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EMPAFISH
European Marine Protected Areas as tools for Fisheries management and conservation

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Conceptual model on relationships among factors determining Marine Protected Areas (MPAs) effectiveness

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European Marine Protected Areas as tools for Fisheries management and conservation

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Abstract

The driver-pressure-state-impacts-response (DPSIR) framework is used to develop a conceptual model thet identifies the elements affecting MPAs. The evaluation framework developed has helped in selecting an appropriate suite of indicators to support an ecosystem approach to conservation, and to evaluate MPA functioning and policy considerations. Gaps derived from the management and policy responses in the MPAs were also outlined with this framework. We conclude that the DPSIR framework provides a tractable approach to analysing the complexity of MPA management. This document is a resource for policy makers, scientists and the general public interested in the relevance of indicators to monitor changes and MPA management.

1. Introduction

The marine system is arguably complex with highly interrelated processes between its physical, chemical and biological components. The study and management of marine resources requires information on many inherent processes and an understanding of the structure and function of the systems. In addition, the increasing amount of national, supra-national and global legislation and agreements requires the development of tools for the sustainable use of the marine environment, in particular management for conservation and biodiversity in order to protect habitat integrity. The paradox is that the scientific community is mostly working on very detailed and narrow aspects, whereas managers entail a more holistic and ecosystem-based approach. This calls for multi-disciplinary strategies for MPA research and resource management.

The first MPA, (Fort Jefferson Marine Sanctuary, Florida US) was established in 1932. However, it was not until the First World Conference on National Parks Seattle in 1962 that countries were invited to create marine areas and parks. Subsequently, the number of marine protected areas has risen to around one and a half thousand, which have been established with different aims (Kelleher et al. 1995). In the Mediterranean, the first MPA was the Port-Cros National Park (France) established in 1964. Most of the Mediterranean MPAs were created from the 1980's onwards, principally in France, Spain and Italy (Cognetti 1990). In general, MPAs have been proposed throughout the world as an optimal way to protect marine ecosystems and associated fisheries (Lubchenco et al. 2003).

To be effective, MPAs have to be properly managed. This task includes defining objectives and goals from the outset, site selection, zoning, planning and implementing a surveillance and enforcement system, as well as monitoring actions (Kelleher 1999). In order to determine the validity of MPAs as fisheries management tools it is essential to evaluate MPA performance by means of regular monitoring.

Indicators are increasingly being developed and used as management tools to address environmental issues (OECD 1991, OECD 1994; EEA 1999 a, b).

Indicators are quantitative representations of the forces that drive an ecosystem, of responses to forcing functions, or of previous, current, or future states of an ecosystem. When they are used effectively, indicators are expected to reveal conditions and trends that help in development planning and decision making (Unluata, 1999). In this sense indicators can contribute to monitoring of the effectiveness of MPAs.

Waltz (2000) and Meadows (1998) listed the characteristics of a good indicator: 1) to have an agreed scientifically sound meaning, 2) to be representative of an important environmental aspect for the society, 3) to provide valuable information with a readily understandable meaning, 4) to be meaningful to external audiences, 5) to help in focusing information necessary for answering important questions, and 6) to assist decision-making by being efficient and cost-effective to use.

Therefore, the selection of a set of indicators must ultimately provide information that can be understood by the managers and stakeholders, and provide them with a base for decision making. However, before selecting and choosing indicators it is necessary to have the cause-effect relationships clear, and an established framework from which the indicators can be selected.

One of the techniques available in defining indicators is the driver-pressure-state-impact-response (DPSIR) framework. This methodology works well at simplifying the complexity of environmental management and facilitates communication among policy makers, scientists and the general public, leading to improved cooperation.

The DPSIR conceptual framework was suggested by Environment Canada and the OCDE[1]. Its structure is being used more and more to select indicators in the implementation of the European Water Framework Directive (e.g. Jeunesse et al. 2003; Mysiak et al. 2005; Borja et al. 2006), coastal zone studies (e.g. Cooley *et al.* 1996; Chesapeake Bay Program/USEPA 1999; EEA 1999; ME 2001; Casazza *et al.* 2002 a y b; Elliott 2002; Jorge *et al.* 2002; Silva and Rodrigues 2002; Nunneri and Hoffman 2003; Picollo *et al*. 2003) and in fisheries management (Mangi *et al*. 2006).

The DPSIR scheme of indicators is a flexible model that can be adapted to the necessities of specific programmes to stress the different indicator types. It allows a better understanding of the effects of a management action on the different system components (e.g. the fisheries, the socio-economics), and hence is more suitable in the identification and analysis of indicators

The purpose of this document is to identify, define and discuss basic indicators that can be used to assess the effectiveness of MPAs designed to conserve and restore fisheries and marine biodiversity. Specific goals include: a) to select the main factors affecting fisheries, other activities in the area and marine biodiversity, including their descriptors and their derived consequences; b) to define a conceptual model relating the selected components; c) to propose a set of parameters that can potentially be used as indicators at each level in the DPSIR framework.

2. Materials and methods

DPSIR model and main concepts

The DPSIR model (Fig. 1) offers a systematic and complete approach to organizing indicators (OECD 1994) allowing a holistic and multidimensional view of casual relationships.
The DPSIR framework is an extended version of the Pressure – State – Response (PSR) approach, that is based on the idea that anthropogenic activities impact the environment and that adverse environmental impacts drive humans to control the pressures.

1 http://www.ec.gc.ca/

The DPSIR framework introduces two new concepts: 1) human welfare and environmental quality and 2) societal behaviour and economic pressures affecting the environment. This framework incorporates these concepts adding "Driving Forces" and "Impacts" as categories. Therefore, in the DPSIR framework, societal Driving Forces lead to anthropogenic Pressures, which affect the State of the natural environment, and cause Impacts that provoke Responses. The responses generate feedback to all other parts of the framework.

This conceptual framework has three principal purposes: 1) to provide an abstract view of how the different factors may be interconnected, 2) to define and outline important concepts and organize them into a logical structure and 3) to help in the development and interpretation of the indicators.

This approach can help in development of EU policies on fisheries management, by facilitating the identification and effective use of indicators.

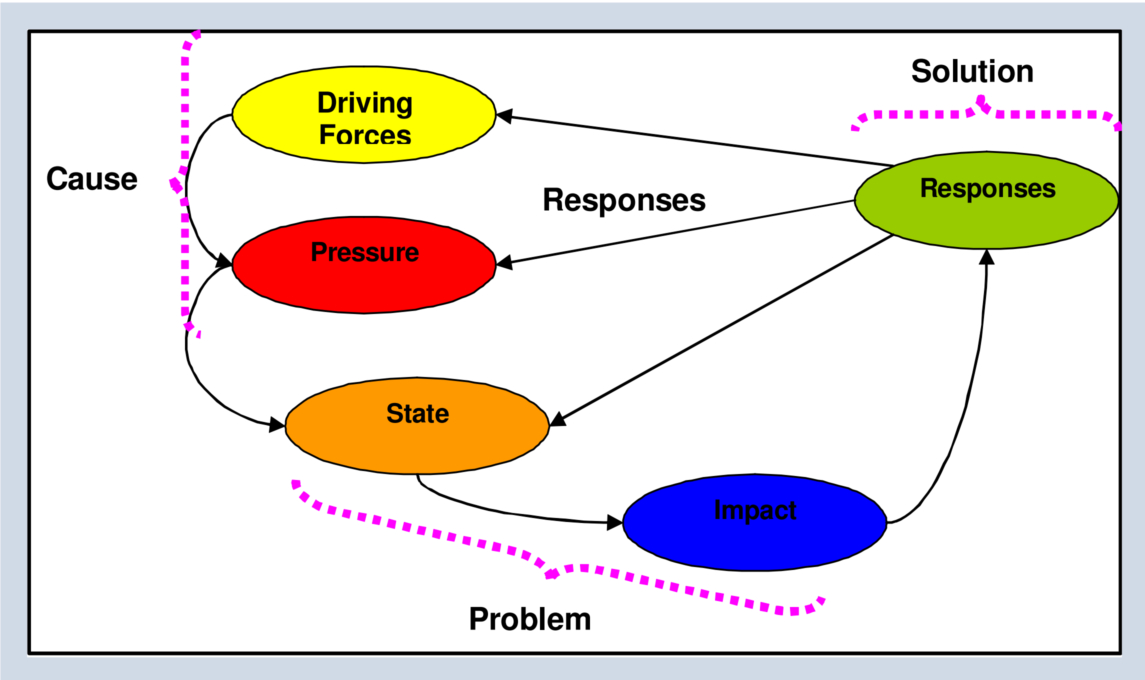

Figure 1. DPSIR (driver-pressure-state-impact-response) conceptual model.

The definitions of the components in the DPSIR framework (OECD, 1994) are the following:

Driving Forces:

Driving forces are the factors that cause changes in the system. They can be social, economical or ecological and can have positive or negative influences on pressures. Examples of Driving Forces are the size of the human population, the use of resources, climatic change, the fishing sector and the tourism sector.

Pressure:

Pressures are the human activities that directly affect the system and are generated by the driving forces. They change environmental quality and the quantity of natural resources. The level of pollution, harvesting, diving, trampling, sailing, can be considered examples of pressures.

State:

State is the condition of the system at a specific time and is represented by a set of descriptors of system attributes that are affected by pressures. Examples of state descriptors could be the features or quality of water, sediment, species composition, habitat structure.

Impacts:

Impacts are the effects on human health and/or ecosystems produced by a pressure. Common examples are disease incidence and the concentration of pollutants in biological populations, and reduction in abundance or biodiversity.

Response:

Responses are the efforts made by society as a result of the changes manifested in the impacts. As directed actions, responses typically take the form of programme activities, such as the number of inspections done, or number of people working in the surveillance of an MPA, establishment of new MPAs and reforestation plans.

Key elements:

We define our key elements as those components of the ecosystem (e.g. protected and/or target species, habitats or ecological processes) that are susceptible to being affected by any of the components of the DPSIR model (e.g. driving forces-pressure-state-impact-responses). They play an important role in the DPSIR framework, as cause-effect diagrams are based on the relationships these elements have with the system studied.

Building the DPSIR Model

The methodological approach (Fig. 2) of this research project started with the establishment of an expert panel consisting of people working in the EMPAFISH project (http://www.um.es/empafish/). This group comprises experts in fisheries, MPAs, marine ecology, maths and statistics (data-mining, meta-analysis), and in multi-criteria analysis. Background research involved, through bibliographical review, the compilation of all types of data related to the MPAs, its fisheries and tourism.

The DPSIR framework was developed following the objectives proposed in the EMPAFISH Project. Using *cause–effect* diagrams, the DPSIR framework model was broken down into the different elements from the driving forces to the responses.

Each element was explained in detail based on the experience of the expert panel and the bibliography, and every cause or factor that might interact with a given element was included. As our main project objective was to assess the suitability of MPAs as tools to manage fisheries and marine biodiversity, the expert panel selected three restricted criteria: fishing and tourism as driving forces; and MPAs as responses.

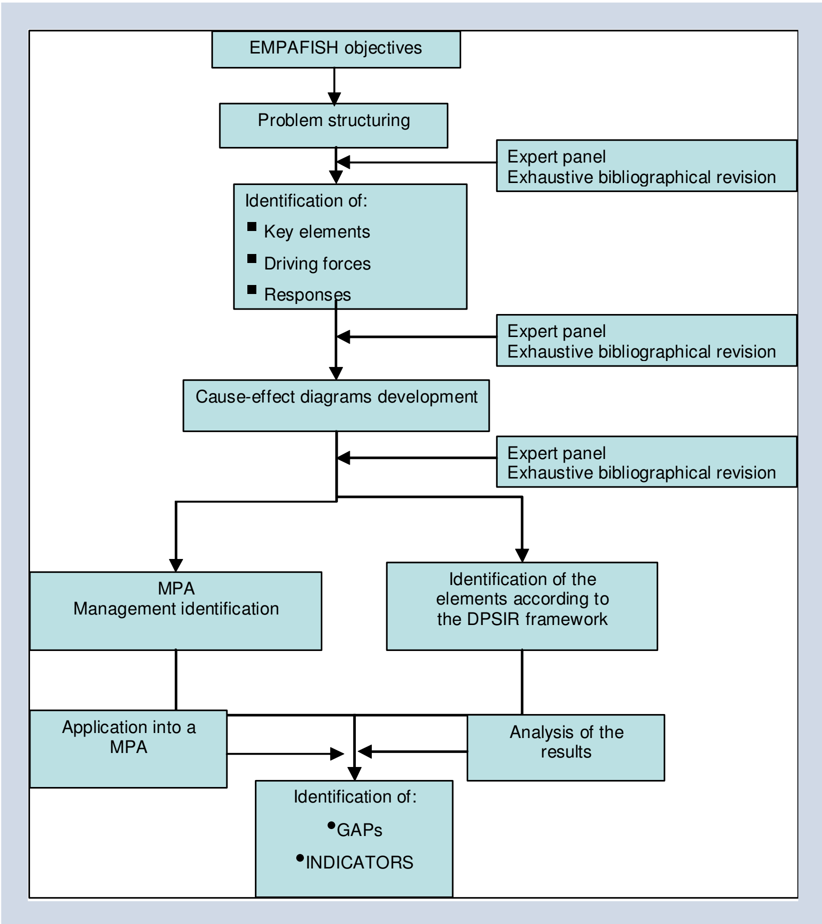

Figure 2. Methodological approach diagram of the research.

After identifying the key elements, the driving forces and the responses, to be used in the framework, general cause-effect diagrams were developed. The development of these diagrams led to the identification of the pressures and impacts. Each element (represented in a box) was identified according to the DPSIR framework, establishing at which level of the model they were found. On the other hand, management was identified and broken down into different parts. We have only considered management inside MPAs, as we defined our DPSIR framework within the scope of the EMPAFISH objectives.

This is a general model of the cause-effect relationships that occur in MPAs, but the framework can be applied to any case study by altering the selection of components to suit local circumstances.

3. Key Elements

The first results obtained from the DPSIR framework are the selection of the key elements, the driving forces and the responses.

In this study, key elements (Appendix I) were selected by means of different European Directives and laws: the Habitats Directive, the Protocol concerning Specially Protected Areas and Biodiversity in the Mediterranean adopted in Barcelona 1995, the OSPAR Convention and those featured in the IUCN red list.

We have considered the following key elements: species and habitats protected by the Habitats Directive, commercially exploited species, ecological processes (e.g. recruitment, biological production, species interaction and genes transference) and socio-economical processes (e.g. incomes, socio-economical resources, investment and demography). The protected habitats considered as key elements are: reefs (1170); sand banks which are slightly covered by seawater all the time (1110), including *Cymodocea nodosa*; and *Posidonia* meadows (1120). Protected species considered as key elements include: *Cystoseira* sp., *Posidonia oceanica*, *Cymodocea nodosa*, *Zostera noltii*, *Charonia lampas*, *Pinna* sp., *Palinurus elephas*, *Scyllarides* spp., *Homarus gammarus*, *Paracentrotus lividus*, Signathidae, *Epinephelus marginatus*, *Sciaena umbra*, *Umbrina cirrhosa*, sea mammals, turtles and birds.

4. Driving Forces, Pressures and Impacts

In this section some diagrams are shown and DPSIR parts of the framework are described. The full set of diagrams for the fishing and tourism sectors can be found in Appendix III.

Only impacts on the natural environment were considered. Effects on human beings, such as changes in health or emotional state were not considered.

Although the model should be used as a system guide, the number and type of indicators must not be limited by it. The exact composition of the model can change in response to the concerned person and/or institution necessities.

4.1. Fishing sector

Identification and description of driving forces

Fisheries exert pressure on the environment as well as on targeted fish stocks. The total reported captures of the European Union (EU) and the rest of the world are decreasing as a consequence of selective species depletion. The volume of landings in the European Union, as a whole, has been declining, due to the overexploitation of several fish species. In spite of the volume of landings decreasing by 3% since 2000, the first-sale value has risen by more than 9%, and the mean price in the EU has increased from 1.2 € kg^{-1} to 1.39 € kg^{-1} (EEA 1999b).

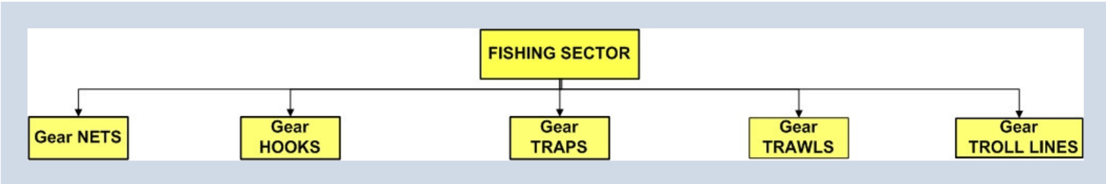

Figure 3. Driving forces (yellow) for the fishing sector.

Fleet technology in the industrialised EU countries is very high and there has been a shift from labour-intensive vessels to more capital-intensive vessels, such as larger trawlers and multi-purpose vessels. There have been relatively few changes in fishing techniques in the Mediterranean area during recent years. However, there has been an increase in the number of vessels between 1980 and 1992 (overall increase 19.8%, FAO, 1994). More recently, and due to the decline in fish stocks, the European Union has adopted policies to decrease the fleet capacity. In 2002, the number of vessels was around 90 000, a 10% decrease from 1998. This decreasing trend is also shown in the power and tonnage of fishing vessels.

Different types of fishing gears are used in the EMPAFISH study areas, and therefore the fishing sector driving forces have been sub-divided according to fishing gear (Fig. 3). Depending on the type of fishing gear used, the fishing activities affect the marine environment in different ways. In our study, each sub-driving force embraces the different types of fishing gears in operation.

Identification of existing pressures

Several actions contribute to pressures on the system. Pressures (Fig. 4) that affect our key elements were chosen. Different fishing gears may cause similar types of pressure on the key elements, but the relative magnitude of these effects differs among the sub-driving forces.

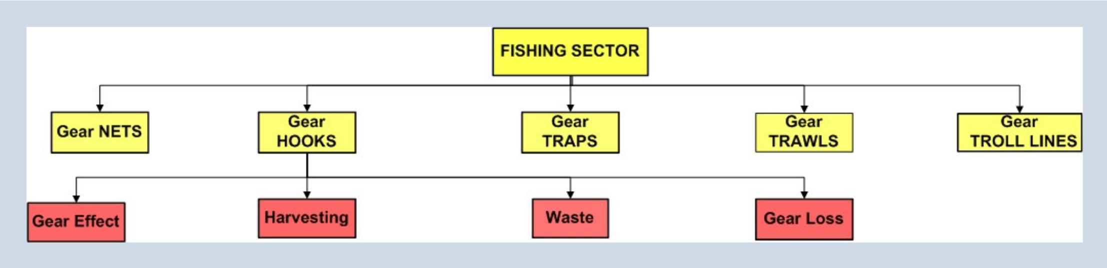

Figure 4. Driving forces (yellow) and pressures (red) for the fishing sector gear net.

Fishing has an environmental effect on many coastal areas (Tudela *et al*. 2005; Goñi, 1998). It can negatively impact the coastal environment in a number of different ways. Extraction of the resources at a higher rate than its capacity to regenerate is the most direct pressure. This is not only unsustainable in economic terms, but also has significant effects elsewhere in the ecosystem due to the effects produced by the fishing gears on non-target species and habitats (e.g. complete or partial breakage of species such as *Pinna nobilis* or coral species). With troll line gears, this pressure has not been considered, because the fishing tackle is considered not to have such effects. Waste from fishing, such as detritus generated by the fishermen, litter dropped from the deck, hydrocarbon emissions by boats, organic emissions and chemical pollution, is an indirect pressure produced by the fishing sector. Lost fishing gear is also a hazard to wildlife (e.g. fishes, marine mammals, turtles and birds). We did not include otter trawls or troll lines in this pressure, because these tackle do not continue fishing once lost.

Impacts

Recall, impacts are the causes that evoke responses (Fig. 5). Fishing activities usually cause a decrease in the abundance, biomass and size of commercial and non-commercial species (Koslow et al*.* 1988; Bohnsack 1989; Gislason 1994; Goñi 1998; Sluka and Sullivan 1998). As the number of target species decline due to overfishing, others become more dominant and the structure of the ecosystem may be altered. Stocks can be over–exploited, so there is a decrease in total catch. The dumping of discards may cause an increase in the abundance of scavenger fish (Sánchez and Olaso, 2004), invertebrates and seabirds (Camphuysen *et al*. 1995; Garthe *et al*. 1996), further distorting the natural balance of the ecosystem.

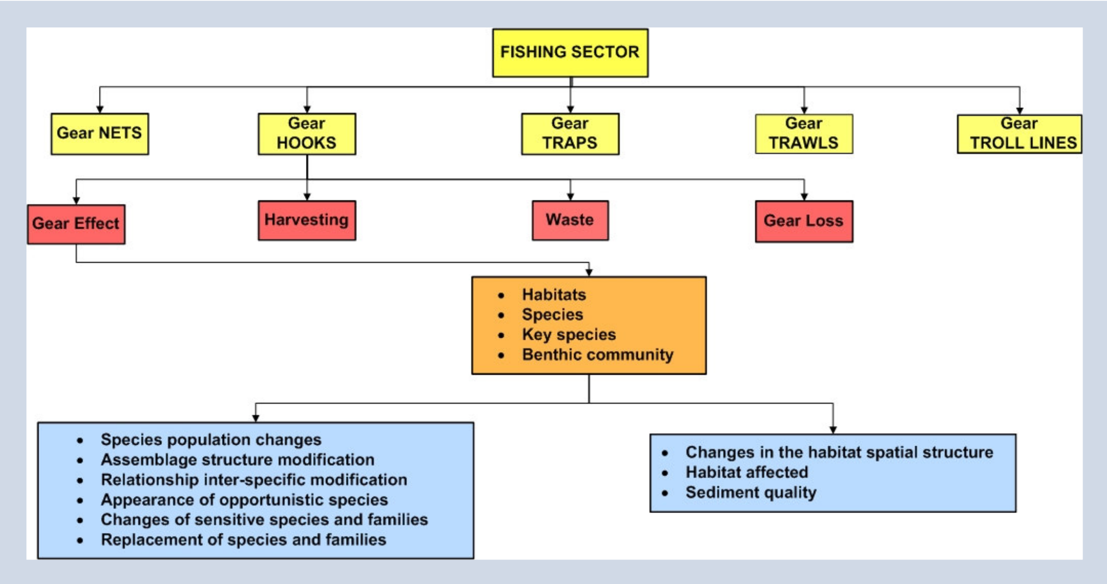

Figure 5. Driving forces (yellow), pressures (red) and impacts (blue) for the fishing sector gear net. Also states (orange) are represented.

