

Example: assume that n catches (or fishing effort) are sampled randomly from N made by a segment/stratum (e.g. boat fishing) during a quarter of a year, and total numbers of fish (or fishing days) y. The mean number (or mean weight) per trip is

$$\bar{y} = \frac{\sum y}{n}$$

and the estimated total caught number (or weight) Y for the segment/stratum is

$$Y = \bar{y}N$$

the raising factor is thus

$$\frac{N}{n}$$

This approach could be used also for raising Length Frequency Distribution (LFD) of catches (ICCAT, 2016).

4.4.2 In-depth estimations

For most types of data collection procedures, such as non-probabilistic sampling, working with sample statistics is enough: they are easy to calculate and highly informative about the data at hand.

However, for making rigorous inference from probabilistic sampling, considering information in the sample is not enough, for two reasons.

First, a practitioner or a researcher needs to understand if, and how, collected information must be treated, accounting for those units that we did not observe. While sample means can coincide with population means in simple random sampling, this does not hold for other forms of sampling designs.

Moreover, another daunting task is measuring the uncertainty associated with a certain estimate: this calculation differs among different sampling designs.

A complete overview about statistical estimators is needed, to address these two issues. The following section is more technically demanding than the previous one and briefly introduces how statistical estimators can be constructed. This text refers to a design-based paradigm, which is covered in detail in Hankin et al. (2019). Complete understanding of this paradigm is not necessary if using non-probabilistic sampling or if simply aiming to measure means and totals in simple random sampling.

This short section introduces statistical estimation of population parameter, following design-based inference. It serves three purposes: first, it shows how it is be possible to move from sample statistics to population-level estimates, second, it explains the properties characterizing good estimation and finally it explains why estimates always come with uncertainty. Until now we have always explained how to calculate population measures, such as the mean, without focusing on their accuracy. Well-designed random sampling, such as simple random sampling enables you to do this: the mean of your sample corresponds to the population mean. However, this approach ignores the fact that when we move from samples to populations, estimates are also characterized by uncertainty. Ignoring uncertainty is dangerous and we encourage you to better understand estimators, to better interpret information at hand.

An estimator is a statistic which is used to estimate a population parameter, a formula that can be applied to sample data to generate a numerical estimate of a population parameter. For example, estimating the average seasonal catch of a certain fish species by recreational fishers in a certain area, is based on the arithmetic mean, that we calculate over our sample:

$$M\hat{e}an = \sum_{i \in S} y_i / n$$

However, it is important to note that population mean is an estimated value. It is different from sample mean, which comes with no uncertainty, because its calculation is exclusively based on observed data only. Estimated population mean is uncertain, because its value depends on S, which is the overall sample space containing all the samples that can be extracted. Given a realized sample selection $S = s$, the population mean will be calculated as:

$$M\hat{e}an = \sum_{i \in s} y_i / n$$

Therefore, it will be calculated using the sample s and y values of its units. While y values are fixed, the population mean is a random variable, because several different samples could be extracted from the target population. If we sample different recreational fishers and we calculate their average catches, these will slightly differ: estimators account for this variability. The probability distribution of the estimator, as a random variable, is the distribution that is generated by all the possible samples that could be extracted, the sampling distribution. The sampling distribution of the population parameter is fundamental to assess the performance of a certain estimator at estimating a population parameter.

The sampling distribution of an estimator depends, at least, on three elements: the distribution of the population variable, the sampling design and the estimator itself. Just like we can characterize the location and spread of the distribution of our observed values, we could also characterize them for a sampling distribution, in terms of expectation and sampling variance. Expectation is a measure of the average value of the estimator, and variance is inversely related to its precision: the higher the variance, the lower the precision of our estimate. A good estimator has a low, or inexistent bias:

$$Bias = Expected\ value\ of\ the\ estimator - Real\ value\ of\ the\ population\ parameter$$

Bias is the difference between the expected value of the estimator and the real value of the population parameter: if bias is zero, the estimator is unbiased and its expected value is centered on the real value of the population parameter. This does not mean that the estimation will be precise, but it means that its distribution will always be sampled on the real value which it tries to estimate. For example, in a simple random sampling survey estimating average seasonal catches from recreational fishers, our estimator is unbiased if its distribution has the expected value which is centered on the real average catches of fishes that all the recreational fishers realize, in the study area. This could seem an obvious concept, but it is not: only few statistical designs guarantee unbiased estimates and an analytical, not approximated, estimation of the variance.

