Overview of the methodology for the assessment of the vulnerability of fisheries in the Mediterranean and the Black Sea to the effects of climate change

This Appendix summarizes the methodology proposed to be used in the assessment of the vulnerability of fisheries in the Mediterranean and Black Sea to the effects of climate change. The methodology was based on literature review and on inputs received during the expert meeting on the implications of climate change to fisheries in the Mediterranean and Black Sea, Rome, 4 – 6 December 2017. Consistent with the Ecosystem Approach to Fisheries, the methodology is based on the application of the precautionary principle through the use of best available knowledge and assumes a broad stakeholder participation throughout the assessment process.

Definitions

The methodology uses the following definitions adopted by the Intergovernmental Panel on Climate Change (IPCC). Although variations to these definitions have been put forward more recently (FAO, 2015), the conceptual model of vulnerability described below is valid and used widely in vulnerability assessments.

- *Vulnerability*: the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate change and variation to which a system is *exposed*, its *sensitivity*, and its *adaptive capacity* (Figure 1).

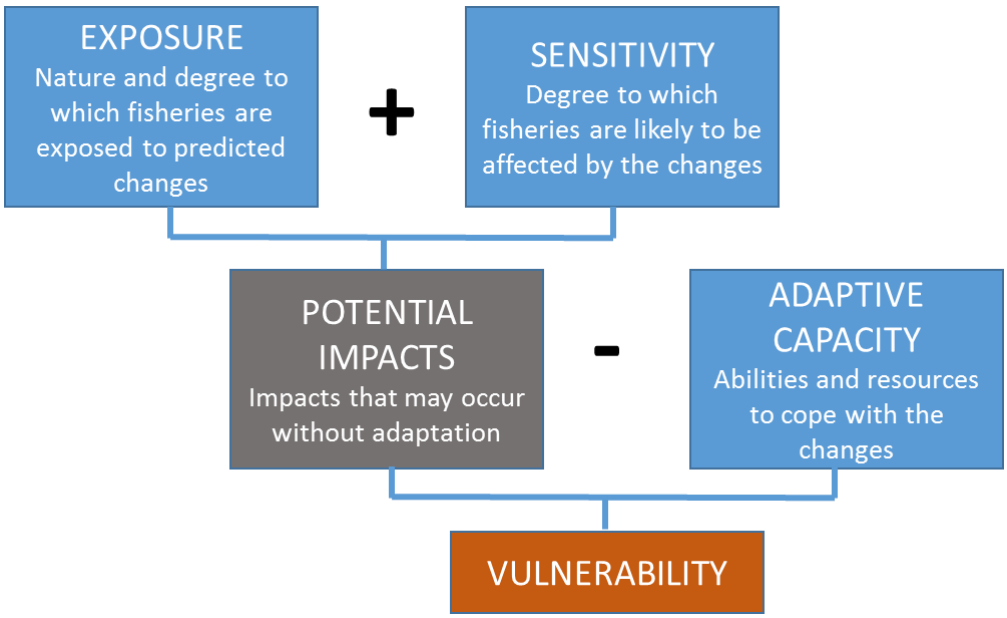

Figure 1. IPCC conceptual model of vulnerability.

- *Exposure*: the degree to which a system is stressed by climate, such as the magnitude, frequency and duration of a climatic event (e.g. temperature anomalies, extreme weather events). In a practical sense, exposure is the extent to which a region, resource or community experiences change. For fishing communities, exposure would relate, for instance, to how much the resource they depend on will be affected by environmental change.

- *Sensitivity*: the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct (e.g. a change in yield in response to a change in the mean, range or variability of temperature) or indirect (e.g. damages caused by an increase in the frequency of coastal flooding due to sea-level rise). The sensitivity of social systems depends on economic, political, cultural and institutional factors that allow for buffering of change.

- *Adaptive capacity*: the ability of a system to adjust to climate change, to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. For example, systems with low adaptive capacity may have difficulty adapting to change or taking advantage of the opportunities created by changes in the availability of ecosystem goods and services stimulated by climate change or changes in management. Social systems are more likely to be sensitive to climate change if they are highly dependent on a climate vulnerable natural resource. These factors can confound (or ameliorate) the social and economic effects of climate exposure.