Lost gears may affect habitats and specially species. Key species like *Pinna nobilis*, coral species, gorgonians, turtles, sea mammals (Chan *et al*. 1988), can be completely or partially broken or trapped by them. Birds are also affected by lost gears, suffering amputations of wings and feet (Tasker *et al*. 2000). Trapped animals eventually die and their decomposing carcasses attract scavengers, which may themselves become trapped (Bullimore *et al*. 2001). Different gears have different effects on species and habitats. For example, trawling can damage the physical structure of habitat, whereas other gears, such as trammel nets, may cause little physical damage, but may nevertheless affect the abundance and population structure of target and non-target species.

The major impact of inert solid wastes, is the mortality of species such as turtles, that mistake plastics and other debris for jellyfish and ingest them. Hydrocarbons are also a problem as they are deposited on sessile and pelagic species, as well as birds. Inert solids are a problem for filter-feeding species whose filtering appendages may become choked resulting in death. Most species and habitats are buried by inert solids and hydrocarbons, limiting their vital functions, such as photosynthesis. Organic pollution can lead to a variety of chemical changes, especially reduction in oxygen concentration, which can result in the death of many species. Species behaviour is also altered by the toxicity generated

4.2 Tourism sector

Identification and description of the driving force

Ocean and coastal tourism is widely regarded as one of the fastest growing areas of contemporary tourism (Hall 2001). Europe is the world's largest holiday destination, receiving 60% of international tourists and business that continues to grow by 3.8% per year (EEA 2005). Tourist activity is highest in the Mediterranean coastal zone, with France, Spain and Italy receiving 75 million, 59 million and 40 million visitors a year, respectively. This represents increases of between 40 and 60% since 1990. France and Spain are the world's two top tourist destinations (EEA 2005). The Canary islands have a total population of 2 million inhabitants, and the number of tourists each year reaches 10 million, five times its permanent population. Malta receives more than a million tourists a year, three times its permanent population.

Tourism is the largest sector of the economy in many coastal zones, and construction of hotels, apartments and other tourist infrastructure is the dominant form of development. In French coastal regions, tourism provides an estimated 43% of jobs, generating more revenue than fishing or shipping. This dominance of tourism is reflected in the seasonal changes in population density, with an influx of both tourists and people to work in the tourist industry each summer. Population densities on the Mediterranean coasts of France and Spain can reach 2300 people per square kilometre: more than double the winter populations. A further 40% increase in peak populations is expected in the next 20 years.

The exact numbers of marine tourists remains unknown. Nevertheless, the selling of 'sun, sand and surf experiences', the development of beach resorts and the increasing popularity of marine tourism (e.g. fishing, scuba diving, windsurfing, whale watching and yachting) have all placed increased pressure on the coast, which already has a high concentration in terms of agriculture, human settlements, fishing and other industries (Hall 2001). Recreational use by coastal residents is also high, and in many circumstances, the impacts of recreational users can be impossible to separate from those of commercial tourism activities.

The increase in tourism extends beyond the Mediterranean to the Atlantic coasts of France and Portugal, and also to the Canary Islands. Tourism is expected to continue to grow, though this could be limited by higher climatic temperatures, fires and droughts, and a desire by tourists for emptier and less-developed resorts. Tourism is now having a major environmental impact on many coastal areas. Besides land-use, its demand for resources and need for waste disposal facilities cause pressure on water resources and natural coastal habitats and structures such as wetlands and sand dunes. For example, demand for water in Mediterranean coastal localities doubles during the tourist season. Many regions, including Spanish and Maltese resorts, are experiencing water shortages and in some areas, it has been necessary to invest in desalination of sea water.

The increase in tourism is accompanied by urban expansion and a rapid increase in the resident population, due to new economic opportunities in the tourist industry. This implies an increase in buildings, wastes and altered ecosystems. Development of tourism is also associated with a set of social and cultural impacts, resulting from the abandonment of traditional economic activities (Santana 1997).

Uncontrolled development of tourism can affect coastal ecology, e.g. disruption of the ecological balance through eutrophication. Construction in coastal regions, sand erosion and unstables beaches have destructive effects on fauna and flora and, in particular, on endemic species (Burak *et al.* 2004). Habitat loss through urban development, the provision of tourist facilities, the direct destruction of vegetation through trampling, and the direct disturbance of animals are additional impacts. Furthermore, effects include: erosion by trampling, gradual changes in vegetation structure and plant species composition as an adaptation to mechanical pressure, soil compaction and subsequent changes in species composition.

Identification of existing pressures

Pressures of marine tourism can be broadly categorised as ecological, social and cultural. Anchoring and diving are the pressures most studied (Harriott 2002). We consider that anchoring and mooring are associated with other principal pressures derived from the driving forces of recreational fishing, shipping and diving. Angling from shore, angling from boats and spear fishing are very popular activities in most countries where they are practiced at recreational and competitive levels (Sluka and Sullivan 1998; Coll *et al*. 1999; Murray *et al.* 1999). Diving and snorkelling have been well studied overseas (e.g. Rouphael and Inglis, 1995; Harriott *et al*., 1997; Barker and Roberts 2004) and this pressure also generates most of the income of coastal areas. Most divers do not directly break sessile species, but a small percentage of divers who swim too close of them may break sessile species (Rouphael and Inglis, 1995; Harriott *et al.*, 1997). Tourism produces problems due to trampling (Schiel and Taylor, 1999; Milazzo *et al.*, 2002, 2004) and illegal species collection in rocky shore areas (Addessi, 1994). Also visitors, divers, shipping and recreational fishers, generate waste in many other ways. Visitors need to have infrastructure built and they create a seasonal demand for resources.

The escalating number of permanent and seasonal residents generates a demand for municipal infrastructures, such as desalination plants, sewage treatment plants and other public services,. as well as facilities, such as ports, airports and rail stations, hotels, shops, restaurants, marinas and other coastal facilities.

Impacts

As previously mentioned, the best studied of tourism impacts are those associated with anchoring and diving (Harriott 2002). A series of extensive impact assessments have found that pressures of moorings on the surrounding areas are minimal, apart from the 'footprint' under the moorings. Anchoring of both tourist and recreational boats is a significant issue in heavily visited sites (García-Charton *et al*. 1993). Anchors and anchor chains are capable of breaking multiple species (e.g. coral colonies) at each deployment.

Angling from shore or from boat and spear fishing are forbidden in most MPAs, but are allowed along the coast. However, there are still certain problems, such as the illegal selling of the catches or the resistance of spear fishermen to comply with protection measures. Although spear fishing is usually carried out at low intensity (except during competition events) along all suitable stretches of coast, there is published evidence that, in the western Mediterranean, spear fishing can affect the composition of fish communities (Bell 1983; García-Rubies and Zabala 1990; Moranta *et al.* 1997; Reñones *et al.* 1997) and the structure of fish populations (Harmelin and Marinopoulos 1993; Garcia-Rubies 1997; Zabala *et al.* 1997; Coll *et al.* 1999; Reñones *et al.* 1999; Jouvenel and Pollard 2001). Conflicts between different user groups can arise because recreational fishing may take place in areas closed to commercial fishers and they may compete for the same resources.

Diving and snorkelling can cause damage to several species. Fragile branching corals are the most susceptible to breakage by divers (Harriott 2002). Bryozoans and sea fans are also vulnerable (Zabala 1996; Sala *et al.* 1996). Some studies have detected larger numbers of broken species (e.g. corals) in areas actively used by snorkellers, including snorkel trails, than undived areas (Harriott 2002). In addition to physical damage, divers may cause changes in fish behaviour through fish feeding.

Tourism in coastal localities involves millions of visitors each year. It produces problems due to trampling and illegal species collection in accessible rocky shore areas. It can provoke the replacement of slow growing species (e.g. *Cystoseira* spp.) with rapidly growing, opportunistic species.

5. Identification of states for the fishing and tourism sector

The descriptors chosen to represent the state of the system at specific times are habitats, key species, commercial and non-commercial species and economic elements. All of these descriptors are affected by a defined pressure type.

The marine phanerogam *Posidonia oceanica* (L.) Delile, is the most widespread seagrass in the Mediterranean Sea, and *P. oceanica* beds are listed as a priority habitat in the Habitats Directive (Habitat 1120). *P. oceanica* plays an important role in shallow water coastal ecosystems, as do other phanerogams, by: (1) providing habitat for a highly diverse fauna and flora (Mazzella *et al*. 1989); (2) significantly reducing coastal erosion (Casazza *et al*. 2000b); and (3) offering a nursery area for many fish and invertebrate species (Macpherson *et al*. 1997; Guidetti 2000). However, *P. oceanica*, like other sea grasses worldwide (Shepherd *et al*. 1989), is sensitive to pressures from port construction, pollution, anchoring, mooring and trawling. Rocky reefs and sandbanks are also listed in the Directive and are also threatened by certain tourist activities.

In this study, key species are considered as those defined as "in danger" by the Habitats Directive, (e.g. *Pinna nobilis* and *Dendropoma petraeum*), some of which are also referred to in other laws or regulations, like the IUCN Red List. These are affected by pressures such as fishing, lost fishing gear, divers and visitors.

The state of the local economy is represented by incomes, costs, employment and unemployment generated by a pressure. This can be due to the fisheries or tourism driving force.

6. MAPs as a response to the decline of fisheries and marine biodiversity

Responses may have effects at all levels in the DPSIR framework, but at the pressure and state level, measures are technically and economically hardly feasible (Ban and Buuren 2003). Because usually policies aim to avoid fishing sector problems, rather than solve and mitigate effects, measures should preferably be designed to act at the level of the driving forces. MPAs responses can occur in two different stages: <u>planning</u> the uses and activities allowed or prohibited in the MPA and <u>management</u> of the different activities planned to enhance different programs developed in the MPA

The IUCN defines a Marine Protected Area as "any area of the intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment" (IUCN 1988). MPAs have much diverse legislation and many protection schemes hroughout the history of their use (Ortiz García 2002). They have been established as National Parks, natural parks, fisheries reserves. Even in the same country, legislation may differ by region.

The figure 6 shows the relationship between the MPAs responses with other DPSIR components. This framework can be applied to every MPA. This application should be done with the inclusion of legislation and specific characteristics of each MPA.

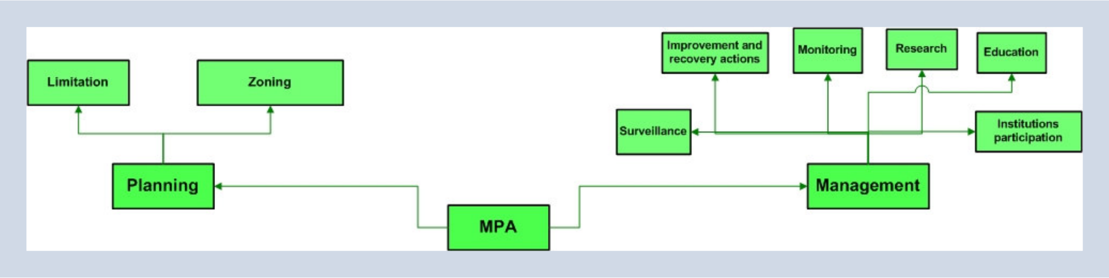

Figure 6. Relationship between the MPAs responses with other DPSIR components

Measurement of indicators

The use of indicators is fundamental in the DPSIR framework as indicators can provide an objective system of information and evaluation about the effectiveness of MPAs. Indicators, therefore, need to be properly selected and the methodology of their calculation specified. (Mangi *et al*. 2007; Casazza *et al*. 2002b). A serie of criteria (Table 1) was defined to select the best set of indicators (Table 2, Table 3). Besides that, we had into account their relevance, priority for MPA assessment and management.

Criteria	Definition	Metric
Consistency	Maintenance of low variability of response	YES(1)/NO(0)
Ease of understanding	How easy is the indicator understood by stakeholders	A value of 0 to 10 on the perception measured by means of questionnaires to stakeholders
Relevance	Importance for that to be assessed	A value of 0 (unimportant) to 10 (important) on the perception measured by means of questionnaires to stakeholders
Feasibility	How difficult is it to obtain and/or measure records for a given indicator, considering cost-effective criteria	Expert evaluation from 0 (very difficult) to 10 (very easy).
Sensitivity	Susceptibility to detect changes that can be adverted by management actions.	YES/NO.

Criteria	Definition	Metric
Availability of reference data	Existence of data for comparing current records	YES(1)/NO(0) or, amount of relevant reference data
Interrelationship	Capabilities of certain indicators to exhibit changes in different processes	Number of processes that can be inferred from a given indicator

Table 1. Criteria definition and metrics.

Indicators were classified into four simple groups following the EEA (1999):

- **Type A or Descriptive Indicators**: what is happening to the environment and to humans? These sets describe the actual situation with regard to the main environmental issues and are based on the DPSIR framework or a subset of it.
- **Type B or Performance Indicators**: does it matter? They compare actual conditions with a specific set of reference conditions. They measure the distances between the current environmental situation and the desired situation. Performance indicators are relevant if specific groups or institutions may be held accountable for changes in environmental pressures or states.
- **Type C or Efficiency indicators:** Is the situation improving? These indicators provide insight into the efficiency of products and processes
- **Type D or Total Welfare indicators**- is the local populace better off? These indicators would aim at describing the total sustainability. Some measure of total sustainability like Index of Sustainable Economic Welfare would be needed.

Type	Possible Indicator	Type			
		A	**B**	**C**	**D**
	FISHING SECTOR				
Drivers	Trends in number of fishing	X			
	Trends in number of fishers	X			
	Fishing sector profit	X			
	Percentage of the gross domestic product (GDP) produced by the fishing sector	X			
	Investment in the fishing sector			X	
	Trends in average fishing vessel power	X			
	Per Capita Income n the influenced area	X			
	Per Capita Income of the fishing sector	X			
	Spatial effort distribution		X		
	Number of fishing vessels using with a particular gear type	X			
Pressures	Fishing ground area	X			
	Number of vessels fishing per day	X			
	Daily CPUE		X		
	Length of trammel or gill net fished over particular habitats		X		
	Number of hooks fished in a particular habitat		X		
	Fishing time		X		
	Total biomass extracted	X			
	Biomass extracted by species		X		
	Number of individuals caught / total capture		X		
	Number of species caught	X			
	Fishing vessel fuel consumption	X			
	Quantity of organic matter discarded by fishing boats	X			
	Quantity of fishing gear lost		X		
State	Abundance	X			
	Biomass	X			
	Density	X			
	Size structure	X			
	Diversity	X			
	Relative abundance	X			
	Species richness	X			
	Dominance	X			
	Community structure	X			
	Coverage of benthic species	X			
	Number of trophic categories affected	X			
Impacts	Total surface affected by the gear		X		
	Habitat surface affected		X		
	Changes in density		X		
	Changes in coverage of key benthic species		X		
	Changes in community structure		X		
	Changes in Species size		X		
	Changes in relative abundance		X		
	Changes in abundance, diversity, richness and/or dominance		X		
	Changes in sediment composition and/or quality		X		
	Species substitution		X		
	Families substitution		X		
	Changes in recruitment rates		X		
	Index of breakage (of fragile species)		X		
	Rugosity		X		
	Loss of vertical profile		X		
	Changes in habitat heterogeneity		X		
	Changes in trophic levels		X		
	Appearance of opportunistic species		X		
	Changes in sensitive species		X		

Table 2. Classification of indicators for the fishing sector. Type A: Descriptive Indicators; Type B: Performance Indicators; Type C: Efficiency indicators; Type: D: Total Welfare indicators.

Type	Possible Indicator	Type A	B	C	D
	TOURISM SECTOR				
Drivers	Trends in number of recreational fishing vessels per km of coast	X			
	Trends in number of spear fishers per km of coast	X			
	Trends in number of anglers per km of coast	X			
	Trends in number of fishing rod sales	X			
	Trends in number of specialised shops	X			
	Trends in number of spear guns sold per inhabitant	X			
	Trends in the number of divers	X			
	Trends in the number of diving clubs/centres	X			
	Trends in the local income from diving	X			
	Trends in the number of diving licences issued	X			
	Trends in the number of visitors	X			
	Trends in guided activities in MPA	X			
	Trends in recreational boat sales	X			
	Trends in motor boat or jet ski sales	X			
	Trends in the number of companies offering water sports	X			
	Trends in hotel accommodation offer	X			
Pressure	Number of anglers / km of coast per day	X			
	Number of anglers from boats	X			
	Number of spear fishers / day	X			
	Density of recreational fishers / time	X			
	Recreational fishing surface	X			
	Number of recreational boats / day	X			
	Number of motor boating or jet sky/day in the AMP or influence area	X			
	Number of recreational divers/ day in the AMP	X			
	Number of visitants/day	X			
	Number of visitants for littoral itineraries or route	X			
	Hydrocarbons (L) consumed by boat in harbours	X			
	Quantity of organic matter dumped from recreational boats	X			
	Number of recreational boats (fishing boats, tourism boats, whale watching...)	X			
	Number of divers	X			
State	Abundance	X			
	Biomass	X			
	Density	X			
	Size structure	X			
	Diversity	X			
	Richness	X			
	Evolution in the community composition	X			
	Recruitment rate	X			
	Changes in substratum coverage	X			
	Number of key species endangered by solid objects	X			
	Changes in recruitment rate		X		
	Habitat cover	X			
	Concentration of hydrocarbons in the water column	X			
	Concentration of chemical products in the water column	X			
	Quantity of solid waste per unit area of habitat	X			
	Number of species broken by anchoring or diving	X			
	Density of bird nests	X			
Impact	Variation of size and weight of target species		X		
	Changes in mortality rate		X		
	Changes in captures along time		X		
	Trends in recruitment rate		X		
	Trends in extracted biomass		X		
	Trends in extracted biomass by species		X		
	Reduced abundance of fragile species and rate of disappearance of protected species		X		
	Changes in abundance	X			

Continuation

Type	Possible Indicator	A	B	C	D
	TOURISM SECTOR				
Impact	Changes in richness	X			
	Changes in diversity	X			
	Changes in coverage	X			
	Changes in sediment composition and/or quality	X			
	Changes in abundance of opportunistic species		X		
	Changes in abundance/population density of filter-feeding species		X		
	Trends in anchor damage to substratum		X		
	Trends in diver damage to substratum		X		
	Decrease in whale watching		X		
	Number of boat collisions with sea mammals		X		
	Trends in trampling damage to substratum		X		
	Changes in water quality		X		
Responses	Size of core protected area	X			
	Size of whole MPA	X			
	% of the total surface (MPA) allowed for sport fishing			X	
	Number of licences for sport fishing			X	
	Number of licences for particular kinds of sport fishing			X	
	Number of surveillance hours	X			
	Budget for surveillance	X			
	Number of reports of illegal fishing / divers / boats			X	
	Budget for investigation for each pressure			X	
	Number of education programs			X	
	Budget for education programs	X			
	Budget for waste programs	X			
	Number of anchoring points	X			
	Budget for anchoring points	X			
	Budget for duties of management of anchoring points	X			
	Anchoring surveillance			X	
	Size of areas in which diving is permitted	X			
	Number of anchoring points for diving	X			
	Changes in limits on diving in an MPA, or licences issued	X			
	Budget for research programmes for divers?			X	
	Budget for managing diving activities			X	
	Terrestrial surface allowed for visitors			X	
	Total budget	X			
	Zoning surface for each use	X			
	Number of improvement actions / year			X	
	Budget for improvement actions / year			X	
	Number of people contracted	X			
	Research budget	X			
	Number of publications			X	
	Number of research projects / year			X	
	Budget for participant organisms			X	
	Number of meetings between the actors			X	
	Number of people working in the projects			X	
	Budget invested in participation	X			
	Changes in laws, normative, restrictions and/or limitations			X	

Table 3. Classification of indicators for the tourism sector. Type A: Descriptive Indicators; Type B: Performance Indicators; Type C: Efficiency indicators; Type: D: Total Welfare indicators.

4. Conclusions

The main purpose of this document was to provide a framework to analyse the environmental changes, policy responses and socio-economic issues of MPAs, to identify key indicators for the appropriate evaluation and gaps in the management, in order to develop policy and management options for the EMPAFISH case study MPAs. The conceptual model shows that, in general terms, MPAs included in the EMPAFISH project are subjected to similar drivers and environmental pressures.

The evaluation also shows that there is a need to explain, demonstrate and illustrate the complexity of linkages between the causes and impacts on MPAs to managers, politicians, resource users and other actors. This requires a broadening of the data domains and a much broader linking with other sectors and disciplines. The need for information on the state of MPAs, the dependence on MPAs by coastal human? populations and the progress of management in relation to objectives impose the requirements for highly parameterized frameworks. Broad indicator systems combined with modelling of some sub-parts of the system is one approach (Mangi *et al*., 2007).