Another important metric is the Mean Squared Error (MSE), which corresponds to:

$$MSE = Variance + (Bias)^2$$

The MSE is a sum between the variance and the squared value of the bias and it provides an overall measure of estimator precision. It is possible to calculate the standard error (SE) and the coefficient of variation (CV) of our estimator:

$$SE = \sqrt{Variance\ of\ the\ estimator}$$

$$CV = Standard\ error/Expected\ value$$

Finally, because of the central limit theorem, stating that the distribution of a sample mean converges to a Gaussian distribution when $n \rightarrow \infty$ regardless of the shape of the sampled distribution, it is possible to compute confidence intervals for the estimator. It is important to note that is not always possible to obtain an exact expression of the variance of an estimator, but for many situations variance can only be approximated with the Delta method, based on Taylor series.

For simple random sampling without replacement, where we extract *n* observations from a population of *N* units, estimating sample mean (μ, e.g. the average seasonal catch of a certain species among anglers), proportion (π, e.g. the proportion of households containing recreational fishers in a certain area, for y_i which is 1 or 0) and total (τ, e.g. the total number of recreationists which fish in a certain area) is straightforward through mean per unit estimators (mpu):

From population mean $\mu = \frac{\sum_{i=1}^{N} y_i}{N}$ sample mean is estimated as ^ $= \frac{\sum_{i=1}^{N} y_i}{N}$

From population proportion $\pi = \frac{\sum_{i=1}^{N} y_i}{N}$ sample proportion is estimated as $\pi_{\hat{mpu}} = \frac{\sum_{i \in S} y_i}{n}$

From population total $\tau = \sum_{i=1}^{N} y_i = N\mu$ sample total is estimated as

$\tau_{\hat{mpu}} = N \cdot \sum_{i \in S} y_i / n = N\mu_{\hat{mpu}}$

Similarly, it is possible to estimate the sampling variance for the averages (μ), proportions (π) and totals (τ). In this case, we will denote the parameter of interest as θ:

$$V_{\mu_{\hat{mpu}}} = V_{\pi_{\hat{mpu}}} = \frac{(1 - f) \cdot \sigma^{2}_{\hat{mpu}}}{n}$$

or

$$V_{\tau_{\hat{mpu}}} = N^2 \cdot \hat{V} \cdot (\mu_{mpu})$$

where f is the sampling fraction, the fraction of the N units that appear in the sample of size n.

$$\sigma^{2}_{\hat{mpu}} = \frac{\sum_{i \in S} (y_i - \mu_{\hat{mpu}})^2}{n - 1}$$

When using stratified random sampling, the situation is slightly more complex. Units are divided into *L* strata of size N_h, $h=1, 2, \ldots, L$, such that the sum of their observations equates *N*, the size of the population. Samples are selected independently from each of the *L* strata, usually through simple random sampling. With any particular stratum is possible to obtain unbiased estimates of means, proportions and totals. Moreover, by using properly weighted stratified estimators it is also possible to obtain unbiased estimates of the overall parameters, across strata. The main advantage of stratified random sampling lies in its capability of significantly reduce the variance of estimated parameters, compared to simple random sampling. However, if strata are not correctly identified, estimation will be biased. In the next few lines we will refer to stratified estimators of a population parameter, denoted by the lowercase "st" (e.g. μ_{st}) and combining information from multiple strata, and to stratum-specific estimators, denoted by the lowercase "h" (e.g. μ_h).