Objectives of the Vulnerability Assessment

The assessment of the vulnerability of fisheries in the Mediterranean and Black Sea to the effects of climate change has the following objectives:

- To understand the potential risks to the fisheries sector in the Mediterranean and Black Sea of the ongoing and projected climate-driven environmental changes.
- To identify areas and/or sectors more vulnerable and in need of adaptation options.
- To contribute to a regional (GFCM) adaptation strategy to cope with the potential effects of climate change in the Mediterranean and Black Sea.

Scope of the Vulnerability Assessment

The focus of the vulnerability assessment is the fisheries production systems in the Mediterranean and Black Sea. Fisheries production systems are here understood as the coupled social-ecological systems composed of the resource base (stocks) and supporting ecosystems, the fishers, the fishing technologies and practices used in the capture production and the fisheries value chain.

The fisheries production systems are affected by different types of drivers (Figure 2). On the one hand, there are socioeconomic and institutional drivers that affect how fisheries operate and influence the sustainability and profitability of the activity. They include governance factors such as policies and regulatory frameworks that conditions where, what and how resources are harvested and by whom, cultural/traditional factors that condition the maintenance of fishing livelihoods and practices, and economic factors that define market opportunities and constrains and the dynamics of the value chain. On the other hand, the systems are influenced by anthropogenic drivers such as overfishing, habitat degradation and pollution that affect the productivity and resilience of the stocks and ecosystems. The systems are also affected by climate change drivers, such as changes in sea surface temperature, circulation, weather, etc. that can generate direct and indirect impacts on fisheries. The known direct effects of climate change include changes in the abundance and distribution of exploited species and the impacts of weather events on fishing operations and infrastructure. Indirect effects can include changes in other ecosystem components that interact with the fisheries resources, as well as environmental changes that affect other food production systems and people's health (Cochrane et al., 2009; Heenan et al., 2015).

The vulnerability of the fisheries production systems will depend on how they can cope with the impacts of climate change giving the conditions determined by the other drivers.