Drivers, pressures, state, impacts and response indicators for evaluating MPAs are proposed. These indicators are based on the knowledge of the management of EMPAFISH case studies

The definition of response indicators should reflect relationships between driving-forces, pressures, and induced state changes and impacts, thereby helping to assess the policies, practices, and objectives (Pacheco *et al.* 2007). In addition they should improve awareness of management failure and promote effective management (Mangi *et al*. 2007).

Further work is required to validate and refine the indicators proposed here, but as proposed, these socio-economic, ecological and management indicators serve as useful starters to understand and approach the problem of MPAs. A more effective integration of social condition, environmental dynamics and institutional response will enrich the process of informed decision making on sustainable MPAs.

Promoting meetings and workshops involving stakeholders, scientists, and decision-makers is essential in order to clarify the reasons for conflict between stakeholders and to decide the best way of integrating different interests (Pacheco *et al*. 2007) in any application of the DPSIR framework.

The use and integration of social/economic and environmental indicators is needed in order to achieve the sustainable development of MPAs. However, combining environmental, economic, social, and governance aspects, and creating indicators capable of their integration, remains one of the most difficult tasks.

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7. Appendices

Appendix I: List of key species and protection status

B.C.= Barcelona Convention (AII: species in danger or threatened; AIII: species with populations that need regulation)

H.D.= Habitat Directive (AII: species with community interest; AIV: species with strict protection; AV: species with exploitation that need regulation or management)

Berne C.= Berne Convention (AI: flora with strict protection; AII: fauna with strict protection; AIII: protected fauna)

Bonn C.= Bonn Convention (AI: migratory species in danger; AII: migratory species with unfavourable conservation status)

OSPAR= Populations in the OSPAR regions. I: the Arctic, II: Greater North Sea, III: Celtic Seas, IV: Bay of Biscay/Golfe de Gascogne and Iberian coasts, V: Wider Atlantic.

	PROTECTION STATUS				
SPECIES	**C.B.**	**H.D.**	**BERNA**	**BONN**	**OSPAR**
ALGAE					
RHODOPHYTA					
Acrosymphytaceae					
Schimmelmannia schousboei (J. Agardh) J. Agardh[2]	II		I (Med.)		
Corallinaceae					
Goniolithon byssoides (Lamarck) Foslie	II		I (Med.)		
Lithophyllum lichenoides (Philipi)	II		I (Med.)		
Lithothamnion coralloides (Crouan frat.)		V			
Phymattoliton calcareum (Poll.) Adey & McKibbin		V			
Gelidiaceae					
Ptilophora mediterranea (H. Huvé) R.E. Norris	II		I (Med.)		
PHAEOPHYTA					
Cystoceiraceae					
Cystoseira amentacea (C. Agardh) Bory de Saint-Vincent	II		I3 (Med.)		
Cystoseira mediterranea (Sauvageau)	II		I (Med.)		
Cystoseira sedoides (Desfontaines) C. Agardh	II		I (Med.)		
Cystoseira spinosa (Sauvageau)	II		I4 (Med.)		
Cystoseira zosteroides (C. Agardh)	II		I (Med.)		
Laminariaceae					
Laminaria rodriguezii (Bornet)	II		I (Med.)		
Laminaria ochroleuca (Bachelot de la Pylaie)			I (Med.)		
CHLOROPHYTA					
Caulerpaceae					
Caulerpa ollivieri (Dostál)	II		I (Med.)		
FANEROGAMS					
Posidoniaceae					
Posidonia oceanica (Linnaeus) Delile	II		I (Med.)		
Zannichelliaceae					
Cymodocea nodosa (Ucria) Ascherson			I (Med.)		
Zosteraceae					

2 = *S. ornata*.
3 It includes var. *stricta* and var. *spicata*.
4 It includes *C. adriatica*.

SPECIES	PROTECTION STATUS C.B.	H.D.	BERNA	BONN	OSPAR
Zostera marina (Linnaeus)	II		I (Med.)		
Zostera noltii (Hornemann)	II				
SPONGES					
Axinellidae					
Axinella cannabina (Esper, 1974)	II				
Axinella polyploïdes Schmidt , 1862)	II		II (Med.)		
Cladorhizidae					
Asbestopluma hypogea (Vacelet & Boury-Esnault, 1995)	II		II (Med.)		
Geodiidae					
Geodia cydonium (O.F. Mueller, 1798)	II				
Spongiidae					
Hippospongia communis (Lamarck, 1873)	III		III (Med.)		
Ircinia foetida (Schmidt, 1862)	II				
Ircinia pipetta (Schmidt, 1862)	II				
Spongia agaricina (Pallas, 1766)	III		III (Med.)		
Spongia officinalis (Linnaeus, 1759)	III		III (Med.)		
Spongia zimocca (Schmidt, 1862)	III		III (Med.)		
Tethyidae					
Tethya spp.	II				
Tethya citrina (Sara & Melone, 1965)	II		III		
Verongidae					
Aplysina cavernicola (Vacelet, 1959)			II (Med.)		
Aplysina spp.	II				
Petrobiona massiliana (Vacelet & Levi, 1958)	II		II (Med.)		
CNIDARIANS					
Antipathidae					
Anthipathes spp.	III		III (Med.)		
Corallidae					
Corallium rubrum (Linnaeus, 1758)	III	V	III (Med.)		
Dendrophylliidae					
Astroides calycularis (Pallas, 1766)	II		II (Med.)		
Dendrophyllia ramea (Linnaeus, 1830)					
Leptosammia pruvoti (Lacaze-Duthiers, 1897)					
Faviidae					
Cladocora caespitosa (Linnaeus, 1767)					
Gerardiidae					
Gerardia savaglia (Bertoloni, 1819)	II		II (Med.)		
Stylasteridae					
Errina aspera (Linnaeus, 1767)	II		II (Med.)		
MOLLUSCS					
Gastropoda					
Patellidae					
Patella ferruginea (Gmelin, 1791)	II	IV	II (Med.)		
Patella nigra da (Costa, 1771)	II		II (Med.)		
Patella ulyssiponensis aspera (Röding, 1798)					V
Mitridae					
Mitra zonata (Marryat, 1818)	II		II (Med.)		
Muricidae					
Nucella lapillus (Linnaeus, 1758)					I-II-III-IV-V
Cypraeidae					
Erosaria spurca (Linnaeus, 1758)	II		II (Med.)		
Luria lurida (Linnaeus, 1758)5	II		II (Med.)		
Schilderia achatidea (Gray in G.B. Sowerby II, 1837)	II		II (Med.)		
Zonaria pyrum (Gmelin, 1791)	II		II (Med.)		
Ranellidae					
Charonia lampas6 (Linnaeus, 1758)	II		II (Med.)		

5 = *Cypraea lurida.*

SPECIES	PROTECTION STATUS C.B.	H.D.	BERNA	BONN	OSPAR
Charonia tritonis7 (Linnaeus, 1758)	II		II (Med.)		
Ranella olearia (Linnaeus, 1758)	II		II (Med.)		
Tonnidae					
Tonna galea (Linnaeus, 1758)	II		II (Med.)		
Trochidae					
Gibbula nivosa (Adams, 1851)	II	II-IV	II (Med.)		
Vermetidae					
Dendropoma petraeum (Monterosato, 1884)	II		II (Med.)		
Bivalvia					
Arcticidae					
Arctica islandica (Linnaeus, 1767)					I-II-III-IV
Mytilidae					
Lithophaga lithophaga (Linnaeus, 1758)	II	IV	II (Med.)		
Pholadidae					
Pholas dactylus (Linnaeus, 1758)	II		II (Med.)		
Pinnidae					
Pinna nobilis8 (Linnaeus, 1758)	II	IV	II (Med.)		
Pinna rudis (Linnaeus, 1758)	II				
Ostreidae					
Ostrea edulis (Linnaeus, 1758)					I-II-III-IV
CRUSTACEANS					
Balanidae					
Megabalanus azoricus (Pilsbry, 1916)					V
Majidae					
Maja squinado (Herbst, 1788)	III		III (Med.)		
Nephropidae					
Homarus gammarus (Linnaeus, 1758)	III		III (Med.)		
Ocypodidae					
Ocypode cursor (Linnaeus, 1758)	II		II (Med.)		
Palinuridae					
Palinurus elephas (Fabricius, 1787)	III		III (Med.)		
Scyllaridae					
Scyllarides latus (Latreille,1803)	III	V	III (Med.)		
Scyllarus arctus (Linnaeus, 1758)	III		III (Med.)		
Scyllarus pygmaeus (Bate, 1888)	III		III (Med.)		
Pachyplasma giganteum	II		II (Med.)		
ECHINODERMS					
Diadematidae					
Centrostephanus longispinus (Philipi, 1845)	II	IV	II (Med.)		
Echinidae					
Paracentrotus lividus (Lamarck, 1816)	III		III (Med.)		
Ophidiasteridae					
Asterina pancerii (Gasco, 1860)	II		II (Med.)		
Ophidiaster ophidianus (Lamarck, 1816)	II		II (Med.)		
BRYOZOA					
Horneridae					
Hornera lichenoides (Linnaeus, 1758)	II				
FISHES (Elasmobranchii)					
Carcharhinidae					
Prionace glauca (Linnaeus, 1758)			III (Med.)		
Cetorhinidae					
Cetorhinus maximus (Gunnerus, 1765)	II	II	II (Med.)	I-II	I-II-III-IV-V
Lamnidae					

6 = *C. rubicunda* = *C. nodiferum*.
7 = *C. seguenziae*.
8 = *P. pernula*, as listed in Bern Convention.

SPECIES	PROTECTION STATUS C.B.	H.D.	BERNA	BONN	OSPAR
Carcharodon carcharias (Linnaeus, 1758)	II	II	II (Med.)	I-II	
Isurus oxyrinchus (Rafinesque, 1810)	III		III (Med.)		
Lamna nasus (Bonnaterre,1788)	III		III (Med.)		
Myliobatidae					
Mobula mobular (Bonnaterre,1788)	II		II (Med.)		
Rajidae					
Dipturus batis (Linnaeus, 1758)					I-II-III-IV-V
Raja alba (Lacépède, 1803)			III (Med.)		
Raja montagui (Fowler, 1910)					II-III-IV-V
Rhincodontidae					
Rhincodon typus (Smith, 1828)				II	
Squatinidae					
Squatina squatina (Linnaeus, 1758)			III (Med.)		
FISHES (Cephalaspidomorphi)					
Petromyzonidae					
Lampetra fluviatilis (Linnaeus, 1758)	III	II[9]-V	III		
Petromyzon marinus Linnaeus, 1758	III	II[10]	III		I-II-III-IV
FISHES (Actinopterygii)					
Acipenseridae					
Acipenser gueldenstaedtii (Brandt & Ratzeburg, 1833)		V		II	
Acipenser nacarii (Bonaparte, 1836)	II	II(*)-IV	II	II	
Acipenser nudiventris (Lovetzky, 1828)		V		II	
Acipenser stellatus (Pallas, 1771)		V	III	II	
Acipenser sturio (Linnaeus, 1758)	II	II(*)-IV	II	I-II	II-IV
Acipenser ruthenus (Linnaeus, 1758)		V	III	II[11]	
Huso huso (Linnaeus, 1758)	II	V	II (Med.) - III	II	
Anguillidae					
Anguilla anguilla (Linnaeus, 1758)	III				
Clupeidae					
Alosa alosa (Linnaeus, 1758)	III		III		II-III-IV
Alosa fallax (Lacépède, 1800)	III		III		
Alosa pontica (Eichwald, 1838)			III		
Alosa spp.		II-V			
Cottidae					
Cottus poecilopus (Heckel, 1837)			III		
Triglopsis quadricornis (Linnaeus, 1758)[12]			III		
Cyprinidae					
Pelecus cultratus (Linnaeus, 1758)		V	III		
Cyprinodontidae					
Aphanius fasciatus (Valenciennes, 1821)	II	II	II (Med.) – III		
Aphanius iberus (Valenciennes, 1846)	II	II	II (Med.) - III		
Gadidae					
Gadus morhua (Linnaeus, 1758)[13]					II-III
Gasterosteidae					
Pungitius platygaster (Kessler, 1859)[14]			III		
Gobiidae					
Neogobius syrman (Nordmann, 1840)[15]			III		

9 Except Finish and Swedish populations.
10 Except Swedish populations.
11 Only Danube freshwater population is included.
12 = *Myoxocephalus quadricornis,* as listed in Bern Convention.
13 Only populations in the OSPAR regions II and III, that is, the populations/stocks referred to in ICES advice as the North Sea and Skagerrak cod stock Kattegat cod stock, Cod west of Scotland, Cod in the Irish Sea, Cod in the Irish Channel and Celtic Sea.
14 Listed as *Tuntitius platygaster* in Bern Convention, but probably misspelled.

SPECIES	C.B.	H.D.	BERNA	BONN	OSPAR
		PROTECTION STATUS			
Knipowitschia panizzae (Verga, 1841)16		II	III		
Pomatoschistus canestrinii (Ninni, 1883)	II	II	II (Med.) - III		
Pomatoschistus marmoratus (Risso, 1810)			III		
Pomatoschistus microps (Kroyer, 1838)			III		
Pomatoschistus minutus (Pallas, 1770)			III		
Pomatoschistus tortonesei (Miller, 1969)			II (Med.)		
Proterorhinus marmoratus (Pallas, 1814)			III		
Zosterisessor ophiocephalus (Pallas, 1814)17			III		
Salmonidae					
Coregonus oxyrynchus (Linnaeus, 1758)*18*		II19 (*)-IV20			II
Coregonus spp.21		V22	III		
Salmo trutta macrostigma (Duméril, 1858)*23*		II			
Salmo salar (Linnaeus, 1758)		II24-III25	III26		I-II-III-IV
Sciaenidae					
Sciaena umbra (Linnaeus, 1758)			III (Med.)		
Umbrina cirrosa (Linnaeus, 1758)	III		III (Med.)		
Scombridae					
Thunnus thynnus (Linnaeus, 1758)	III				V
Serranidae					
Epinephelus marginatus (Lowe, 1834)	III		III (Med.)		
Siluridae					
Silurus glanis (Linnaeus, 1758)			III		
Syngnathidae					
Hippocampus hippocampus (Linnaeus, 1758)	II		II (Med.)		II-III-IV-V
Hippocampus guttulatus (Cuvier, 1829)27	II		II (Med.)		II-III-IV-V
Syngnathus abaster (Risso, 1826)28			III		
Trachichthyidae					
Hoplostethus atlanticus (Collett, 1889)					I-V
Xiphiidae					
Xyphias gladius (Linnaeus, 1758)	III				
REPTILES					
Cheloniidae					
Caretta caretta (Linnaeus, 1758)	II	II(*)-IV	II	I	IV-V
Chelonia mydas (Linnaeus, 1758)	II	II(*)-IV	II	I	
Lepidochelys kempii (Garman, 1880)	II	IV	II	I	
Eretmochelys imbricata (Linnaeus, 1766)	II	IV	II	I	
Dermochelydae					
Dermochelys coriacea (Vandelli, 1761)	II	IV	II	I	I-II-III-IV-V

15 = *Gobius syrman*, as listed in Bern Convention.
16 = *Padogobius panizzai*, as listed in Bern Convention.
17 = *Gobius ophiocephalus*, as listed in Bern Convention.
18 Listed as *Coregonus oxyrhinchus* in Habitat Directive; listed as *Coregonus lavaretus oxyrhinchus* in OSPAR. Maritime stocks may be extinct.
19 Anadromous populations of some sectors of North Sea.
20 Anadromous populations of some sectors of North Sea, except Finish populations.
21 Species belonging to genus *Coregonus* are primarily freshwater fishes, but some of them are anadromous, spending part of their life at sea or in brackish waters, and returning to freshwater to spawn.
22 Except *Coregonus oxyrinchus* – anadromous populations of some sectors of North Sea.
23 Listed as *Salmo macrostigma* in Habitat Directive.
24 Only freshwater non-Finish populations.
25 Only freshwater populations.
26 Only freshwater populations.
27 = *H. ramulosus*
28 = *S. nigrolineatus*. In Anex III of Bern Convention, *S. abaster* and *S. nigrolineatus* are included as separated species.

SPECIES	PROTECTION STATUS				
	C.B.	H.D.	BERNA	BONN	OSPAR
MAMMALS (Seals)					
Phocidae					
Halychoerus grypus (Fabricius, 1791)		II-V	III	II[29]	
Monachus monachus (Hermann, 1779)	II	II(*)-IV	II	I-II	
Phoca hispida[30]			III		
Phoca hispida bottnica (Gmelin, 1788)		II-V			
Phoca vitulina (Linnaeus, 1758)		II-V	II[31]-III[32]	II[33]	
MAMMALS (Whales, Dolphins & Porpoises)					
Balaenidae					
Balaena mysticetus (Linnaeus, 1758)		IV	II	I	I
Eubalaena glacialis (Müller, 1776)	II	IV	II	I	I-II-III-IV-V
Balaenopteridae					
Balaenoptera acutorostrata (Lacépède, 1804)	II	IV	II (Med.)		
Balaenoptera borealis (Lesson, 1828)	II	IV	II (Med.)	I-II	
Balaenoptera edeni (Anderson, 1878)		IV	II	II	
Balaenoptera musculus (Linnaeus, 1758)		IV	II[34]	I	I-II-III-IV-V
Balaenoptera physalus (Linnaeus, 1758)	II	IV	II	I-II	
Megaptera novaeangliae (Borowski, 1781)[35]	II	IV	II	I	
Delphinidae					
Delphinus delphis (Linnaeus, 1758)	II	IV	II	I[36]-II[37]	
Feresa attenuata (Gray, 1874)		IV	III		
Globicephala macrorhynchus (Gray, 1846)		IV	II		
Globicephala melas (Traill, 1809)	II	IV	II	I[38]	
Grampus griseus (Cuvier G., 1812)	II	IV	II	II[39]	
Lagenodelphis hosei (Fraser, 1956)		IV	III	II[40]	
Lagenorhynchus acutus (Gray, 1828)		IV	II	II[41]	
Lagenorhynchus albirostris (Gray, 1846)		IV	II	II[42]	
Orcinus orca (Linnaeus, 1758)	II	IV	II	II	
Pseudorca crassidens (Owen, 1846)	II	IV	II		
Stenella coeruleoalba (Meyen, 1833)	II	IV	II	II[43]	
Stenella frontalis (Cuvier, 1829)		IV	II		
Steno bredanensis (Lesson, 1828)	II	IV	II		
Tursiops truncatus (Montagu, 1821)	II	II-IV	II	II[44]	
Monodontidae					
Delphinapterus leucas (Pallas, 1776)		IV	III	II	
Monodon monoceros (Linnaeus, 1758)		IV	II		
Phocoenidae					
Phocoena phocoena (Linnaeus, 1758)	II	II	II	II[45]	I-II-III-IV-V
Physeteridae					

29 Only Baltic Sea population.
30 = *Pusa hispida*. In Bern Convention, all subspecies are included.
31 Baltic and Wadden Sea populations.
32 Atlantic populations.
33 Only Baltic and Wadden Sea populations.
34 Listed as *Sibbaldus (Balaenoptera) musculus.*
35 = *M. longimana* = *M. nodosa.*
36 Only Mediterranean population.
37 North and Baltic Sea, Mediterranean and Black Sea populations, apart from eastern tropical Pacific population.
38 Only North and Baltic Sea populations.
39 Only North and Baltic Sea populations.
40 Only southeast Asian populations are included.
41 Only North and Baltic Sea populations.
42 Only North and Baltic Sea populations.
43 Mediterranean population, apart from eastern tropical Pacific population.
44 North and Baltic Sea, western Mediterranean and Black Sea populations.
45 North and Baltic Sea, western North Atlantic and Black Sea populations.

SPECIES	PROTECTION STATUS				
	C.B.	H.D.	BERNA	BONN	OSPAR
Kogia breviceps (de Blainville, 1838)		IV	II		
Kogia simus (Owen, 1866)	II	IV	II (Med.)		
Physeter catodon (Linnaeus, 1758)		IV	II		
Physeter macrocephalus (Linnaeus, 1758)	II	IV	II (Med.)	I-II	
Ziphiidae					
Hyperoodon ampullatus (Forster, 1770)		IV	II[46]	I	
Mesoplodon bidens (Sowerby, 1804)		IV	II		
Mesoplodon europaeus (Gervais, 1855)		IV	III		
Mesoplodon densirostris (de Blainville, 1817)	II	IV	II (Med.)		
Mesoplodon mirus (True, 1913)		IV	II		
Ziphius cavirostris (Cuvier G., 1832)	II	IV	II		

46 Listed as *H. rostratus.*

Appendix II: List of key habitats

Marine habitats included in the Habitat Directive (Annex I: natural habitat types of community interest whose conservation requires the designation of special areas of conservation); (*) = priority habitat type.