The overall population mean (μ) can be expressed as:

$$\mu = \sum_{h=1}^{L} W_h \cdot \mu_h$$

It corresponds to the weighted average of the stratum means, weighted on the basis of the stratum weight, the fraction of the total number of units which are contained in a certain stratum ($W_h = N_h/N$). Then the stratified estimator of the population mean is:

$\hat{\mu_{st}} = \sum_{h=1}^{L} W_h \cdot \hat{\mu_h}$

Individual stratum means are estimated using the mean-per-unit (mpu) estimator, obtained from *Sh* which is a random set of sample units selected from stratum h.

$$\hat{\mu_{st}} = \sum_{j \in Sh} y_{hj}/n_h$$

For simple random sampling within strata, the expected values of the mean of each stratum (μ_h) corresponds to the mean of sampled variables in the stratum (μ):

$$E(\hat{\mu_h}) = \mu_h$$

Therefore, also the expected value of the overall mean (μ_{st}) is unbiased:

$$\hat{\mu_{st}} = \sum_{j \in Sh} y_{hj}/n_h$$

The stratified estimator of the variance of the mean is:

$$V(\hat{\mu}_{st}) = \sum_{h=1}^{L} W_h^2 \, V(\hat{\mu}_h)$$

And considered that the stratum-specific estimator of the variance of the mean is:

$$V(\hat{\mu}_h) = \left(\frac{N_h - n_h}{N_h}\right)\left(\frac{\sigma^2{}_h}{n_h}\right)$$

Then the stratified estimator of the variance of the mean is:

$V(\hat{\mu}_{st}) = \sum_{h=1}^{L} W_h^2 \left(\frac{N_h - n_h}{N_h}\right)\left(\frac{\sigma^2{}_h}{n_h}\right)$ where $\hat{\sigma}^2{}_h = \sum_{j=1}^{N_h} \frac{(y_{hj} - \mu_h)^2}{N_h - 1}$

For estimating population proportions (π), we apply the same procedures, assuming that y_j 's are always 1 or 0:

$$\hat{\pi}_{st} = \sum_{h=1}^{L} W_h \cdot \hat{\pi}_h$$

$V(\hat{\pi}_{st}) = \sum_{h=1}^{L} W_h^2 \left(\frac{N_h - n_h}{N_h}\right)\left(\frac{\sigma^2{}_h}{n_h}\right)$ where $\hat{\sigma}^2{}_h = \left(\frac{N_h}{N_h - 1}\right)\pi_h(1 - \pi_h)$

Finally, for totals (τ), the procedures are almost identical:

$\hat{\tau}_{st} = N\hat{\mu}_{st} = \sum_{h=1}^{L} \hat{\tau}_h$ and also $E(\hat{\tau}_{st}) = E(N\hat{\mu}_{st}) = NE(\hat{\mu}_{st}) = N\mu = \tau$

And the variance is:

$V(\hat{\tau}_{st}) = \sum_{h=1}^{L} V\,(\hat{\tau}_h)$ then $V(\hat{\tau}_{st}) = \sum_{h=1}^{L} N_h^2 \left(\frac{N_h - n_h}{N_h}\right)\left(\frac{\sigma^2{}_h}{n_h}\right)$

5. Stakeholder engagement

Recreational fisheries stakeholders include all parties with an interest in the development of sustainable recreational fisheries.) The term "stakeholder" is most often employed to refer to the recreational fishers themselves, including the federations and associations of recreational fishers and charters (e.g. Federazione Italiana Pesca Sportiva e Attività Subacquee in Italy, Federación Española de Pesca y Casting in Spain, etc.). However, the term "stakeholders" can also include the public authorities at both the local and national levels (e.g. port authorities and ministries in charge of fisheries management, respectively), environmental associations, Non-Governmental Organizations (NGOs) and research institutes. This list is by no means exhaustive and other organisms/stakeholders, such as other users of the aquatic resources and representatives from the secondary industry (e.g. the gear and tourism industries) could be included (Gaudin and De Young, 2007). In this context, the relevant advisory councils in EU countries (EU, 2013) that also work on recreational fishery issues (e.g. MEDAC for the Mediterranean) play an important role, since their opinion includes mediation efforts with recreational fishers and other fisheries sectors sharing and exploiting the same fishing resources.