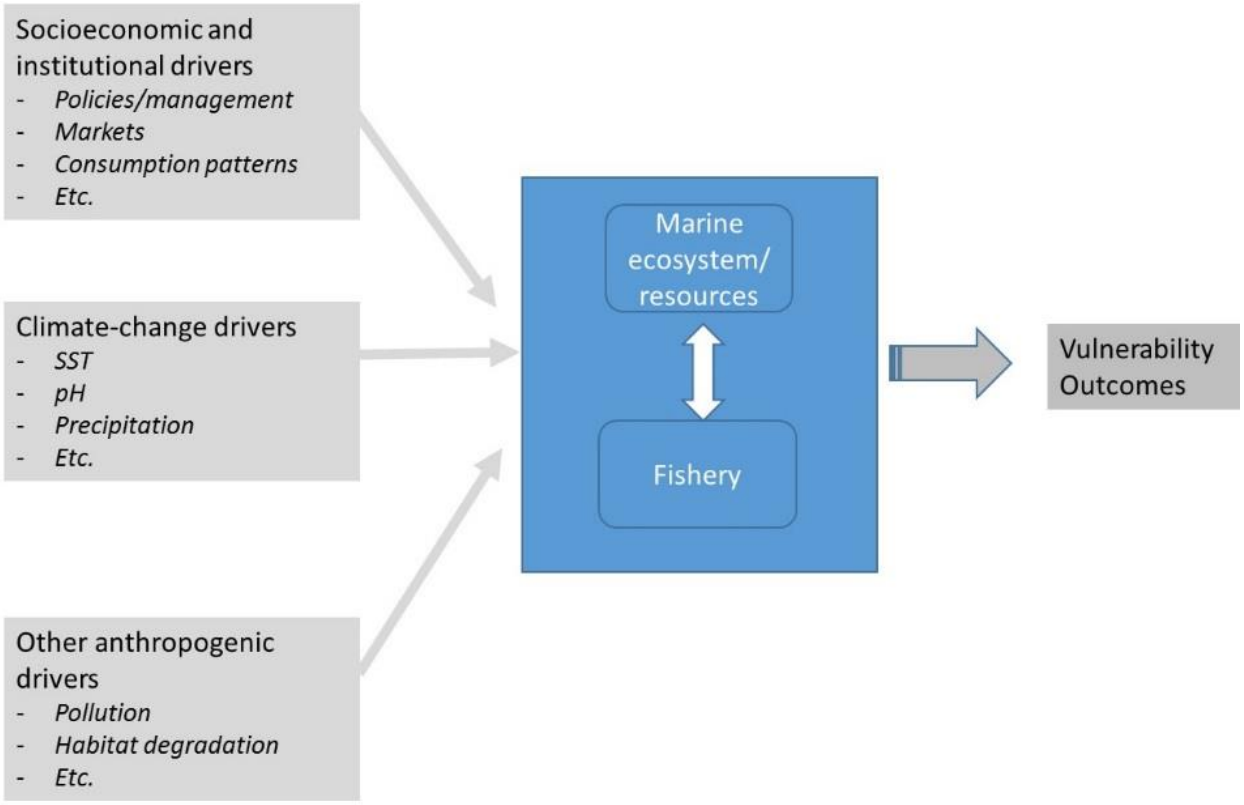

Figure 2. Conceptual model of the fisheries production system and the vulnerability to climate change.

The assessment of the vulnerability of the fisheries production systems could be focused on different spatial scales of analysis, e.g., at the level of the fishing unit (vessel), fleet segment, fishing community, country, sub-regions, etc. Considering the geographic, environmental and socioeconomic differences among sub-regions and fisheries across the Mediterranean and Black Sea, the expert meeting recommended the use of the following minimum level of stratification for a comprehensive view of the impacts and vulnerabilities of fisheries to climate change in the region:

Area	Sub-regions	Fisheries/resources
Mediterranean	Adriatic Sea, Western Mediterranean, Eastern Mediterranean	small-scale fisheries; small-pelagics; large pelagics; demersals; and benthic invertebrates.
Black Sea	Black Sea (as a whole)	anchovy, sprat, turbot, bonito, rapa whelk

Representative fisheries production system will need to be identified within each of the above strata to use as case studies for the vulnerability assessments.

In terms of the temporal scale of analysis, the expert meeting recommended that the assessment consider the projected changes and impacts on the mid-term (until 2050).

<u>Baseline situation</u>

The first step in the scoping analysis is to conduct a baseline assessment to describe the current situation of the fishery production systems. Table 1 list examples of variables that could be used to characterize the fishery production systems in the baseline report.

Table 1. Examples of variables to describe the baseline situation of a fishery production system.

Type	**Variables**
Ecological	- Area of operation - Target and bycatch species - **Status of stocks**
Technological	- Gear - Vessels - Equipment
Socioeconomic	- Landings - Revenue (and crew sharing system) - Economic dependency - Education - Social protection - Access to credit - Market - Level of organization (e.g. cooperatives, associations, etc)
Institutional	- Enabling policies - Management capacity - Management plans and contingency measures
Main drivers of change (non-climate related)	- Pollution - Habitat degradation - Overfishing, etc.

Climate change drivers and expected impacts

The second step in the scoping analysis is to understand the main pathways that climate change can potentially impact the fishery production systems. There are multiple pathways of potential impacts (Figure 3) and it is important to understand which pathways are likely to be relevant to the systems at stake. During the expert meeting participants elaborated generic matrices of drivers and impacts for each of the sub-regions in the Mediterranean and Black Sea (Appendixes IV and V of the report of the expert meeting on climate change implications for the Mediterranean and Black Sea fisheries [GFCM headquarters, December

2017]). These matrices could be used as starting points for discussing and identifying potential pathways of impacts of climate change in specific fishery production systems case studies in each of the sub-regions.