Habitats	Natura 2000 code
Sandbanks which are slightly covered by sea water all the time	1110
Posidonia beds (*Posidonia oceanica*)	1120 (*)
Estuaries	1130
Mudflats and sand flats not covered by seawater at low tide	1140
Coastal lagoons	1150 (*)
Large shallow inlets and bays	1160
Reefs	1170
Submarine structures made by leaking gases	1180
Submerged or partially submerged sea caves	8330

List of threatened and/or declining habitats included in the OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic

Habitats	Regions where the habitat occurs	Regions where such habitats are under threat and/or in decline
Carbonate mounds	I, V	V
Deep-sea sponge aggregations	I, III, IV, V	All where they occur
Oceanic ridges with hydrothermal vents/fields	I, V	V
Intertidal mudflats	I, II, III, IV	All where they occur
Littoral chalk communities	II	All where they occur
Lophelia pertusa reefs	All	All where they occur
Maerl beds	All	III
Modiolus modiolus beds	All	All where they occur
Intertidal *Mytilus edulis* beds on mixed and sandy sediments	II, III	All where they occur
Ostrea edulis beds	II, III, IV	All where they occur
Sabellaria spinulosa reefs	All	II, III
Seamounts	I, IV, V	All where they occur
Sea-pen and burrowing mega fauna communities	I, II, III, IV	II, III
Zostera beds	I, II, III, IV	All where they occur

Appendix III: DIPSIR diagrams

A- FISHING SECTOR

(1) Fishing sector_gear nets

Figure 1.1. Gear effect pressures
Figure 1.2. Gear effect responses
Figure 1.3. Waste pressures
Figure 1.4. Waste responses
Figure 1.5. Harvesting pressures
Figure 1.6. Harvesting responses
Figure 1.7. Gear lost pressures
Figure 1.8. Gear lost responses

(2) Fishing sector_gear hooks

Figure 2.1. Gear effect pressures
Figure 2.2. Gear effect responses
Figure 2.3. Waste pressures
Figure 2.4. Waste responses
Figure 2.5. Harvesting pressures
Figure 2.6. Harvesting responses
Figure 2.7. Gear lost pressures
Figure 2.8. Gear lost responses

(3) Fishing sector_gear traps

Figure 3.1. Gear effect pressures
Figure 3.2. Gear effect responses
Figure 3.3. Waste pressures
Figure 3.4. Waste responses
Figure 3.5. Harvesting pressures
Figure 3.6. Harvesting responses
Figure 3.7. Gear lost pressures
Figure 3.8. Gear lost responses

(4) Fishing sector_gear trawls

Figure 4.1. Gear effect pressures
Figure 4.2. Gear effect responses
Figure 4.3. Waste pressures
Figure 4.4. Waste responses
Figure 4.5. Harvesting pressures
Figure 4.6. Harvesting responses

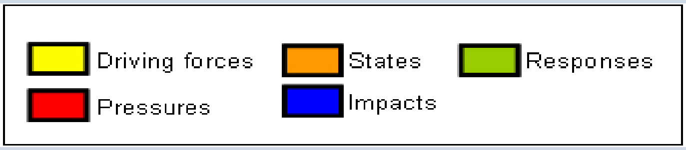
(5) Fishing sector_gear troll lines

Figure 5.1. Waste pressures
Figure 5.2. Waste responses
Figure 5.3. Harvesting pressures
Figure 5.4. Harvesting responses

B- TOURISM SECTOR

C- Summarized whole diagram

A- FISHING SECTOR



(1) Fishing sector_gear nets

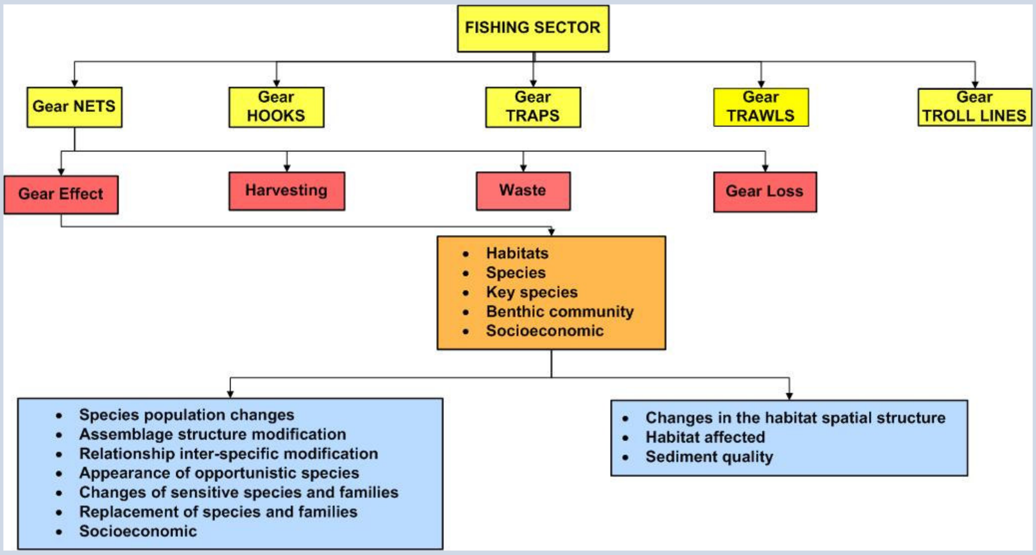


Figure 1.1. Gear effect pressures.

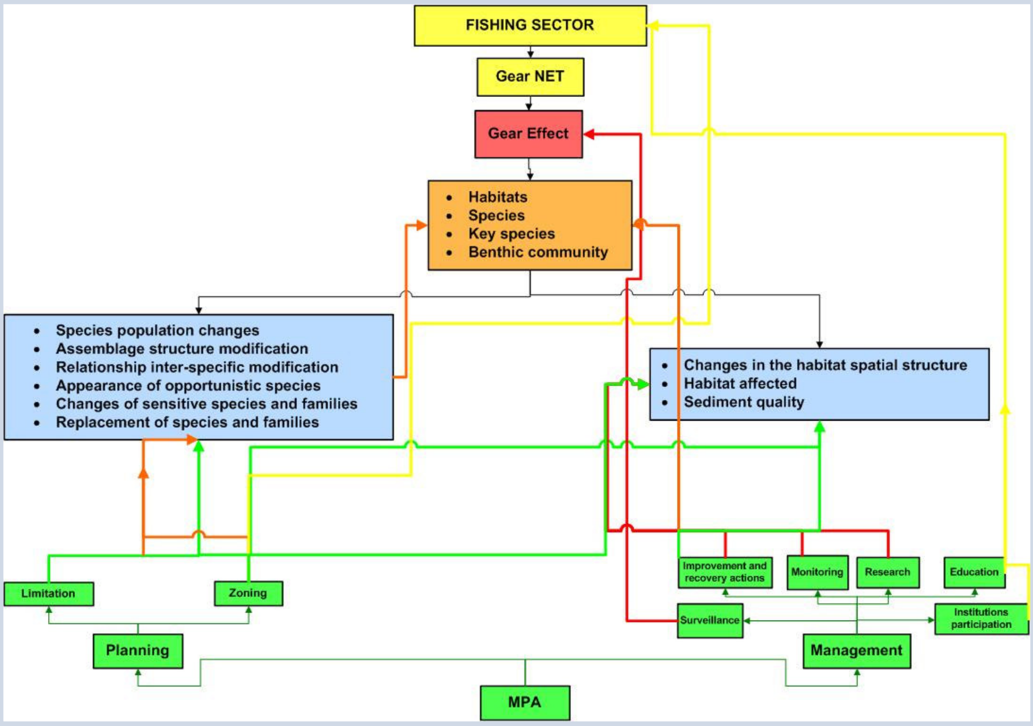


Figure 1.2. Gear effect responses.

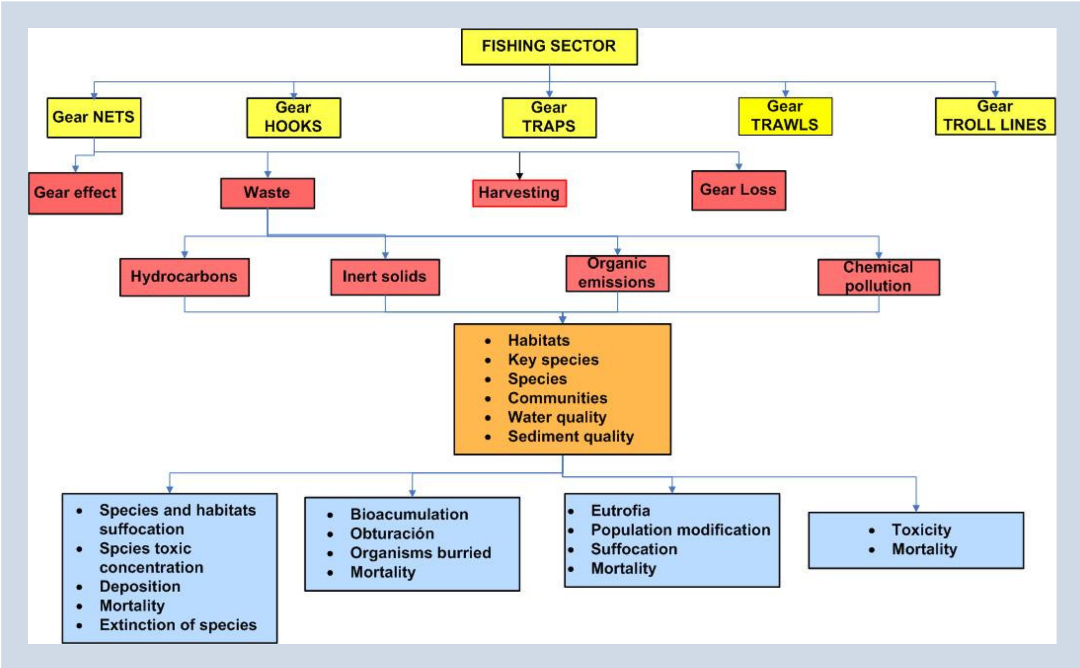


Figure 1.3. Waste pressures.

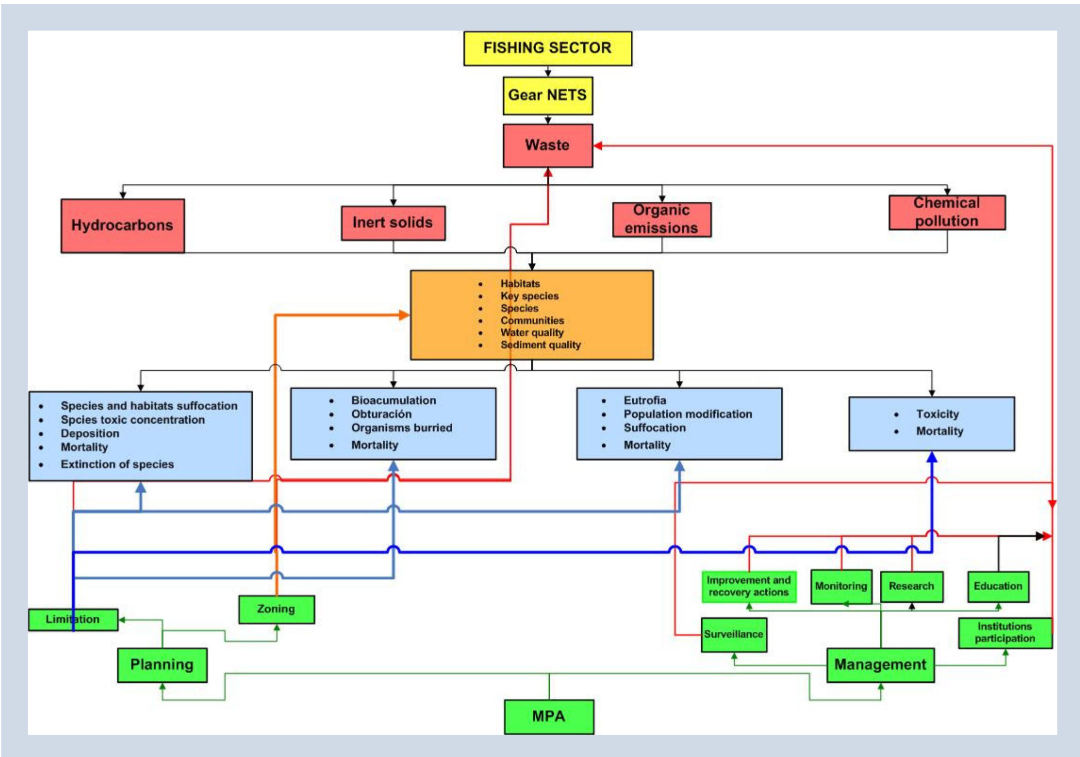


Figure 1.4. Waste responses.

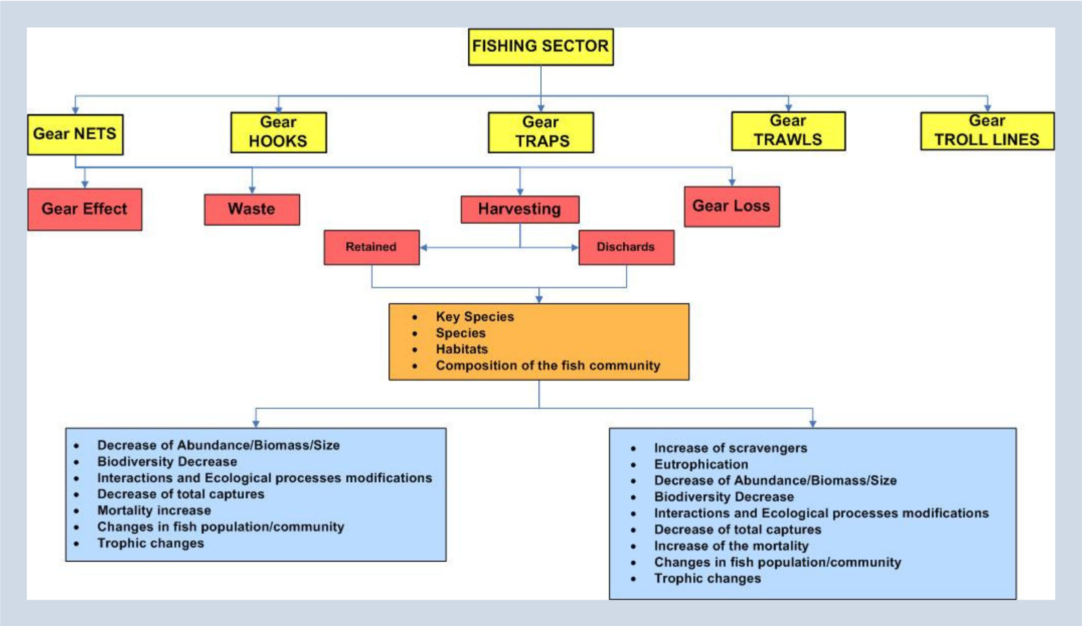


Figure 1.5. Harvesting pressures.

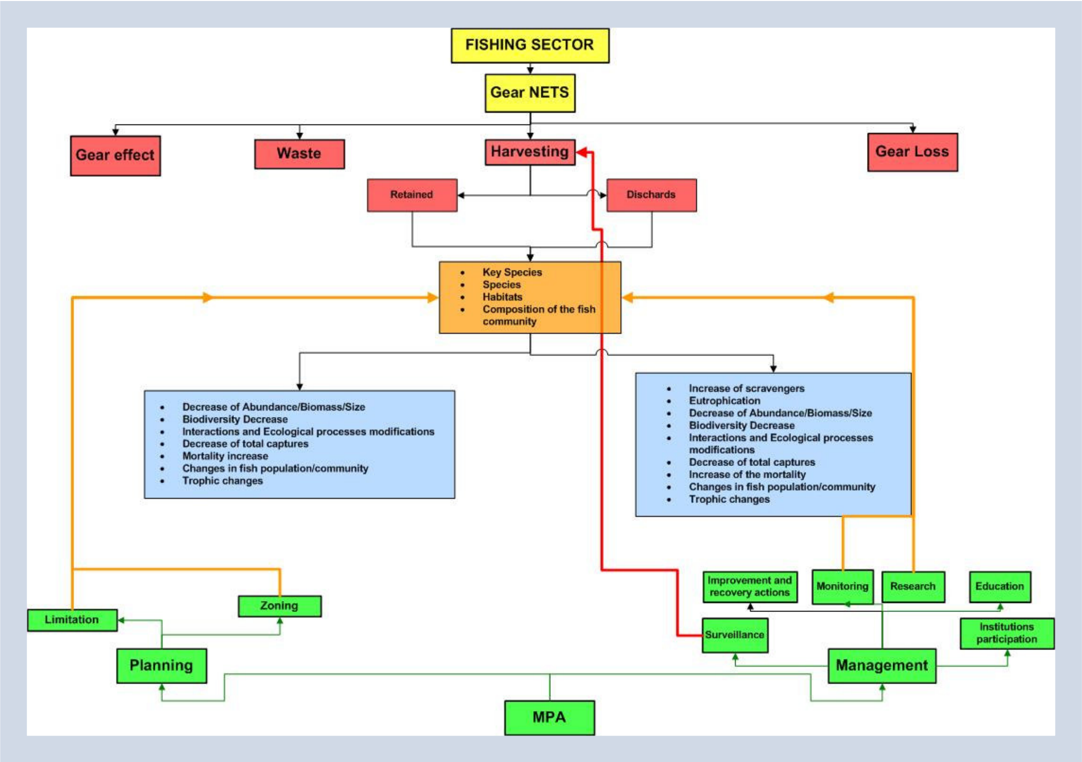


Figure 1.6. Harvesting responses.

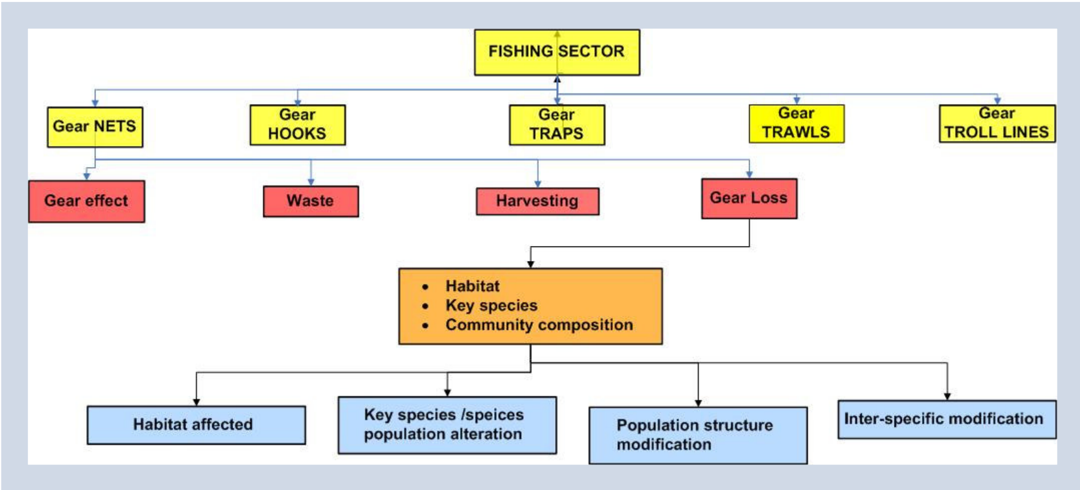


Figure 1.7. Gear lost pressures.

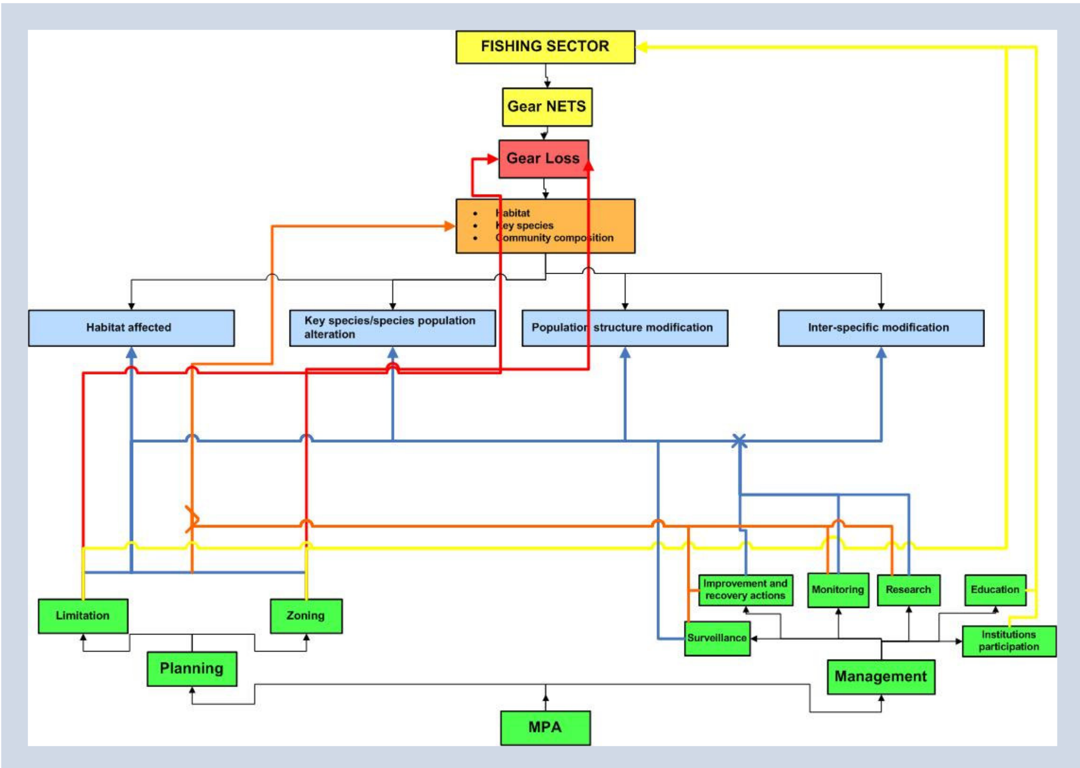


Figure 1.8. Gear lost responses.