Engaging stakeholders is vital for delivering a successful survey and, ultimately, for the sustainable management of recreational fisheries. When done properly, stakeholder engagement can help develop credibility and trust between researchers, decision-makers and fishers. This trust is essential for ensuring robust participation in studies, facilitating accurate data reporting, building a healthy platform for decision-making discussions and securing buy-in for eventual management measures. As an overall objective, stakeholder engagement should seek to close the gap between decision-making and practice.

Stakeholders can be engaged at all stages of the survey process. During the planning and development of the survey, the views of the recreational fishing community should be considered, as they know far more about recreational fishing than most scientists, while scientists know much more about scientific methods than the recreational fishing community. By involving stakeholders in the planning of surveys, clear communication can be established regarding the survey objectives and how the survey is designed to produce reliable results, helping to develop credibility and trust. During the data collection phase of the survey, stakeholder engagement is even more crucial. Stakeholder engagement could be promoted by means of panels for data collection, reference groups and committees, distribution of leaflets (via mail, websites, meetings), websites, journals/newspapers and other media (ICES, 2011). It is important to engage stakeholders as early as possible in data collection and monitoring initiatives in order to build trust through open discussions and transparent processes.

Working together leads to the experience and knowledge of all parties being incorporated in the design and implementation of recreational fishing surveys. This enhances the quality of the data collected, leading to greater utility for scientists and the recreational fishing community alike (ICES, 2012). Finally, efforts should be made to ensure survey results are reported back to stakeholders at the end of the survey. By communicating results, stakeholders are empowered to actively participate in management and decision-making processes. Recreational fisheries clubs, federations and associations can be particularly useful partners in this regard. In this way, the data collected is of use not only for public authorities, but also for angling organizations that may wish to develop their own policies and regulations (ICES, 2012).

There are many successful examples of such stakeholder engagement in the context of recreational fisheries. One example is the US Marine Recreational Information Program, which applied new communication methods in order to re-establish trust in the recreational fishery estimates. This was done by providing fact sheets, videos and background information on a website[3]. In this case a communication team was established to provide expert advice in order to effectively communicate with the stakeholders. To improve communication videos were chosen as new communication method. Similarly, the experience from co-management committees (e.g. the case of the Roses Bay in the Catalonia region of Spain) has showed that when recreational fishers were included in fisheries co-management committees, allowing them a forum for sharing their perspective and engaging in decision-making, fishers were surprisingly willing to self-regulate.

[3] https://www.st.nmfs.noaa.gov/recreational-fisheries/MRIP/what-we-do

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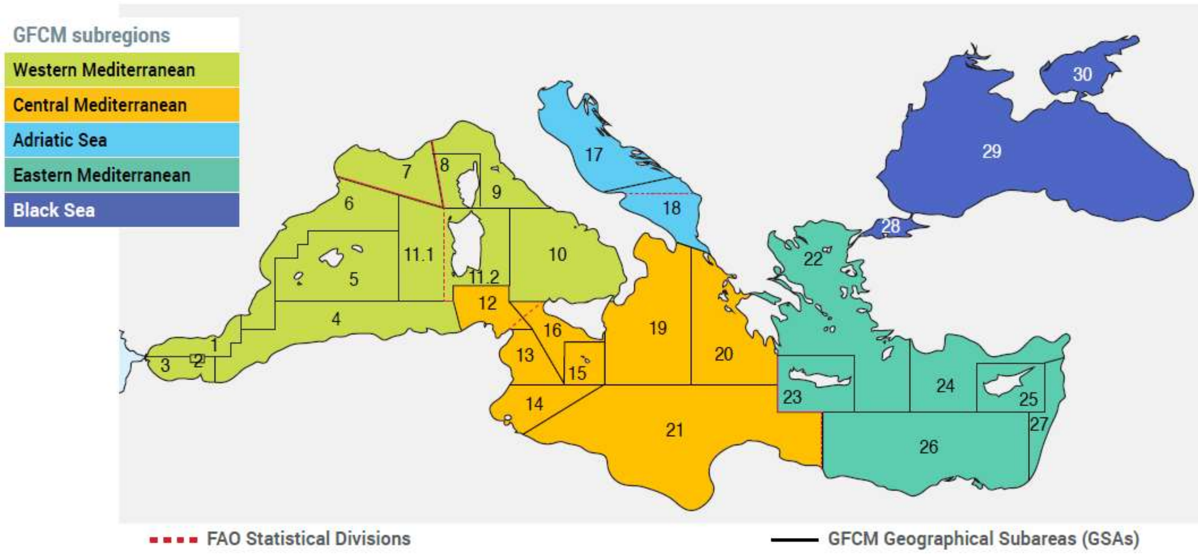
7. Annexes