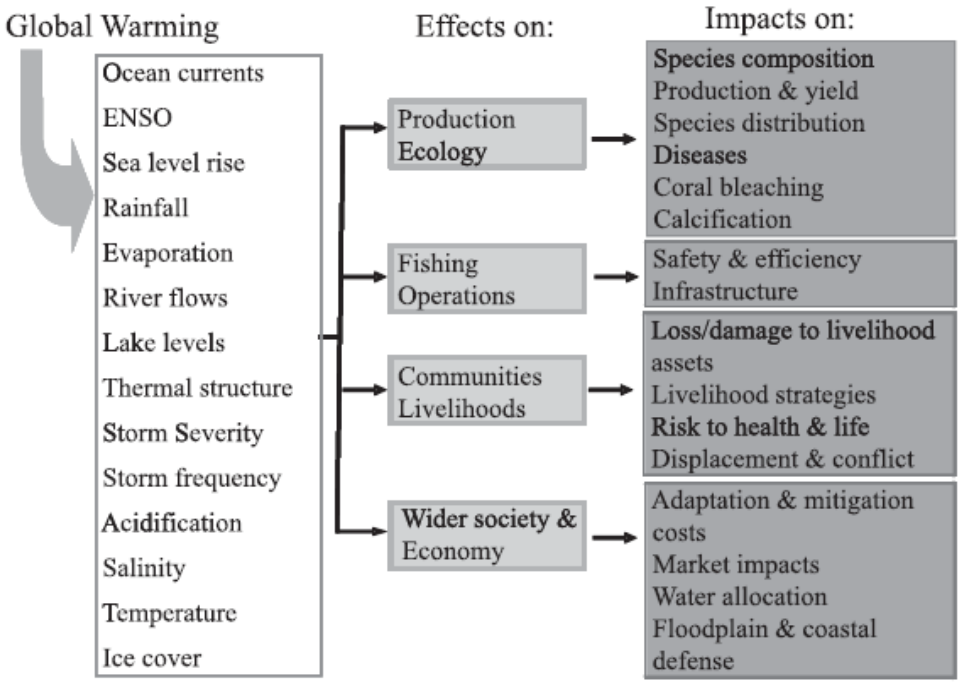

Figure 3. Generic examples of pathways of the impact of global warming on fisheries (Badjeck et al, 2010).

Framework of analysis

The vulnerability assessment is based on the IPCC conceptual model which considers vulnerability a function of the exposure, sensitivity and adaptive capacity of the system (Figure 1). A risk assessment approach is used in the assessment of the vulnerability.

The impacts of climate change can be negative or positive. Negative impacts represent threats – they need to be mitigated. Positive impacts represent opportunities – they need to be explored and benefited from. The importance of the negative or positive impacts can be measured in terms of: 1) the level of expected impact or consequences and 2) the likelihood of the impact occurring. The likelihood of given level of impact occurring is defined as a measure of risk. Therefore, the vulnerability of a system to a given driver/event can be measured in terms of risk levels. While the likelihood of an impact occurring can be interpreted as a measure of exposure of the system to a specific driver/event, the consequences of a driver/event can be linked to its sensitivity and adaptive capacity. FAO (2015) noted that a similar interpretation of the relationships between risk and vulnerability were proposed in the 5th Assessment Report of the IPCC.

For instance, consider two small-scale fisheries in a given sub-region of the Mediterranean, exposed to the same level of changes in the distribution of a target species. Both are exposed to an event that is very likely to occur (based on observed and/or projected changes). Consider further that one of the small-scale fisheries is more dependent on that target species than the other, which has a much more diverse livelihood "portfolio" that includes other species not directly affected by climate change and also activities outside of the fisheries sector. In addition, the system has a social-security mechanism in place to guarantee a minimal level of income during unfavourable situations. The two systems have different levels of sensitivity and adaptive capacity to the climate change driver/event. The consequences of the event to one of the systems

will be higher than to the other. Therefore, the two systems will have different levels of risk to the climate driver/event. The system with higher risk is the one more vulnerable to that particular driver. When analyzing positive impacts, the risk level becomes a measure of the expected capacity of the system to benefit from the opportunities associated with a given driver/event.