(2) Fishing sector_gear hooks

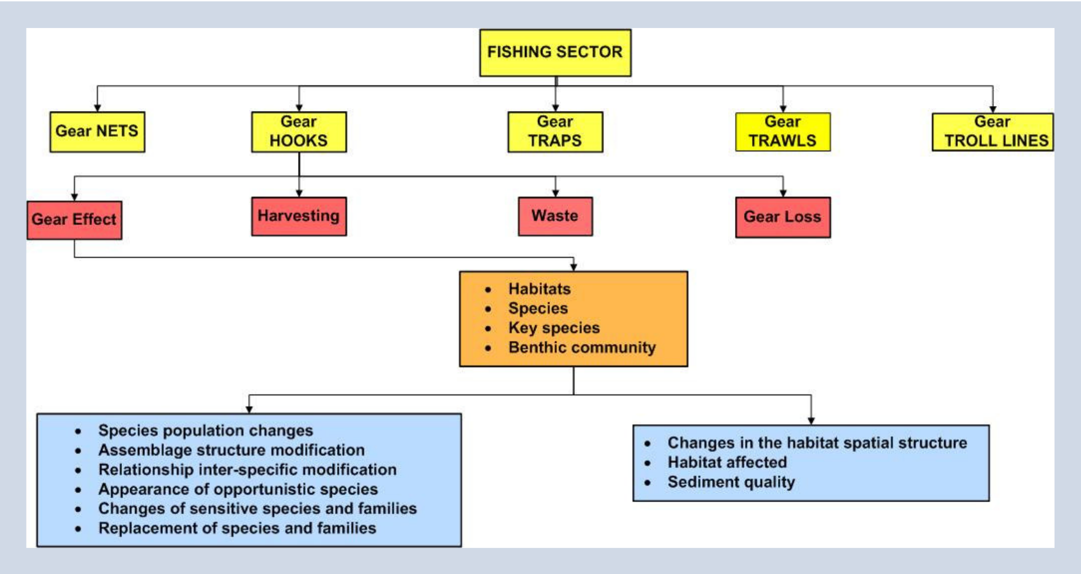


Figure 2.1. Gear effect pressures.

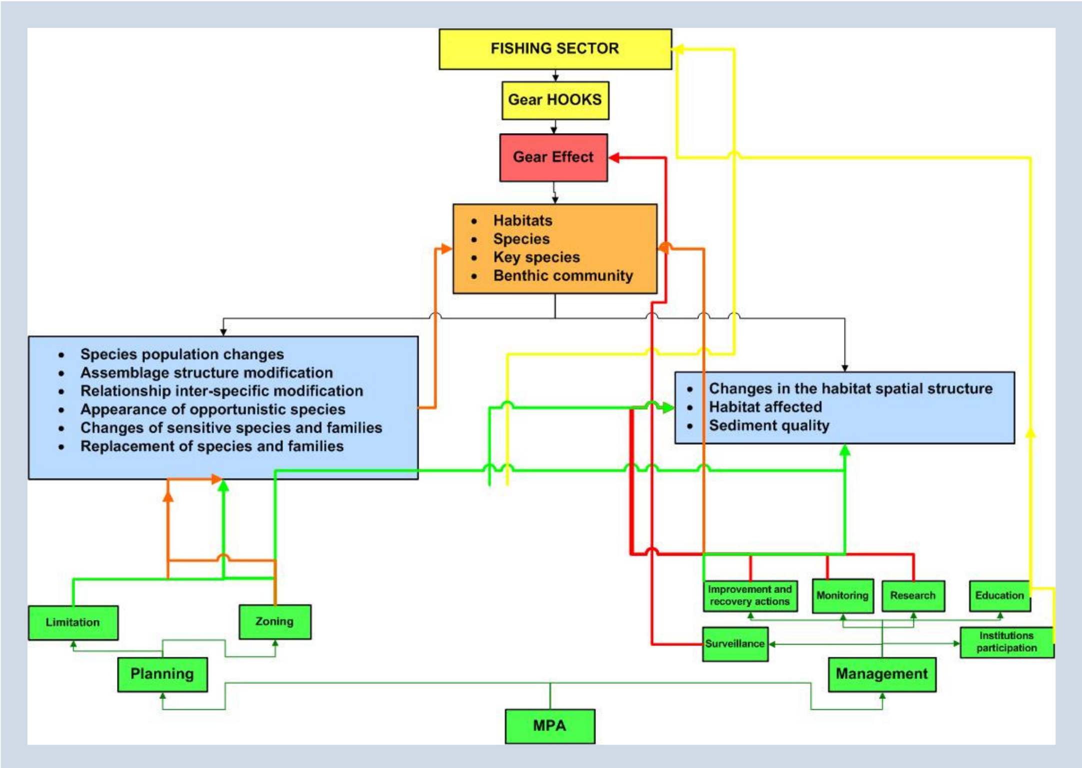


Figure 2.2. Gear effect responses.

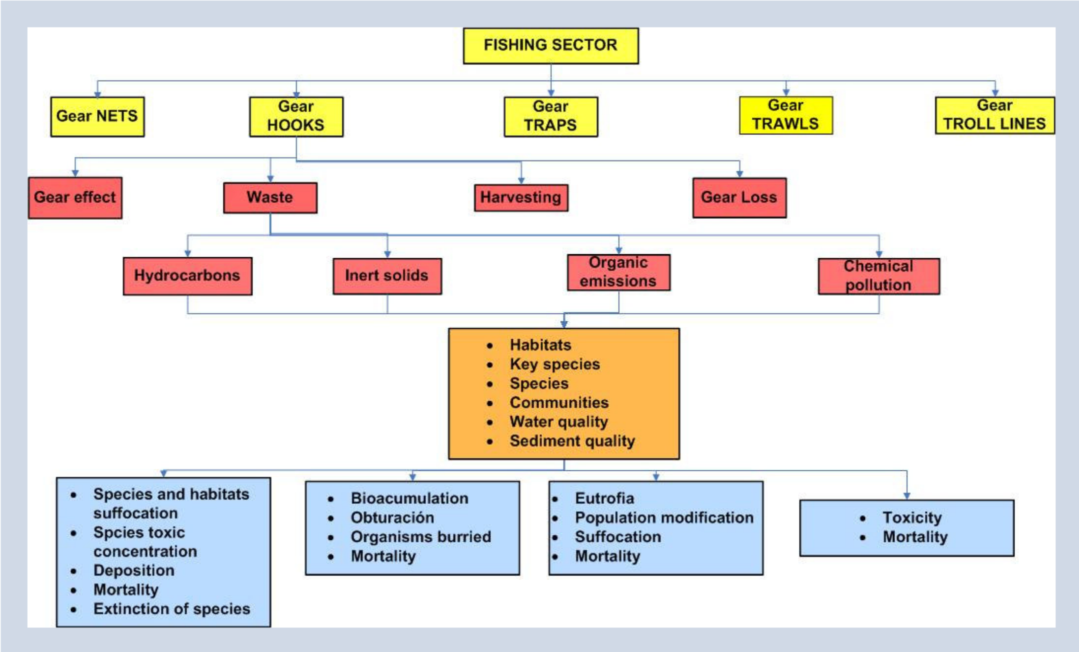


Figure 2.3. Waste pressures.

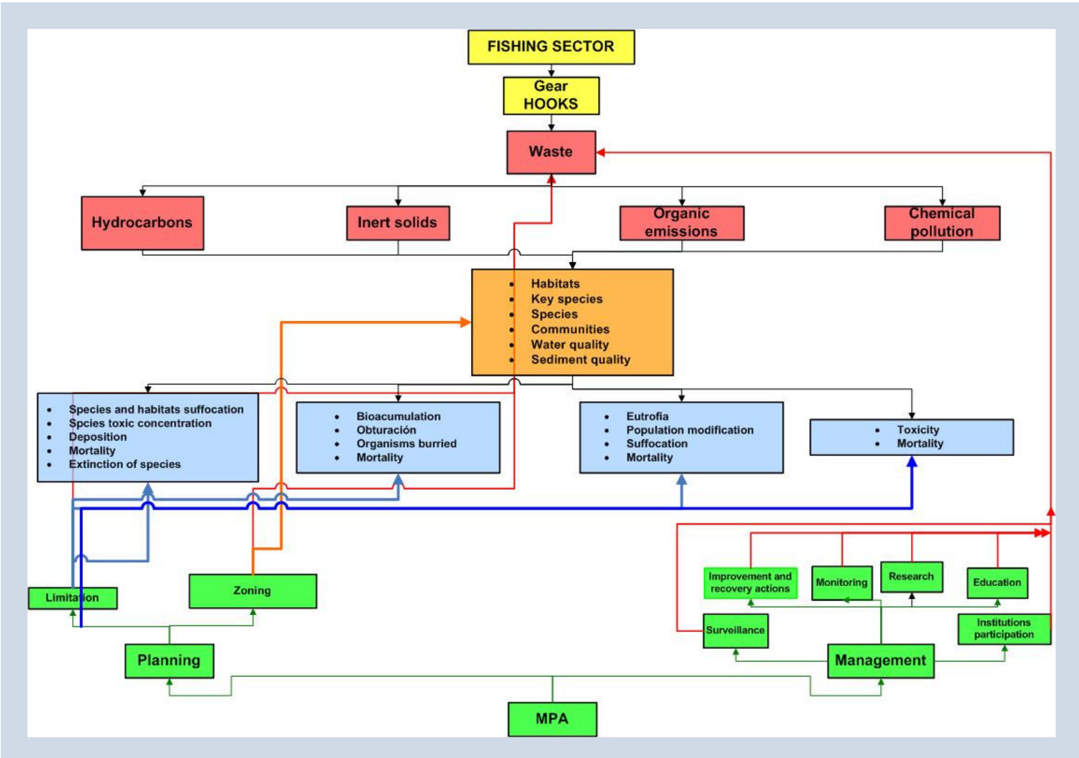


Figure 2.4. Waste responses.

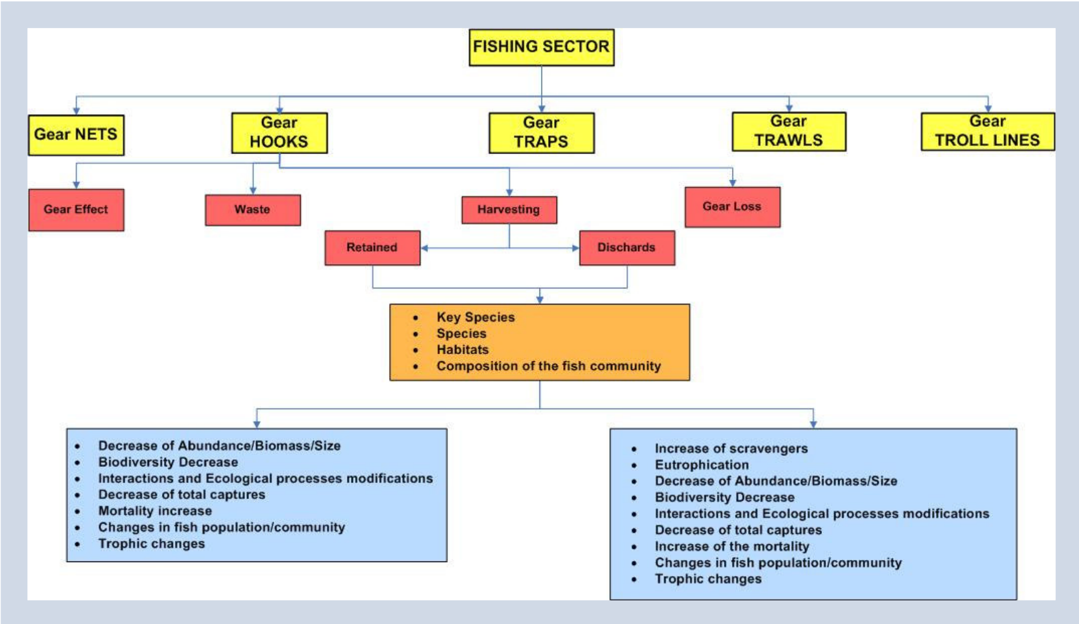


Figure 2.5. Harvesting pressures.

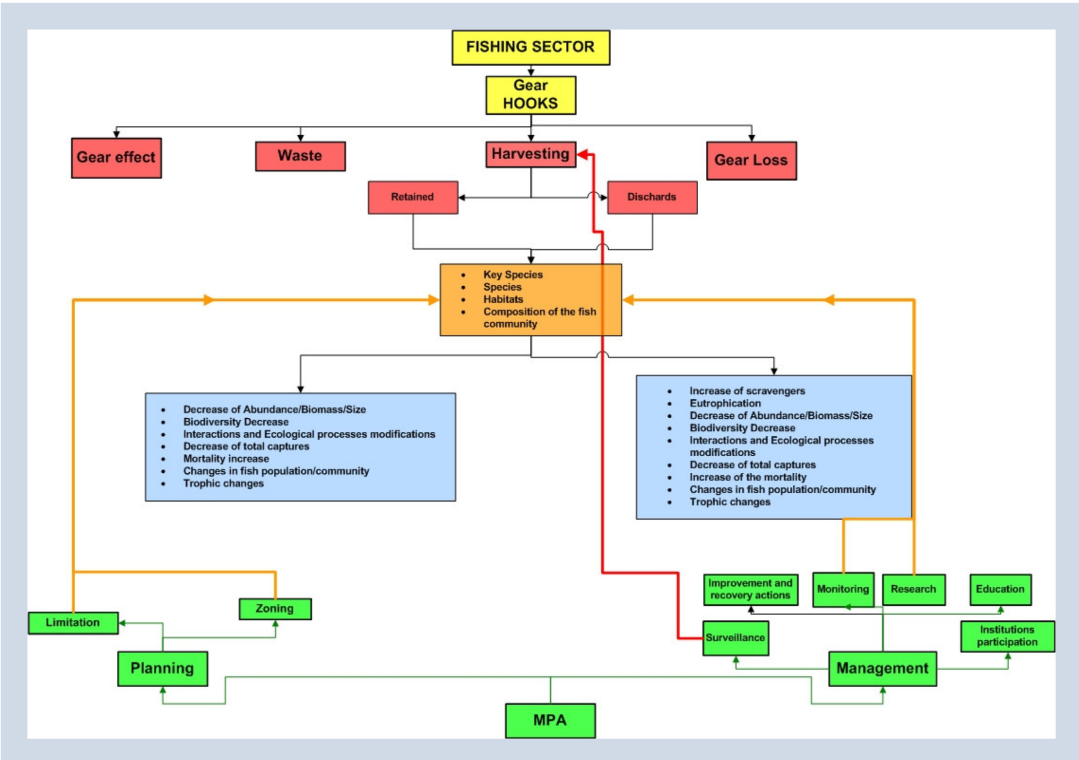


Figure 2.6. Harvesting responses.

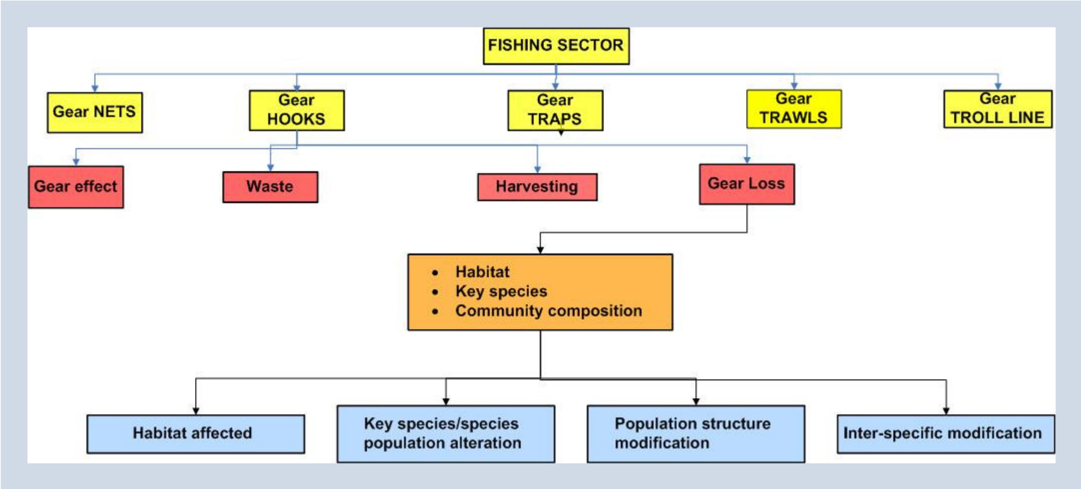


Figure 2.7. Gear lost pressures.

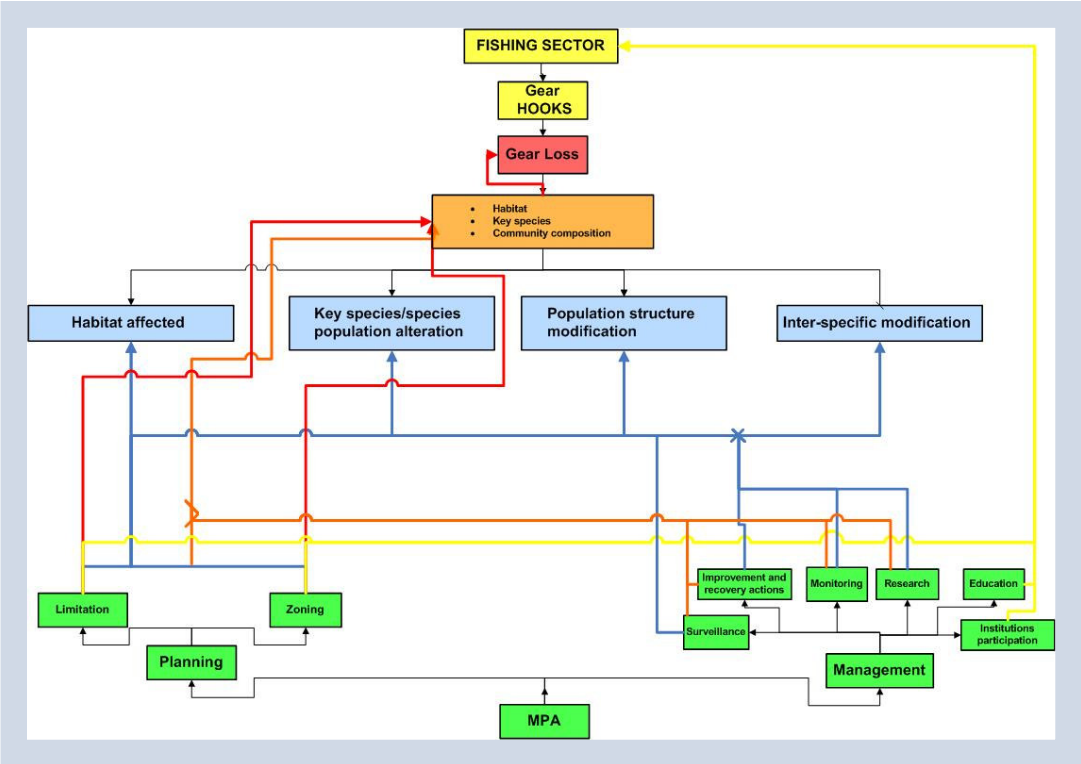


Figure 2.8. Gear lost responses.

(3) Fishing sector_gear traps

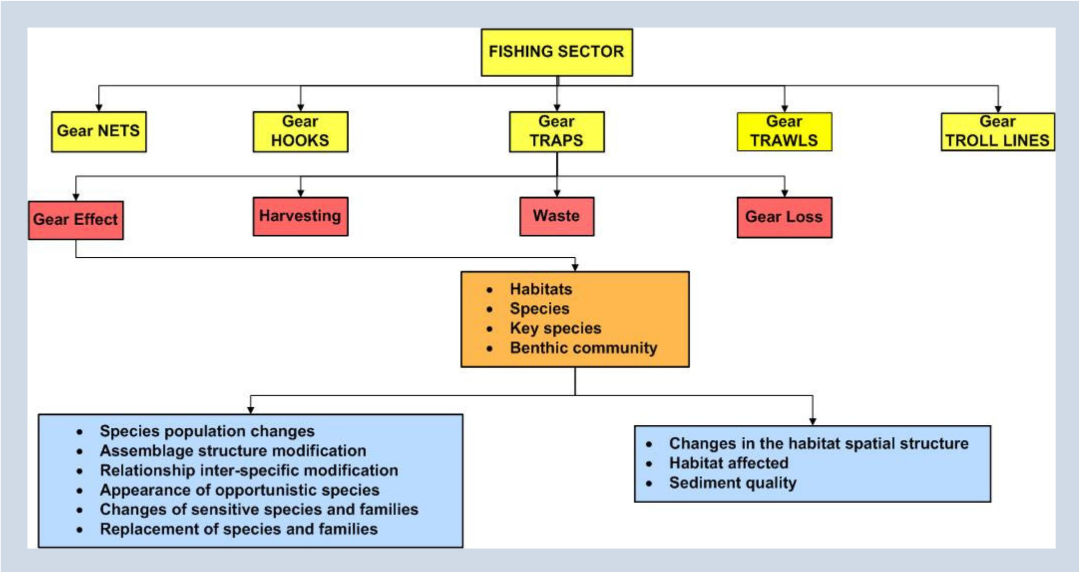


Figure 3.1. Gear effect pressures.