Annex I – GFCM area of application, subregions and geographical subareas (GSAs)



GFCM GSAs

01 - Northern Alboran Sea	07 - Gulf of Lion	13 - Gulf of Hammamet	19 - Western Ionian Sea	25 - Cyprus
02 - Alboran Island	08 - Corsica	14 - Gulf of Gabes	20 - Eastern Ionian Sea	26 - South Levant
03 - Southern Alboran Sea	09 - Ligurian Sea and Northern Tyrrhenian Sea	15 - Malta	21 - Southern Ionian Sea	27 - Eastern Levant Sea
04 - Algeria	10 - South and Central Tyrrhenian Sea	16 - South of Sicily	22 - Aegean Sea	28 - Marmara Sea
05 - Balearic Islands	11.1 - Sardinia (west) 11.2 - Sardinia (east)	17 - Northern Adriatic Sea	23 - Crete	29 - Black Sea
06 - Northern Spain	12 - Northern Tunisia	18 - Southern Adriatic Sea	24 - North Levant Sea	30 - Azov Sea

Annex II – Codes for recreational fishing techniques.

Main recreational fishing gear and codes		
Gear name	**Code**	**Notes**
Hand implements	MHI	Wrenching gear, clamps, tongs, rakes, spears
Harpoons	HAR	Knife, harpoon
Diving (Speargun)	MDS*	
Diving (Hand)	MDH*	
Cast nets	FCN	
Boat seines	SV	
Beach seines	SB	
Hooks and lines (not specified)	LX	
Handlines and hand-operated pole and lines	LHP	Rod, handline
Traps (not specified)	FIX	
Pots	FPO	
Gillnets and entangling nets (nei)	GEN	
Gillnets	GNS	
Trammel nets	GTR	
Longlines (not specified)	LL	
Lift nets (not specified)	LN	
Scoop nets	MSP	
Gear not known or not specified	NK	
Others	OTH	

* Slightly modified from the "*International Standard Statistical Classification of Fishing Gear, 2016*

Annex III - Template for screening survey and enrollment of fishers in data collection panel

Template for screening survey and enrollment of fishers in data collection panel

Phone number ______________________ City ______________________

Number of members of the household ______________

Age	Gender		Marine recreational fisher?		Number of fishing trips in the previous year			Panel		
					Boat	Shore	Underwater	Willingness to participate?		If YES. Contact info (phone/email)
	♂	♀	Yes	No				Yes	No	
	♂	♀	Yes	No				Yes	No	
	♂	♀	Yes	No				Yes	No	
	♂	♀	Yes	No				Yes	No	
	♂	♀	Yes	No				Yes	No	
	♂	♀	Yes	No				Yes	No	
	♂	♀	Yes	No				Yes	No	
	♂	♀	Yes	No				Yes	No	
	♂	♀	Yes	No				Yes	No	
	♂	♀	Yes	No				Yes	No	

Annex IV – Templates for a mandatory fee-free online registration of marine recreational fishers

IVa – Personal information

Template for online registration

STEP 1 - general information

Name	____________________
Surname	____________________
Date of birth	____________________
Place of birth	____________________
Nationality	____________________
Address	____________________
E-mail	____________________
Telephone No.	____________________
Gender	♂ ♀