In lack of availability of fully quantitative methods to assess the risks associated with the different pathways of impacts, a qualitative risk assessment approach is suggested to be used (FAO, 2012). A similar qualitative approach was used in the FAO/WorldFish Workshop on "Adapting to climate change: the Ecosystem Approach to Fisheries and Aquaculture in the Near East and North Africa Region", when a preliminary list of issues and priorities concerning climate impacts on fisheries and aquaculture in the region was identified (Curtis et al., 2011)

An adaptation of the Consequence x Likelihood (C x L) matrix method is used (FAO, 2012). The method combines the scores from the qualitative or semi-quantitative ratings of consequence (levels of impact) and the likelihood (levels of probability) that a specific consequence will occur to generate a risk score and risk rating.

This C x L risk assessment process involves selecting the most appropriate combination of consequence and likelihood levels that fit the situation for a particular objective, based upon the information available and the collective knowledge of the group of stakeholders involved in the assessment process. These scores are multiplied to generate an overall risk score. To allow the assessment of positive impacts, a two-way scale of consequence levels is applied (Garret et al., 2015; Table 2).

Table 2. Generic consequence categories for the assessment of risks of climate-driven impacts on fisheries. Positive consequences are in italics.

Level		Description
1	Minor	Minimal impacts that are highly acceptable. *Few, small-scale impacts providing some minor opportunities across the fishing sector.*
2	Moderate	Maximum acceptable level of impact. *Many, small-scale impacts providing moderate opportunities across the fishing sector.*
3	Major	Above acceptable limit. Wide and long-term negative impacts. *Few, large-scale impacts providing some significant opportunities across the fishing sector.*
4	Extreme	Well above the acceptable limit. Very serious, likely to require long restoration time to undo. *Many, large-scale impacts providing major opportunities across the fishing sector.*

The consequences are assigned considering the expected sensitivity of the fishery system to a given pathway of impact and the adaptive capacity of the system. Different aspects could be considered in the evaluation

of the sensitivity and adaptive capacity of a system. Table 3 provide some examples of variables that could be taken into account (Allison et al., 2009; Cinner et al., 2013; FAO, 2015; Whitney et al., 2017). Many of the variables should be part of the baseline assessment described before.

Table 3. Examples of generic social and ecological variables that could be used in the assessment of sensitivity and adaptive capacity of fishery systems.

Characteristics of adaptive capacity		**Characteristics of sensitivity**	
Category	**Indicators**	**Category**	**Indicators**
Diversity and flexibility	Livelihood and income diversity	*Fisheries sensitivity*	Landings (value) of the affected species as % of total landings (value)
	Economic opportunities		Gear sensitivity (which type of gear make fishery more or less sensitive to changes in species abundance)
	Level of dependence on natural resources		Nutritional dependence on the affected species
	Occupational mobility	*Diversity and flexibility*	Species diversity
	Place attachment		Species' life history traits (e.g. growth, fecundity, resilience)
	Migration patterns		Habitat range and tolerance
			Exploitation status
Access to assets	Household material assets (e.g. boats, gears)	*Habitats and interactions*	Habitat availability
	Community infrastructure		Habitat heterogeneity and diversity
	Levels of education		Habitat connectivity
	Financial status and access to sources of credit		Rate and magnitude of habitat disturbance
	Access to markets		Phenology
	Equity, rights and access to resources	*Capacity to adapt within species*	Behavioral changes and learning
	Access to public services (water, health, education)		Phenotypic plasticity
Learning and knowledge	Resource monitoring and feedback mechanisms		Tolerance limits
	Knowledge of disturbances (e.g. climate change)		Reproductive rate and capacity for dissemination
	Perception of risk		Dispersal/Migration capacity