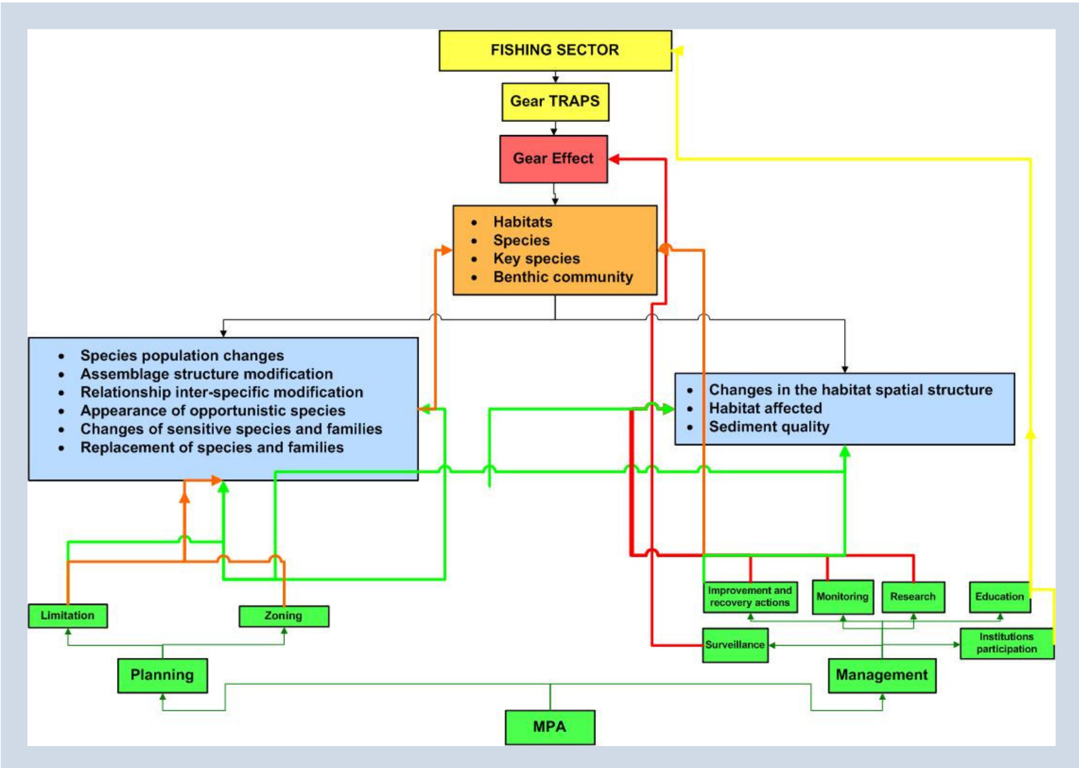


Figure 3.2. Gear effect responses.

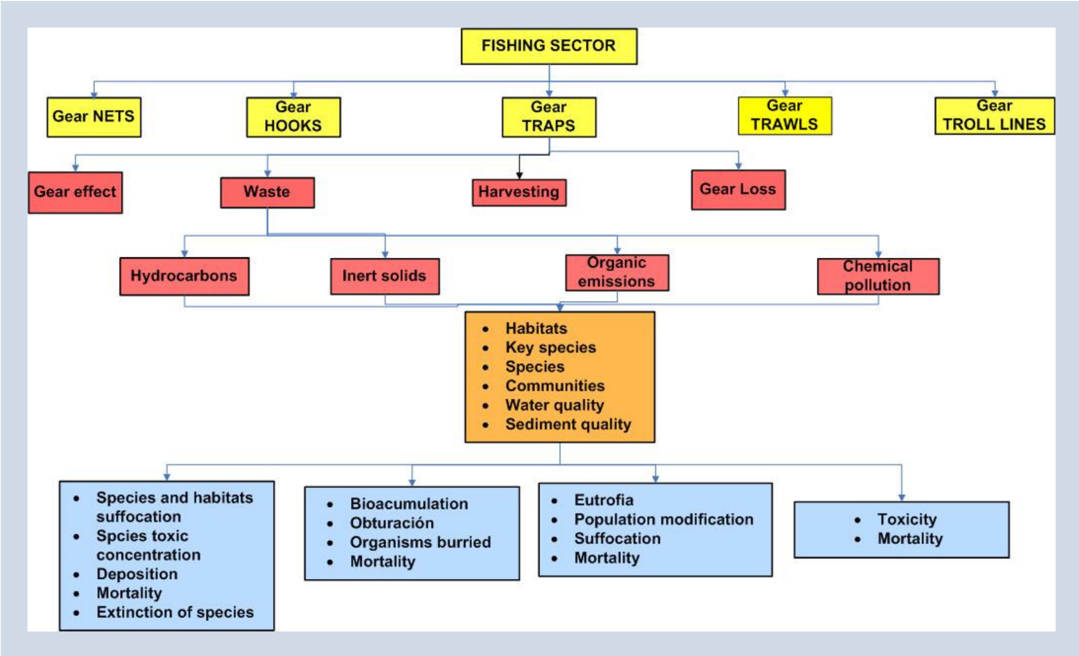


Figure 3.3. Waste pressures.

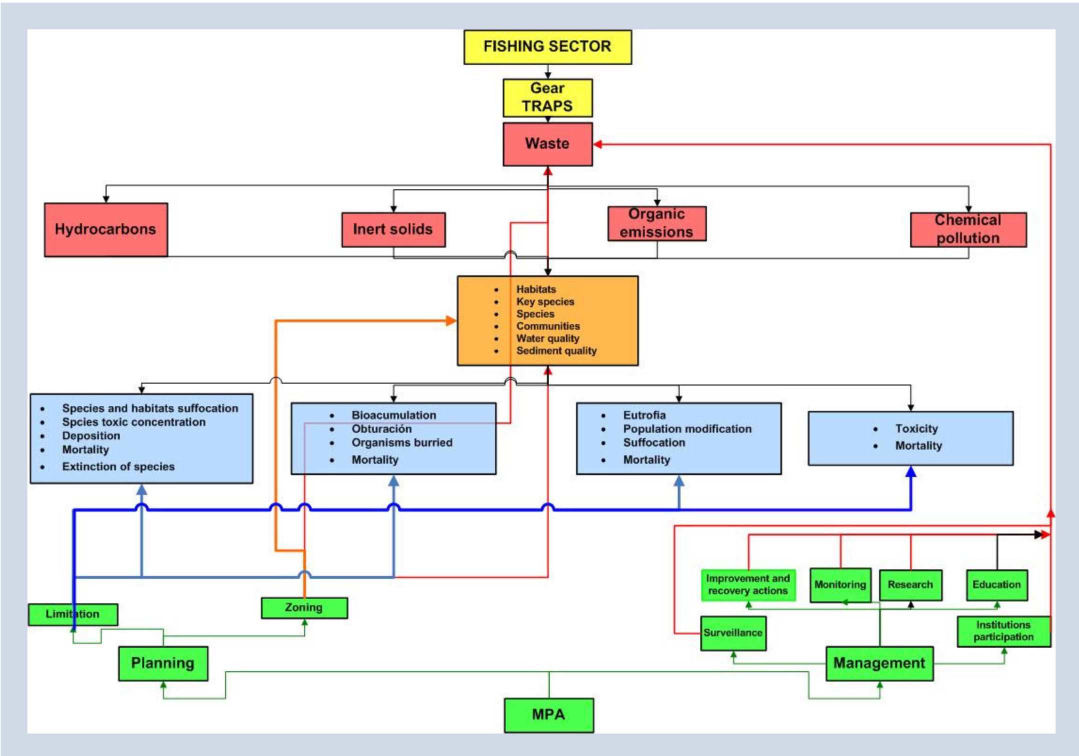


Figure 3.4. Waste responses.

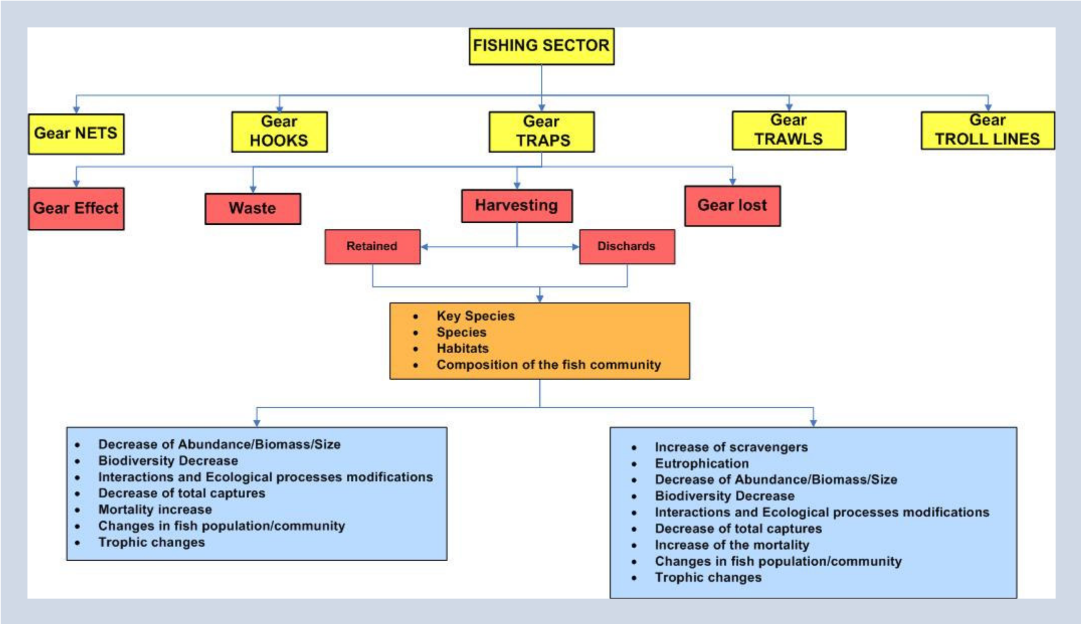


Figure 3.5. Harvesting pressures.

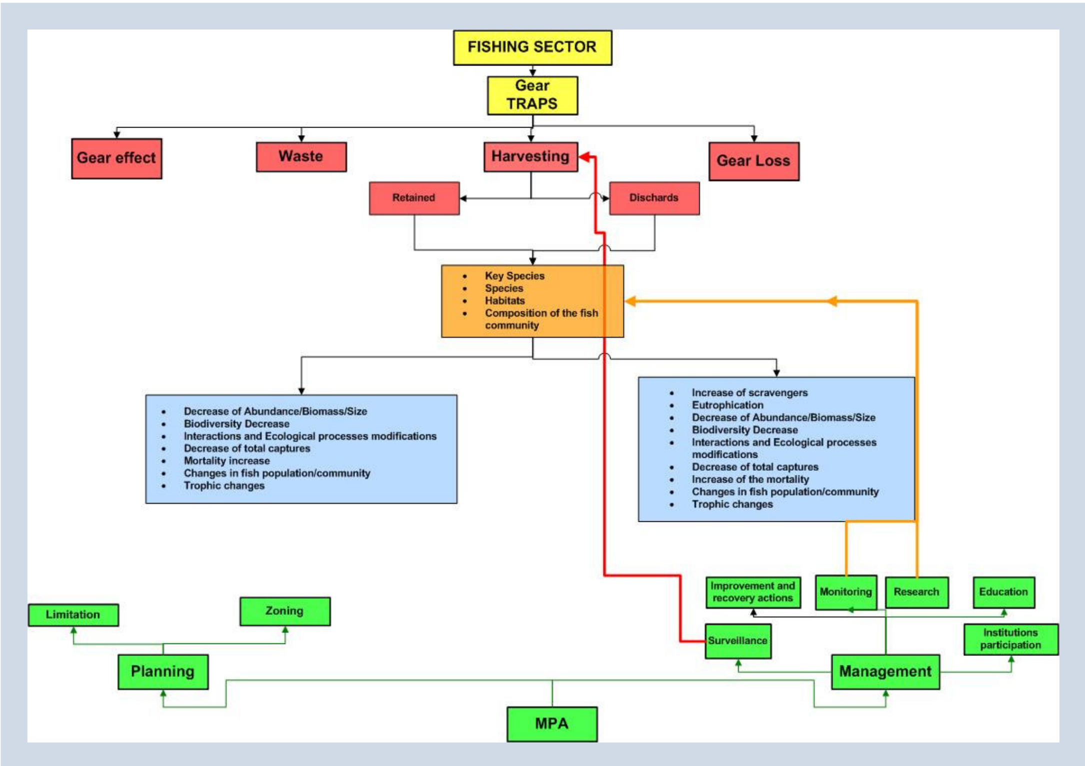


Figure 3.6. Harvesting responses.

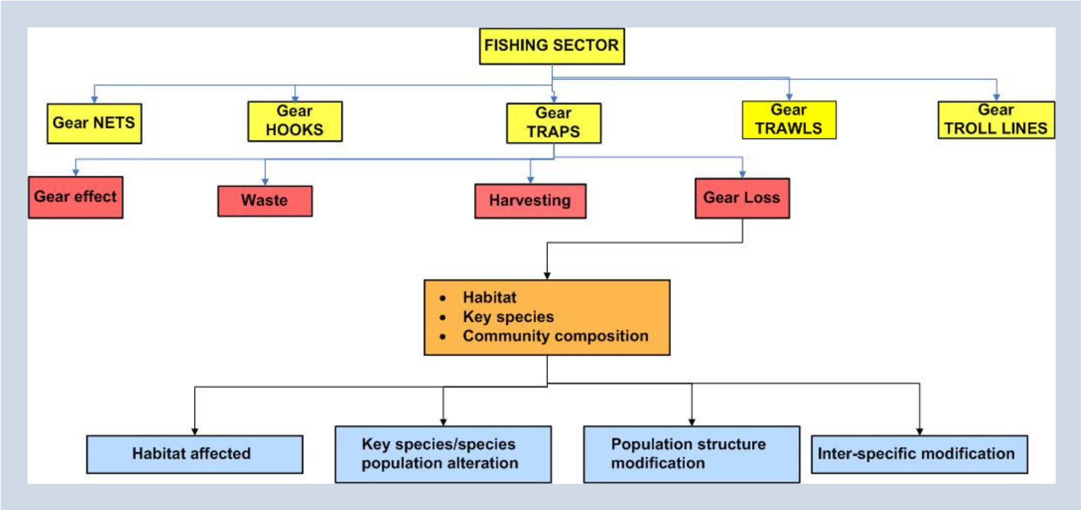


Figure 3.7. Gear lost pressures.

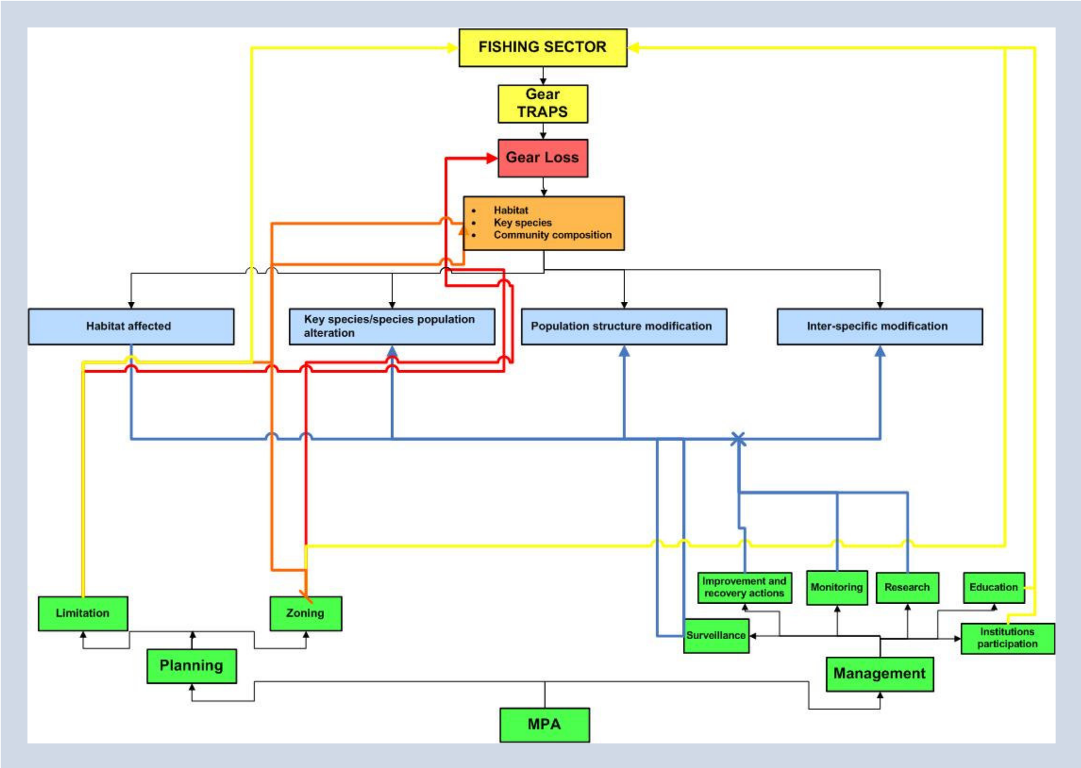


Figure 3.8. Gear lost responses.

(4) Fishing sector_gear trawls

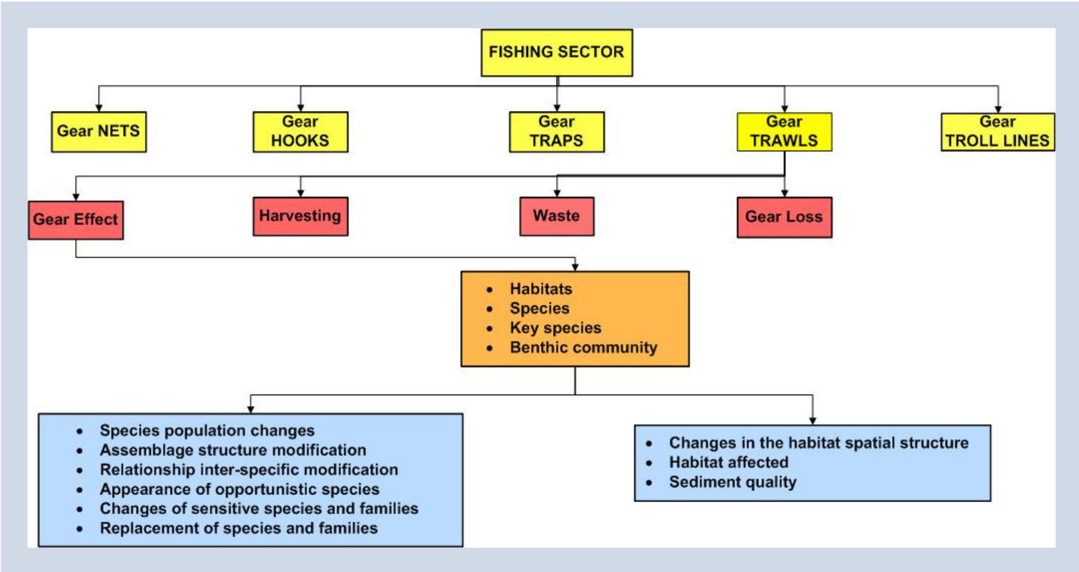


Figure 4.1. Gear effect pressures.

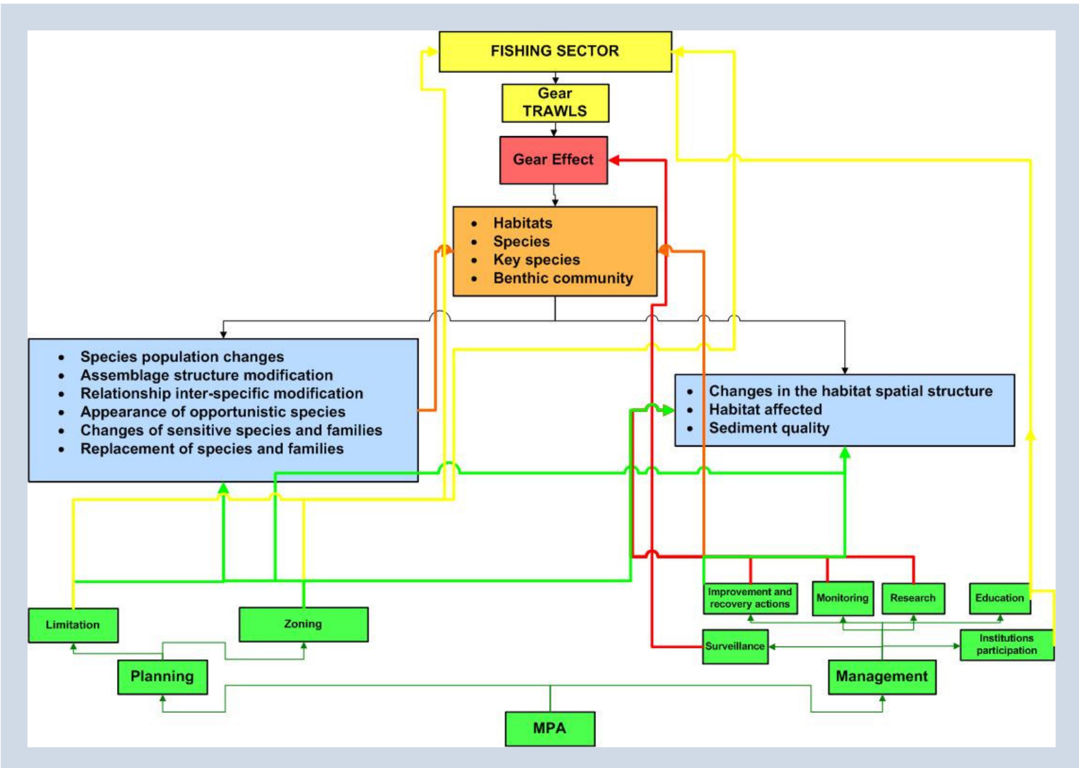


Figure 4.2. Gear effect responses.