IVb – Description of the activity

Template for online registration

STEP 2 - avidity

ID No. ____

Fishing Mode	Gear	How many fishing trips did you perform last year?				
Boat	Hand implements	1-5	6-10	11-25	26-50	>50
	Harpoons	1-5	6-10	11-25	26-50	>50
	Diving (Speargun)	1-5	6-10	11-25	26-50	>50
	Diving (Hand)	1-5	6-10	11-25	26-50	>50
	Cast nets	1-5	6-10	11-25	26-50	>50
	Boat seines	1-5	6-10	11-25	26-50	>50
	Hooks and lines (not specified)	1-5	6-10	11-25	26-50	>50
	Handlines and hand-operated pole and lines	1-5	6-10	11-25	26-50	>50
	Traps (not specified)	1-5	6-10	11-25	26-50	>50
	Pots	1-5	6-10	11-25	26-50	>50
	Gillnets and entangling nets (nei)	1-5	6-10	11-25	26-50	>50
	Gillnets	1-5	6-10	11-25	26-50	>50
	Trammel nets	1-5	6-10	11-25	26-50	>50
	Longlines (not specified)	1-5	6-10	11-25	26-50	>50
	Lift nets (not specified)	1-5	6-10	11-25	26-50	>50
	Scoop nets	1-5	6-10	11-25	26-50	>50
	Gear not known or not specified	1-5	6-10	11-25	26-50	>50
	Others	1-5	6-10	11-25	26-50	>50
Shore	Hand implements	1-5	6-10	11-25	26-50	>50
	Harpoons	1-5	6-10	11-25	26-50	>50
	Diving (Speargun)	1-5	6-10	11-25	26-50	>50
	Diving (Hand)	1-5	6-10	11-25	26-50	>50
	Cast nets	1-5	6-10	11-25	26-50	>50
	Beach seines	1-5	6-10	11-25	26-50	>50
	Hooks and lines (not specified)	1-5	6-10	11-25	26-50	>50
	Handlines and hand-operated pole and lines	1-5	6-10	11-25	26-50	>50
	Traps (not specified)	1-5	6-10	11-25	26-50	>50
	Pots	1-5	6-10	11-25	26-50	>50
	Gillnets and entangling nets (nei)	1-5	6-10	11-25	26-50	>50
	Gillnets	1-5	6-10	11-25	26-50	>50
	Trammel nets	1-5	6-10	11-25	26-50	>50
	Longlines (not specified)	1-5	6-10	11-25	26-50	>50
	Lift nets (not specified)	1-5	6-10	11-25	26-50	>50
	Scoop nets	1-5	6-10	11-25	26-50	>50
	Gear not known or not specified	1-5	6-10	11-25	26-50	>50
	Others	1-5	6-10	11-25	26-50	>50
Underwater	Hand implements	1-5	6-10	11-25	26-50	>50
	Harpoons	1-5	6-10	11-25	26-50	>50
	Diving (Speargun)	1-5	6-10	11-25	26-50	>50
	Diving (Hand)	1-5	6-10	11-25	26-50	>50
	Gear not known or not specified	1-5	6-10	11-25	26-50	>50
	Others	1-5	6-10	11-25	26-50	>50

IVc – Certificate

Template for online registration

STEP 3 - certificate

Name	______________________
Surname	______________________
Nationality	______________________
Address	______________________
ID No.	______________________
Issuing date	______________________
Expiration date	______________________

Annex V – Template of Logbook and Recall Survey

Va – General information for logbook and recall survey

Logbook and Recall template - general information

Logbook ☐ **Recall** ☐ Reference month and year ____________________

Name and Surname of panel participant ____________________

Information reported for:

Only the panel participant ☐

Multiple fishers (in case the panel participant's catch is pooled with other fishers on the same trip) ☐

If multiple fishers:

No. Fishers: ♂ ____ age | | | | | | | | | | | |
♀ ____ age | | | | | | | | | | | |