Characteristics of adaptive capacity		**Characteristics of sensitivity**	
Category	**Indicators**	**Category**	**Indicators**
	Spaces and platforms for learning		
	Diversity of knowledge and information sources		
Governance and institutions	Levels of trust, social capital and networks		
	Gender and race relations		
	Levels of participation and quality of decision-making processes		
	Planning capacity		
	Presence of local environmental institutions and strength of social norms		
	Quality of governance and leadership in environmental policies and agencies		
	Accountability of managers and governance bodies		
	Active risk management and adaptive governance process		

The Likelihood Table defines the levels of likelihood of a particular consequence occurring within the time period of analysis (in this particular case until 2050). The assignment of likelihood levels can be informed by the results of oceanographic and biophysical models, which predicts the magnitude of changes in physical drivers according to different climate change scenarios. See Appendix III of the report of the expert meeting on climate change implications for the Mediterranean and Black Sea fisheries (GFCM headquarters, December 2017) for specific recommendations concerning climate projections and modelling approaches available for the Mediterranean and Black Sea region. Identifying the time to when consequences are likely to occur (proximity, as defined by Garret et al., 2015) could be also used as an additional information for assigning the likelihood levels (Table 4).

Table 4. Example of likelihood definitions.

Level	Description	Proximity (time to consequence(s) occurring)
1 - remote	Insignificant probability of the particular consequence occurring.	Over 50 years
2 – unlikely	Some evidence that the particular consequence level could occur.	Within next 50 years
3 – possible	The consequence level may occur but this is still not likely.	Within next 20 years
4 – likely	The particular consequence level is expected to occur.	Now

The resulting risk matrix and management response are described in Tables 5 and 6. Impacts with risk scores 6 or above should be further considered for the design of adaptive measures.

Table 5. Risk matrix used in the C x L risk assessment. Numbers in cells indicate risk value, the colors/shades indicate risk rankings (source FAO, 2012).

		Consequence Level			
		Minor	Moderate	Major	Extreme
Likelihood		1	2	3	4
Remote	1	1	2	3	4
Unlikely	2	2	4	6	8
Possible	3	3	6	9	12
Likely	4	4	8	12	16

Table 6. Risk/vulnerability levels and recommended management response (adapted from FAO, 2012)

Risk/Vulnerability Level	Risk Scores (C x L)	Management Response
Negligible	1-2	None
Low	3-4	No specific management response
Medium	6-8	Specific management (adaptation) needed
High	9-16	Increased management (adaptation) activities needed

Integration and analysis of results

By assessing the consequences and likelihoods of each of the identified relevant pathways of impacts of climate change to the specific fisheries, risk scores are assigned and the most important vulnerability factors identified. Table 7 illustrates the outcomes of the assessment on a single pathway for a pretended fishery.

The application of the methodology would allow the identification of specific vulnerability factors of importance to one or more fishery systems as well as the fishery systems more vulnerable to the impacts of climate change.

The next step in the process is the identification of potential adaptation measures for the identified high risk/vulnerability impacts, which should be done in consultation with all relevant stakeholders. Different types of measures could be envisaged, depending on the nature of the impact and the context of the fishery systems. Table 3 provides a list of types of adaptation measures to consider.

Expected outcomes

- Identification of main climate drivers of environmental changes affecting fisheries
- Evaluation of potential impacts (risks) of the drivers
- Identification of the most vulnerable fisheries
- Identification of the areas for adaptation capacity development
- Awareness raising regarding the need to be proactive and adopt measures that will increase the resilience of fisheries to the climate change.

Table 7. Example of risk assessment of a possible pathway of climate impact on a pretended fishery.

Driver	**Threat/ Impact**	**Sensitivity**	**Adaptive capacity**	**Consequence**	**Exposure**	**Likelihood**	**Risk Level (Vulnerability score)**
Increase in SST	Change in distribution of the target species	High dependency of the segment on the target species	Weak monitoring and control system; difficult access to credit to upgrade vessels	**Major (3)**	According to ongoing observations and model projections, the most valuable species will move to areas not accessible to the fleet. Changes are already being observed.	**Likely (4)**	**High (12)**
…	…	…	…	…	…	…	…

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