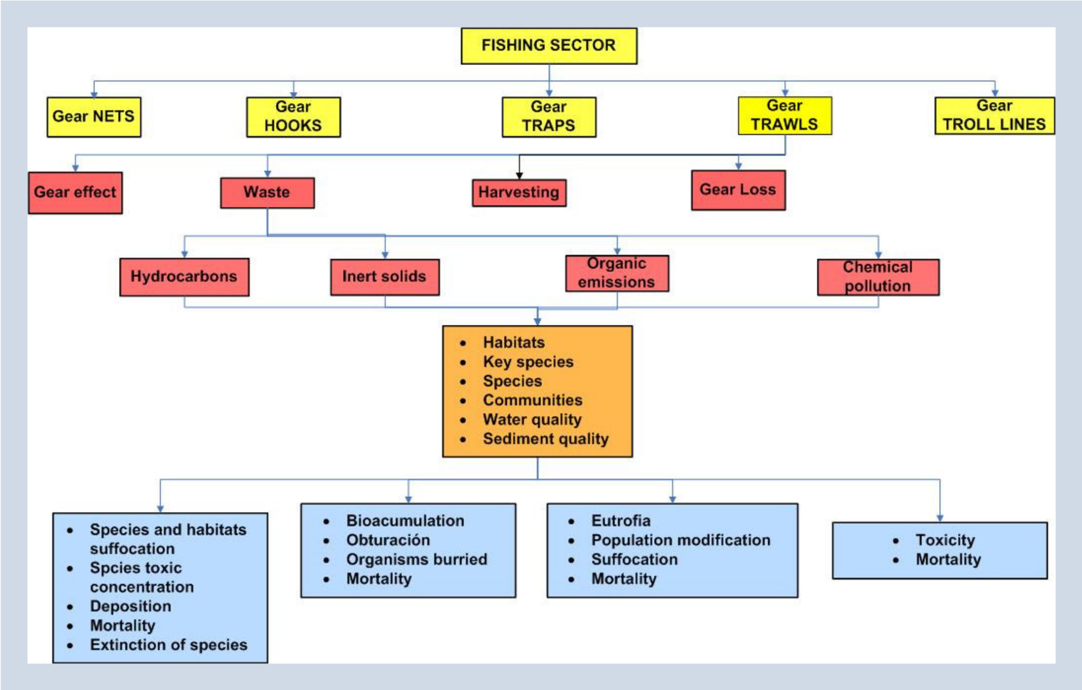


Figure 4.3. Waste pressures.

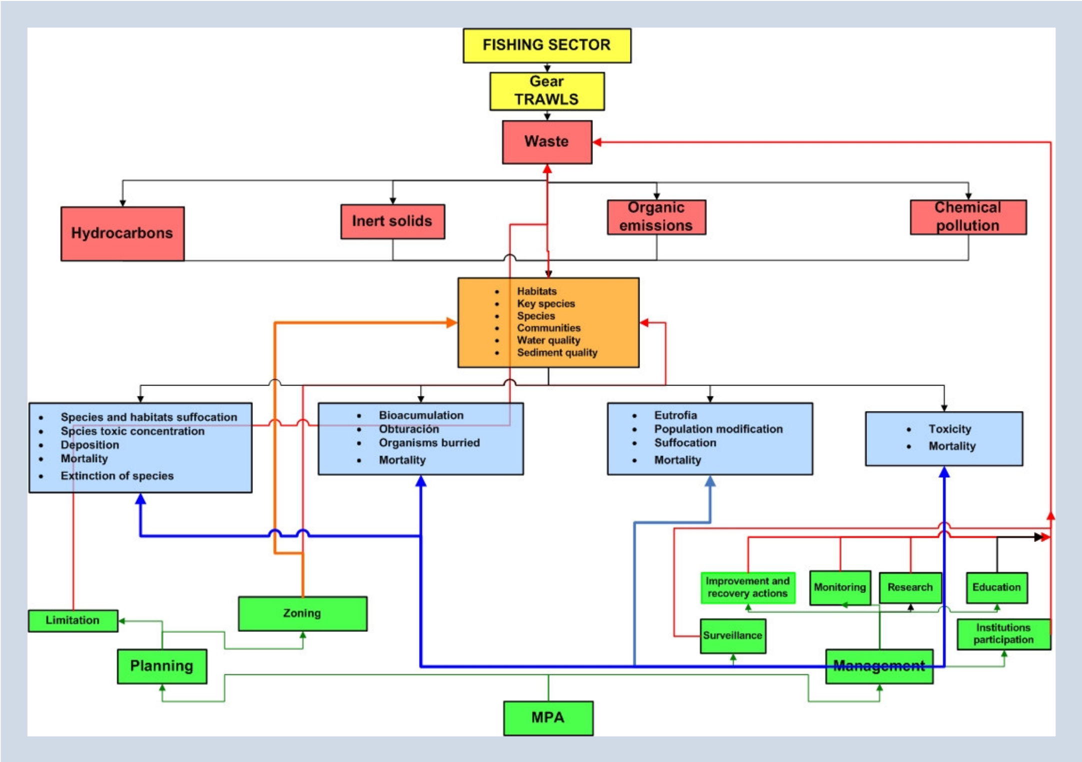


Figure 4.4. Waste responses.

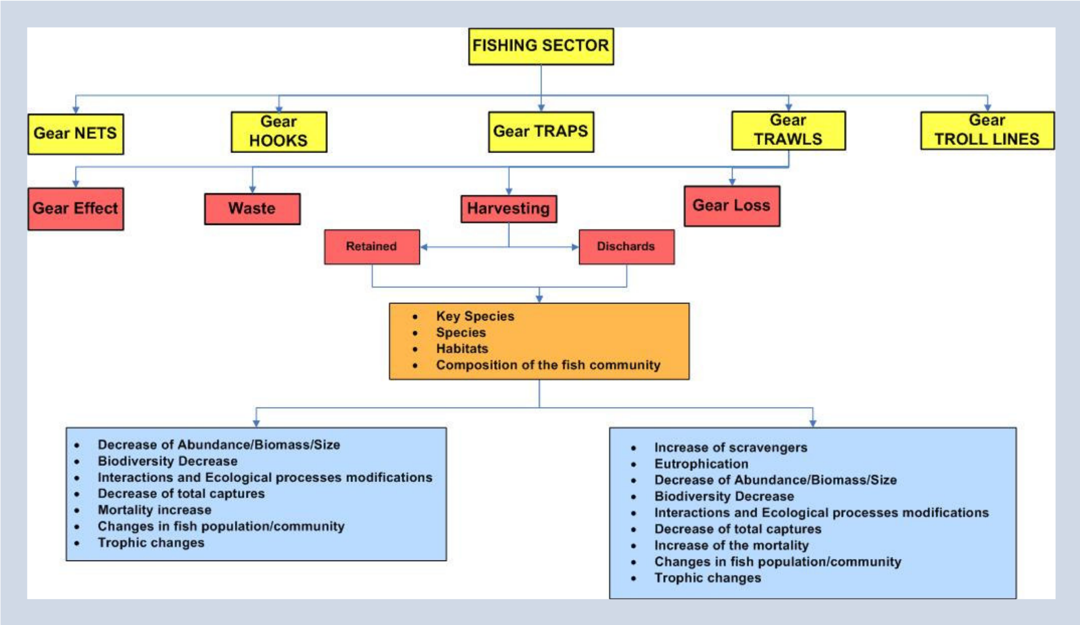


Figure 4.5. Harvesting pressures.

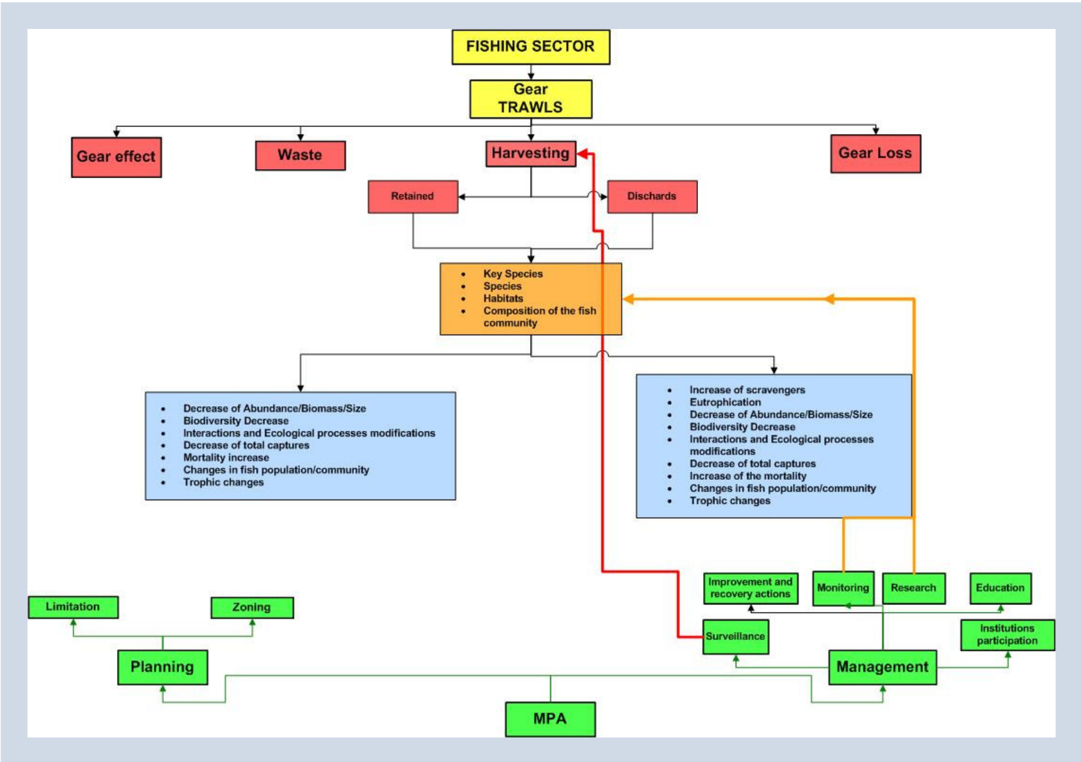


Figure 4.6. Harvesting responses.

(5) Fishing sector_gear troll line

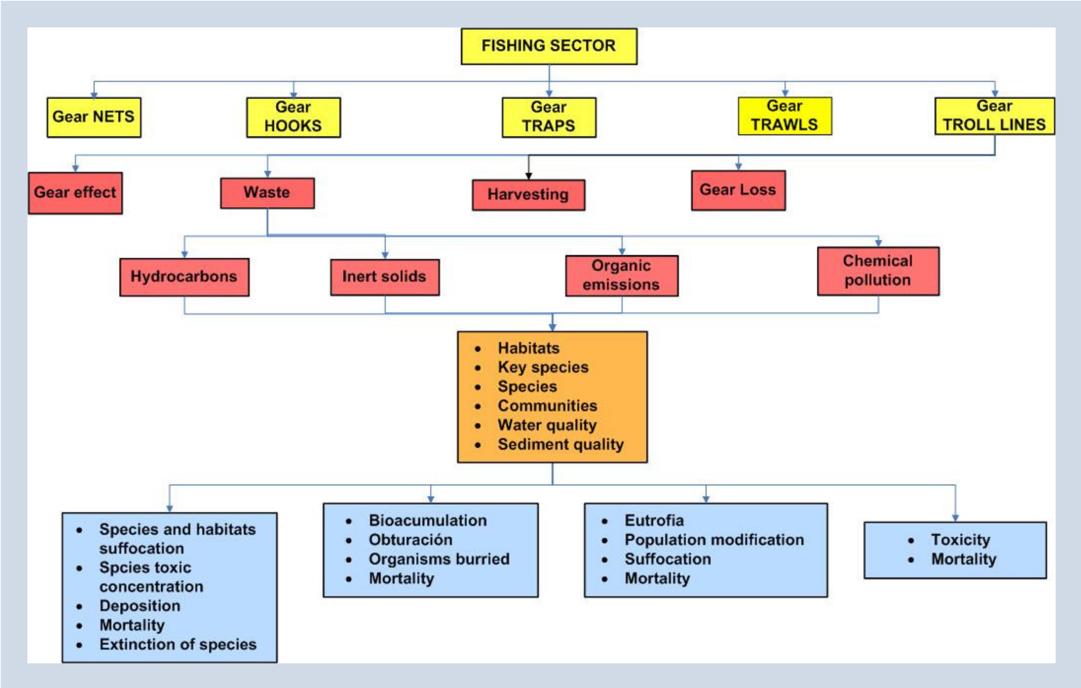


Figure 5.1. Waste pressures.

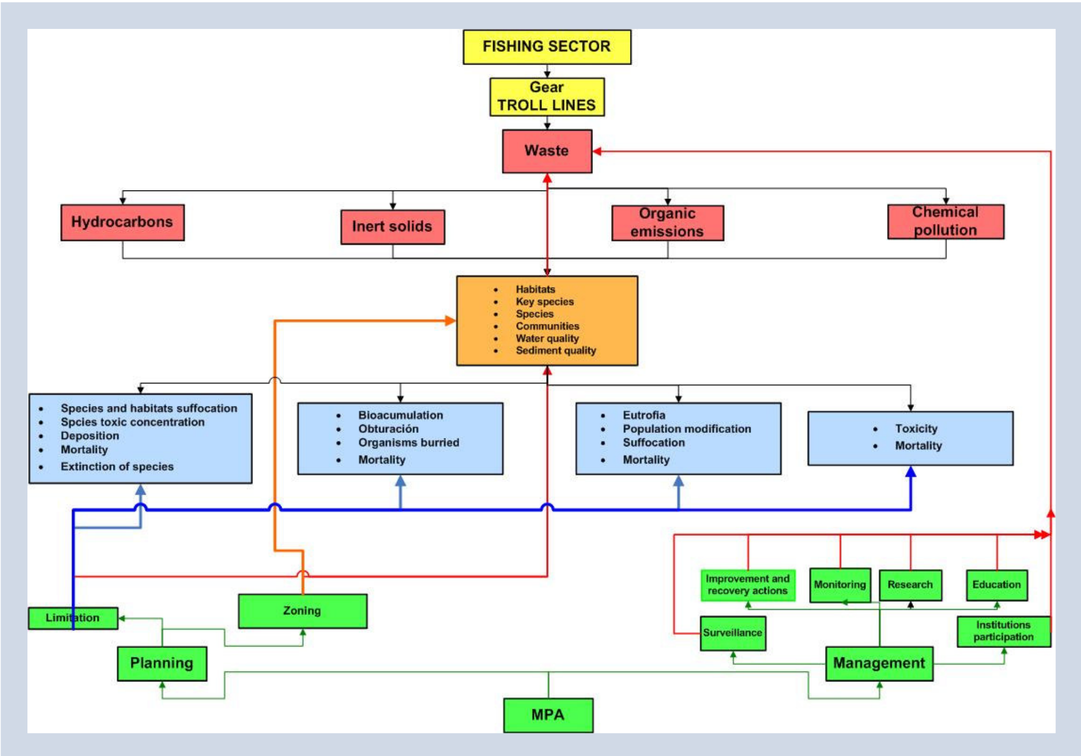


Figure 5.2. Waste responses.

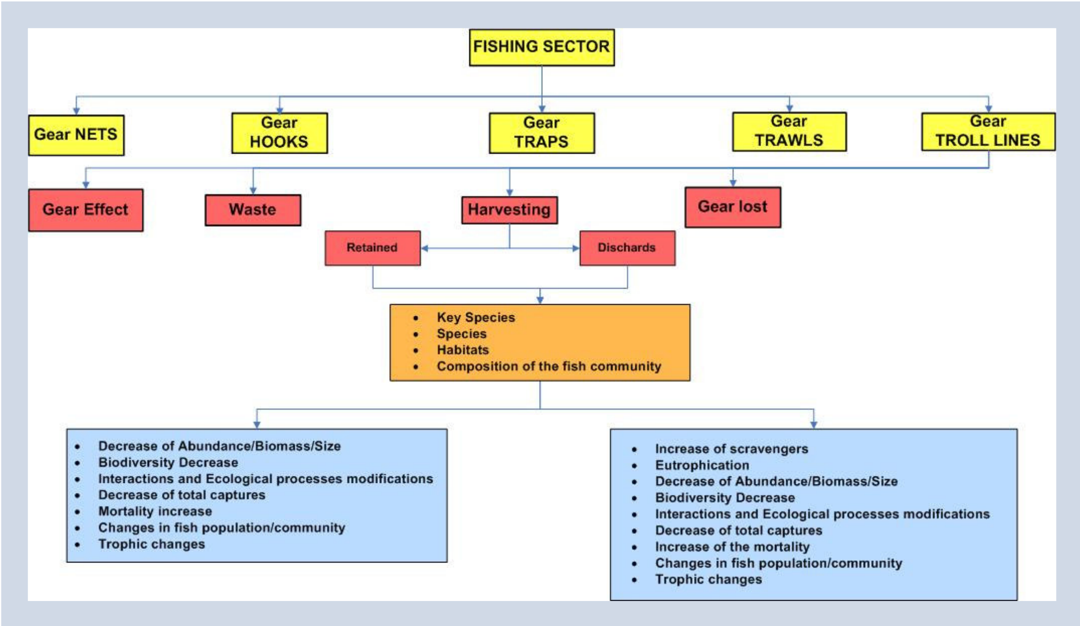


Figure 5.3. Harvesting pressures.

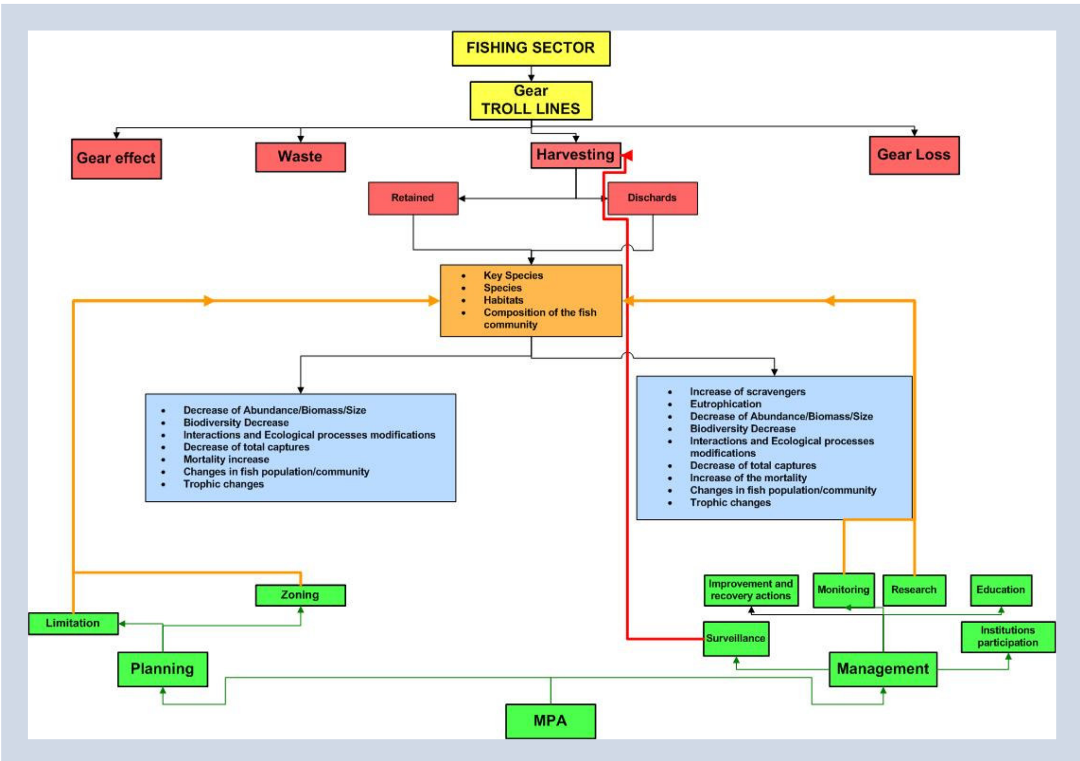
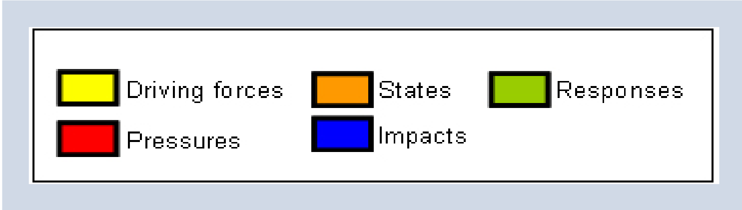


Figure 5.4. Harvesting responses.

B- TOURISM SECTOR



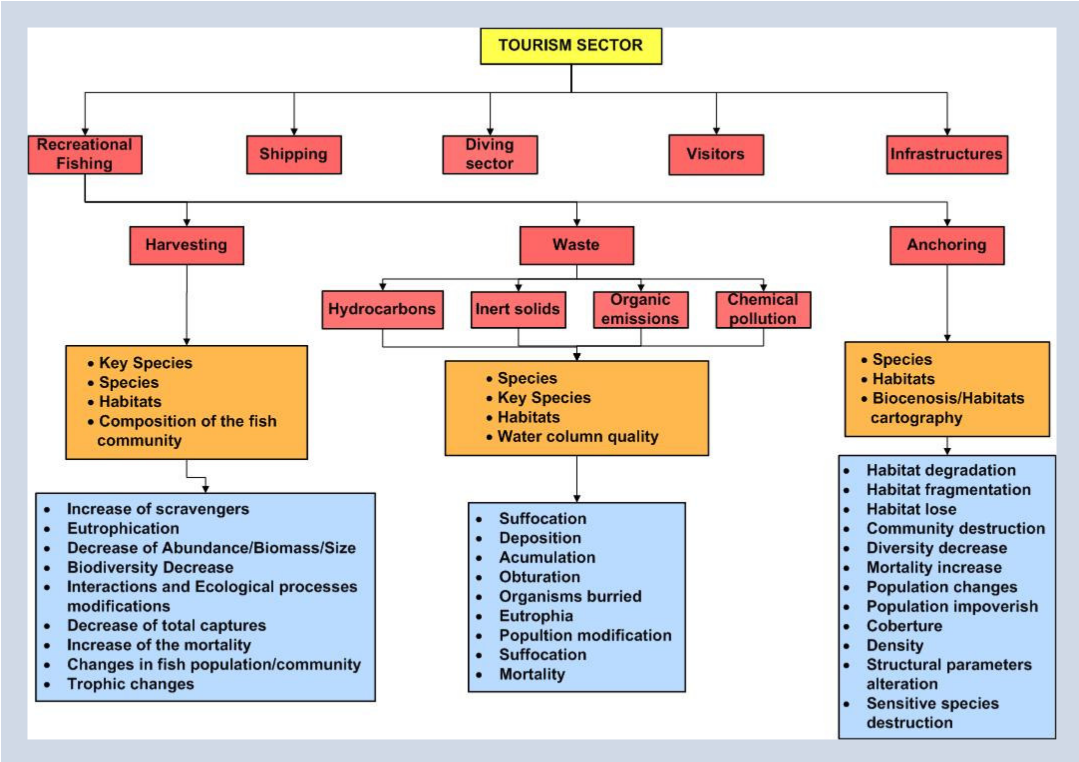


Figure 6.1. Recreational fishing pressures.