Fishing location

Geographical SubArea (GSA) ____________________

City ____________________

Distance from the coast (in nm) ____________________

Total fishing time

	Start	End
Date		
Hour		

Fishing mode* Boat ☐ Shore ☐ Underwater ☐

Gear	Gear code	Fishing time per gear (in hours)	Number of units used per gear
Hand implements	MHI		
Harpoons	HAR		
Diving (Speargun)	MDS		
Diving (Hand)	MDH		
Cast nets	FCN		
Boat seines	SV		
Beach seines	SB		
Hooks and lines (not specified)	LX		
Handlines and hand-operated pole and lines	LHP		
Traps (not specified)	FIX		
Pots	FPO		
Gillnets and entangling nets (nei)	GEN		
Gillnets	GNS		
Trammel nets	GTR		
Longlines (not specified)	LL		
Lift nets (not specified)	LN		
Scoop nets	MSP		
Gear not known or not specified	NK		
Others**	OTH		

Catches

No.	Gear code	Species	No. Retained	Weight (kg) Retained	No. Released
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Comments:

** Complete one logbook/recall template per fishing mode*

*** Provide a description of the fishing gear in the comments section*

Vb – Catch information for logbook and recall survey

Logbook and Recall template - retained species information

Logbook ☐ Date _______________	**Recall** ☐ Reference month and year ____________________

No.	Gear code	Species (retained)	Length*	Weight (kg)	Sex**	Fishing mode***		
						Boat	Shore	Under water
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								

* *Total Length for fish (cm), Mantle Length for cephalopods (cm), Carapace Length for crustaceans (mm)*
** *if known (M: Male; F: Female; ND: Not Determined)*
*** *Select only one fishing mode (boat, shore, underwater) per row*

Vc – Released species information for logbook and recall survey.

Logbook and Recall template - released species information

Logbook ☐ Date ______________	**Recall** ☐ Reference month and year _________________

No.	Gear code	Species (released)	Length*	Post-released status**				Fishing mode***		
				Alive	Almost dead	Dead	Not known	Boat	Shore	Under water
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23										
24										
25										

** Total Length for fish (cm), Mantle Length for cephalopods (cm), Carapace Length for crustaceans (mm)*

*** mark the corresponding cell*

**** Select only one fishing mode (boat, shore, underwater) per row*

Vd – Expenditure information per fishing trip for logbook survey

Logbook template - expenditures

Expenditures per fishing trip

(Any expenditures since the last logbook date, such as purchases of new equipment, should be reported)

Start date of fishing trip: ____________________________

Type of expenditure	Value	Currency
Rods and reels		
Nets (set nets, lift, scoop, etc.)		
Accessories (hooks, lines, etc.)		
Speargun		
Underwater accessories (fins, mask, etc.)		
Traps		
Artificial baits (jigs, lures, etc.)		
Natural baits (worms, sardines, etc.)		
Travel and accommodation		
License fee		
Boat rental		
Charter		
Fuel		
Taxes		
Electronics (GPS, radar, etc.)		
Boat maintenance		
Others ____________________________		
Others ____________________________		
Others ____________________________		
Others ____________________________		

Comments:

Ve – Expenditure information per month for recall survey

Recall template - expenditures

Expenditures per month

Reference month and year: ____________________________

Type of expenditure	Value	Currency
Rods and reels		
Nets (set nets, lift, scoop, etc.)		
Accessories (hooks, lines, etc.)		
Speargun		
Underwater accessories (fins, mask, etc.)		
Traps		
Artificial baits (jigs, lures, etc.)		
Natural baits (worms, sardines, etc.)		
Travel and accommodation		
License fee		
Boat rental		
Charter		
Fuel		
Taxes		
Electronics (GPS, radar, etc.)		
Boat maintenance		
Others ____________________________		
Others ____________________________		
Others ____________________________		
Others ____________________________		

Comments:

Annex VI – Template for onsite surveys

VIa – General information for onsite survey

Onsite survey template - general information

Date of interview ______________________

Information by:

Single fisher ☐ Multiple fishers (in the case that catches are pooled) ☐

No. Fishers: ♂ __________ age
♀ __________ age

Fishing location	Geographical SubArea (GSA)	
	City	
	Distance from the coast (nautical miles)	
	Latitude	
	Longitude	

Total fishing time

	Start	End
Date		
Hour		

Gear	Gear code	Fishing mode* Boat	Shore	Under-water	Fishing time per gear (in hours)	Number of units used per gear
Hand implements	MHI					
Harpoons	HAR					
Diving (Speargun)	MDS					
Diving (Hand)	MDH					
Cast nets	FCN					
Boat seines	SV					
Beach seines	SB					
Hooks and lines (not specified)	LX					
Handlines and hand-operated pole and line	LHP					
Traps (not specified)	FIX					
Pots (not specified)	FPO					
Gillnets and entangling nets (nei)	GEN					
Gillnets	GNS					
Trammel nets	GTR					
Longlines (not specified)	LL					
Lift nets (not specified)	LN					
Scoop nets	MSP					
Gear not known or not specified	NK					
Others	OTH					

Catches

No.	Gear code	Species	No. Retain	Weight (kg) Retain	No. Release
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Number of fishing trips performed by the interviewee during the previous year:

Boat	
Shore	
Underwater	

Willingness of interviewee to participate in a follow-up panel? If yes, name and (mobile) telephone number:

Comments:

** Complete one logbook/recall template per fishing mode*

*** Provide a description of the fishing gear in the comments section*

VIb – Catch information for onsite survey.

Onsite survey template - retained species information

Date ______________________

No.	**Gear code**	**Species (retained)**	**Length***	**Weight (kg)**	**Sex****	**Fishing mode*****		
						Boat	Shore	Under water
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								

**   Total Length for fish (cm), Mantle Length for cephalopods (cm), Carapace Length for crustaceans (mm)*

*** if known (M: Male; F: Female; ND: Not Determined)*

**** Select only one fishing mode (boat, shore, underwater) per row*

VIc – Released species information for onsite survey.

Onsite survey template - released species information

Date ______________________

No.	Gear code	Species (released)	Length*	Post-released status**				Fishing mode***		
				Alive	Almost dead	Dead	Not known	Boat	Shore	Under water
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23										
24										
25										

** Total Length for fish (cm), Mantle Length for cephalopods (cm), Carapace Length for crustaceans (mm)*

*** Mark the corresponding cell*

**** Select only one fishing mode (boat, shore, underwater) per row*

Annex VII – Fishing effort measurement

Effort measurement by fishing gear				
Gear name	**Code**	**Unit of capacity**	**Unit of activity**	**Nominal effort**
Hand implements	MHI	Number	Fishing days	Number x Fishing days
Harpoons	HAR	Number	Fishing days	Number x Fishing days
Diving (Speargun)	MDS	Number	Fishing days	Number x Fishing days
Diving (Hand)	MDH	Number	Fishing days	Number x Fishing days
Cast nets	FCN	Number	Fishing days	Number x Fishing days
Beach seines	SB	Net length*	Fishing days	Net length x Fishing days
Hooks and lines (not specified)	LX	Number of hooks	Fishing days	Number of hooks x Fishing days
Handlines and hand-operated pole and lines	LHP	Number	Fishing days	Number x Fishing days
Traps (not specified)	FIX	Number of traps	Fishing days	Number of traps x Fishing days
Pots	FPO	Number of pots	Fishing days	Number of pots x Fishing days
Gillnets and entangling nets (nei)	GEN	Net length*	Fishing days	Net length x Fishing days
Gillnets	GNS	Net length*	Fishing days	Net length x Fishing days
Trammel nets	GTR	Net length*	Fishing days	Net length x Fishing days
Longlines (not specified)	LL	Number of hooks	Fishing days	Number of hooks x Fishing days
Lift nets (not specified)	LN	Number	Fishing days	Number x Fishing days
Scoop nets	MSP	Number	Fishing days	Number x Fishing days

**Length of net expressed in 100-metre units*