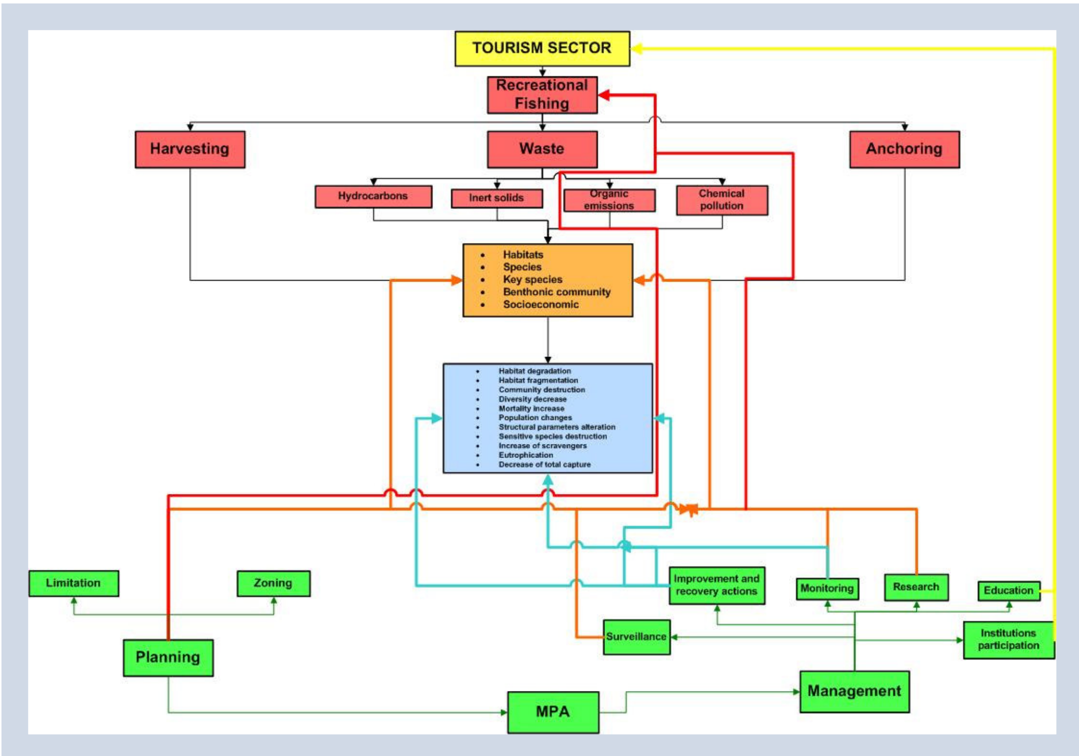


Figure 6.2. Recreational fishing responses.

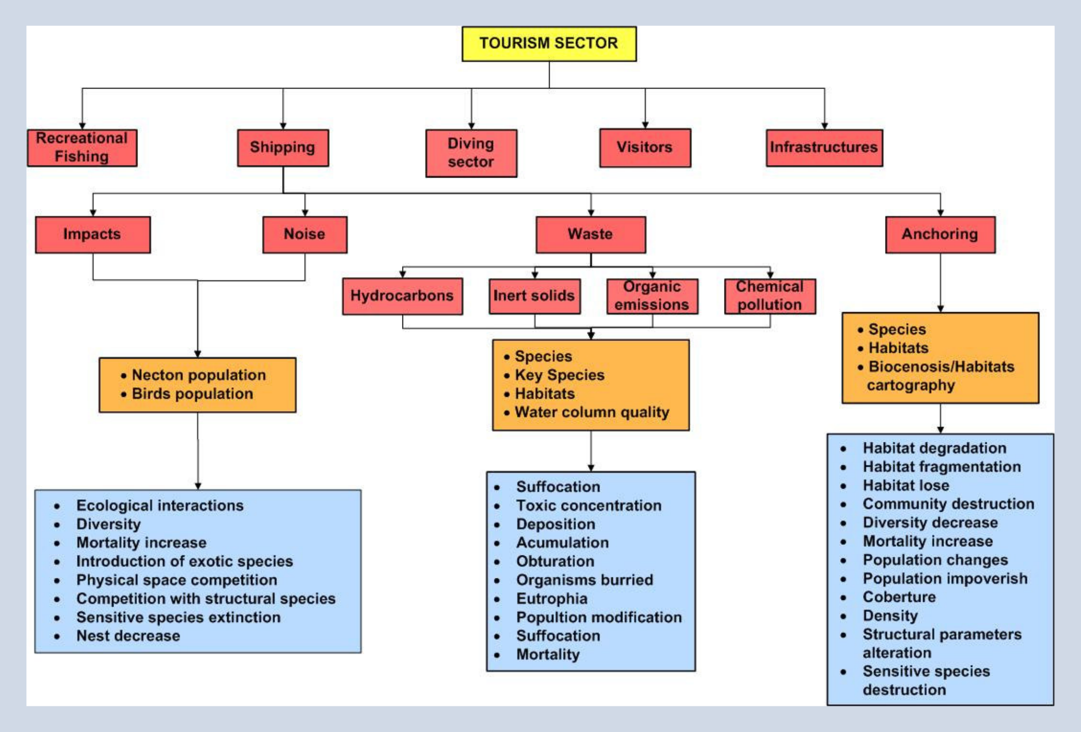


Figure 6.3. Shipping pressures.

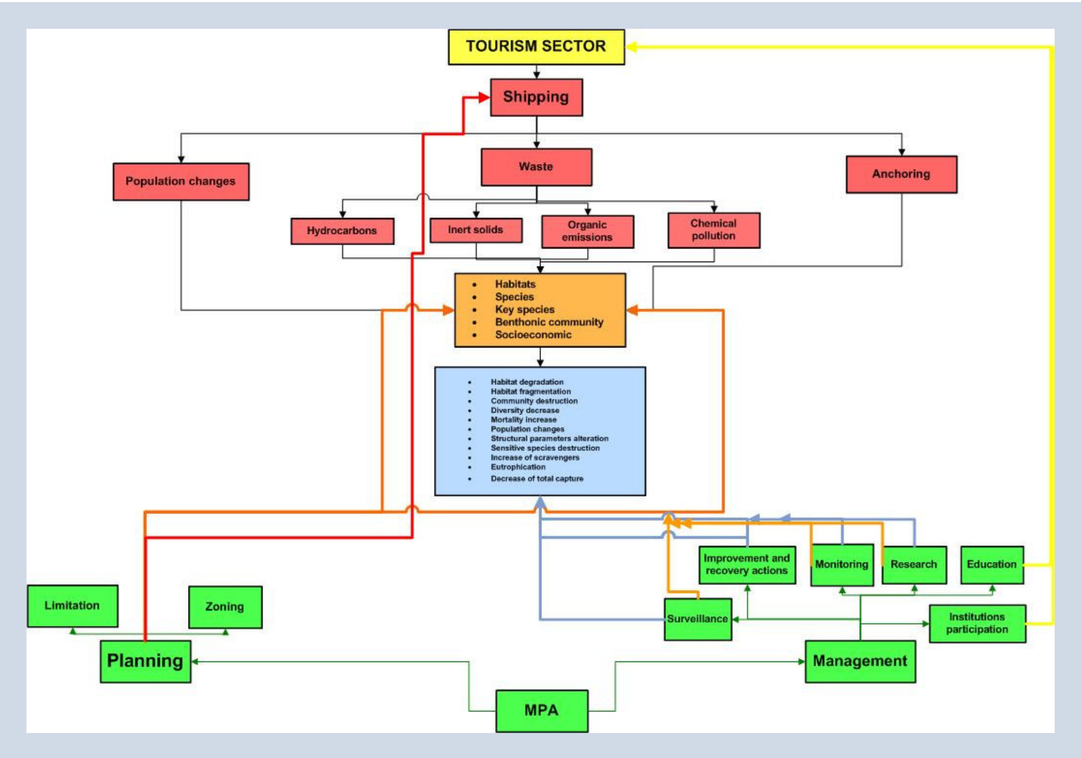


Figure 6.4. Shipping responses.

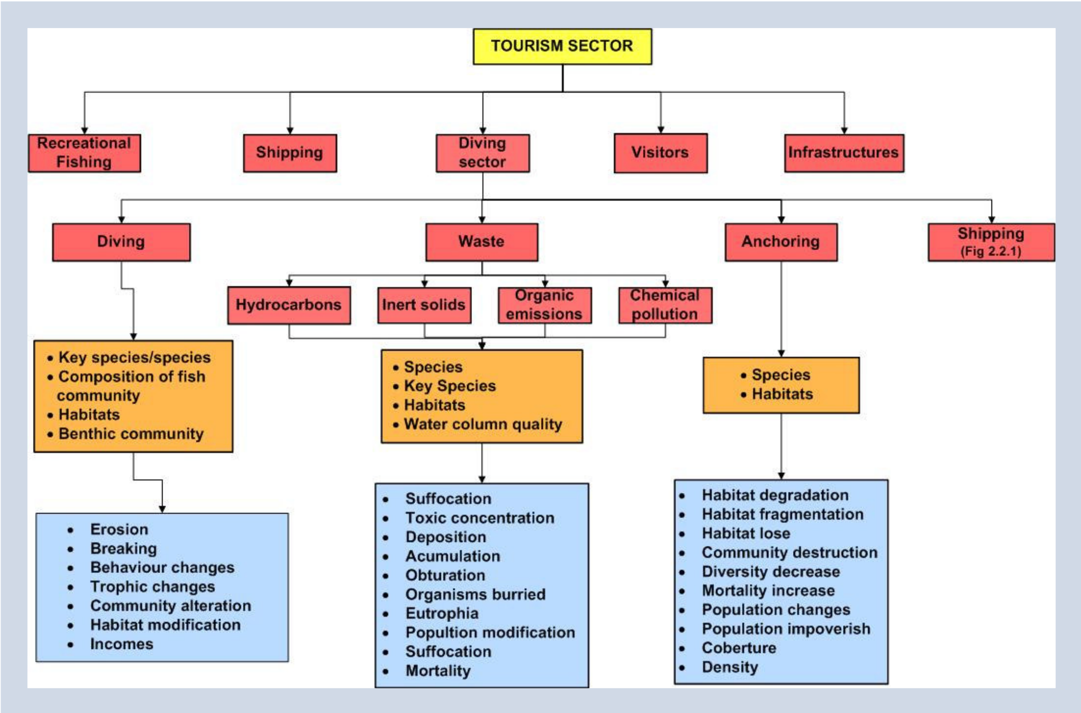


Figure 6.5. Diving pressures.[check figure layout]

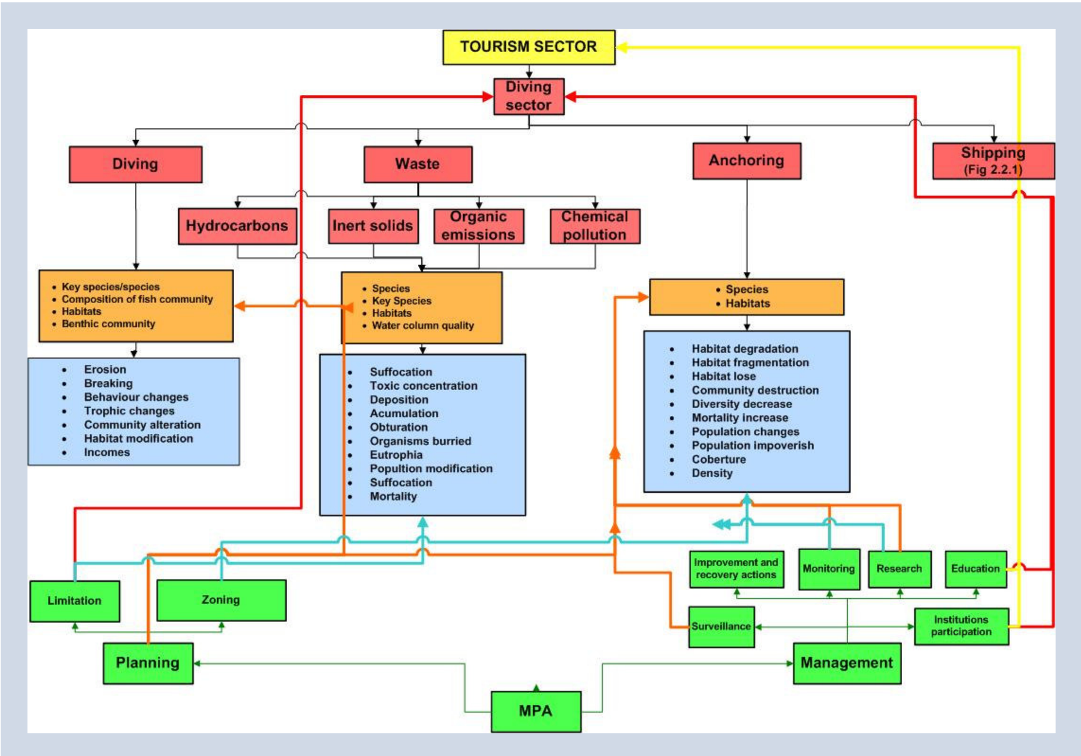


Figure 6.6. Diving responses.

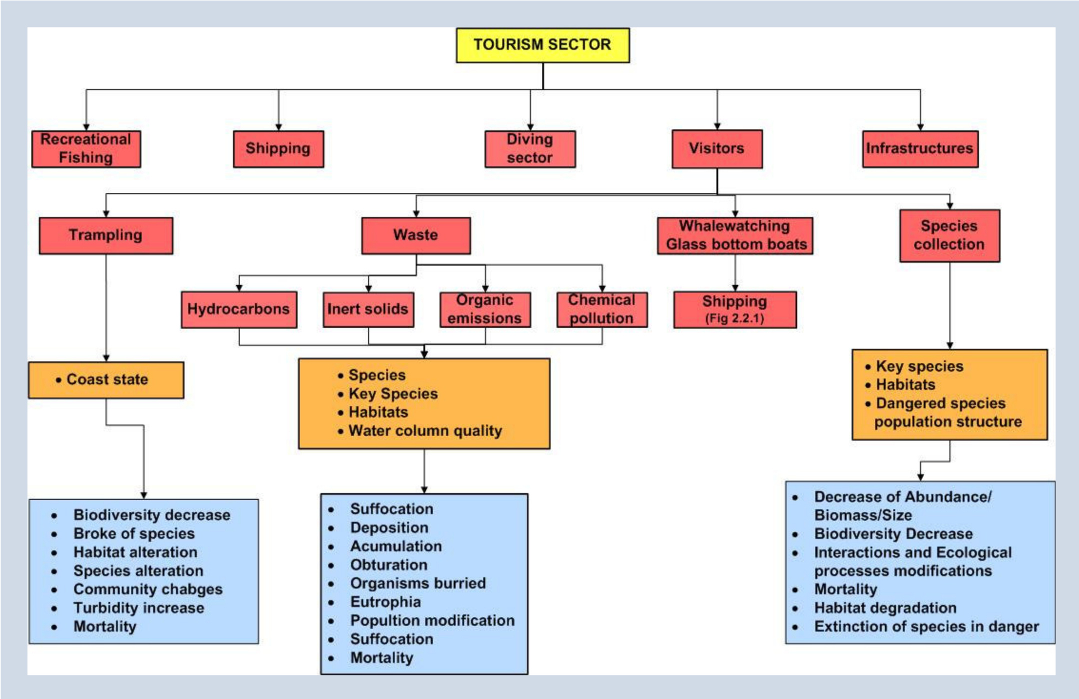


Figure 6.7. Visitor pressures.

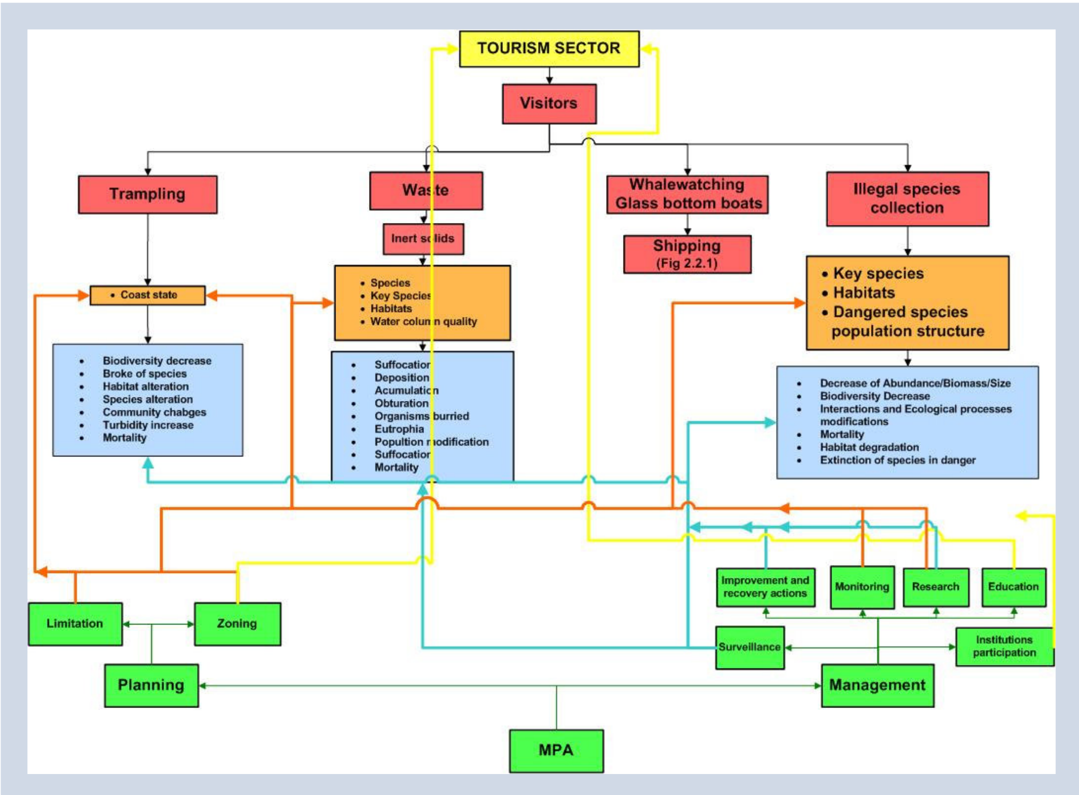


Figure 6.8. Visitor responses.

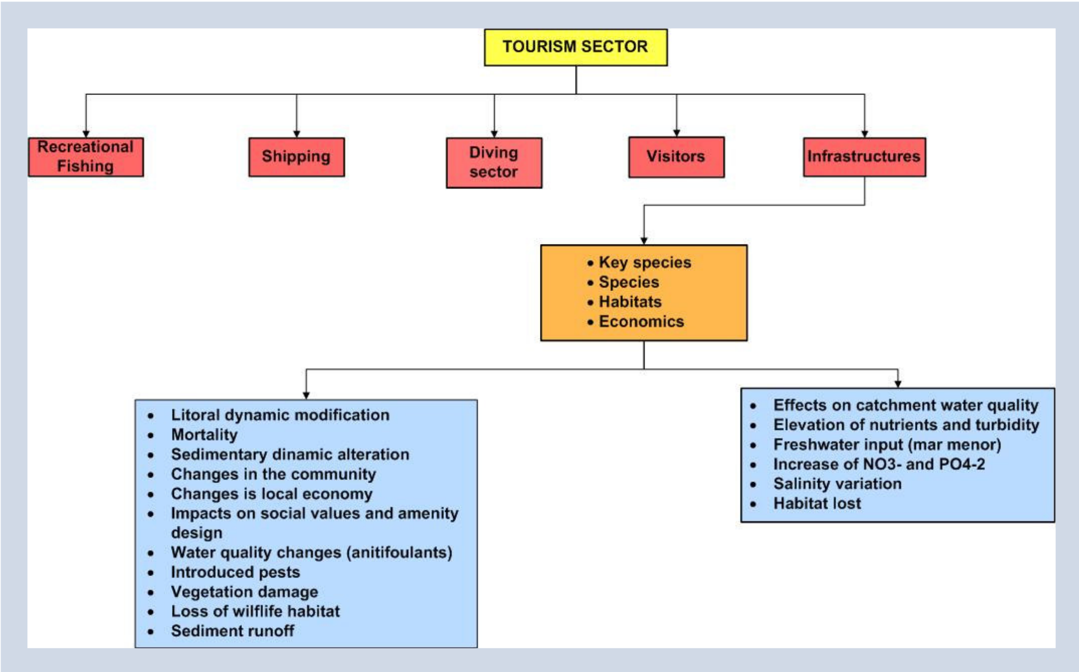


Figure 6.9. Infrastructure demand pressures.

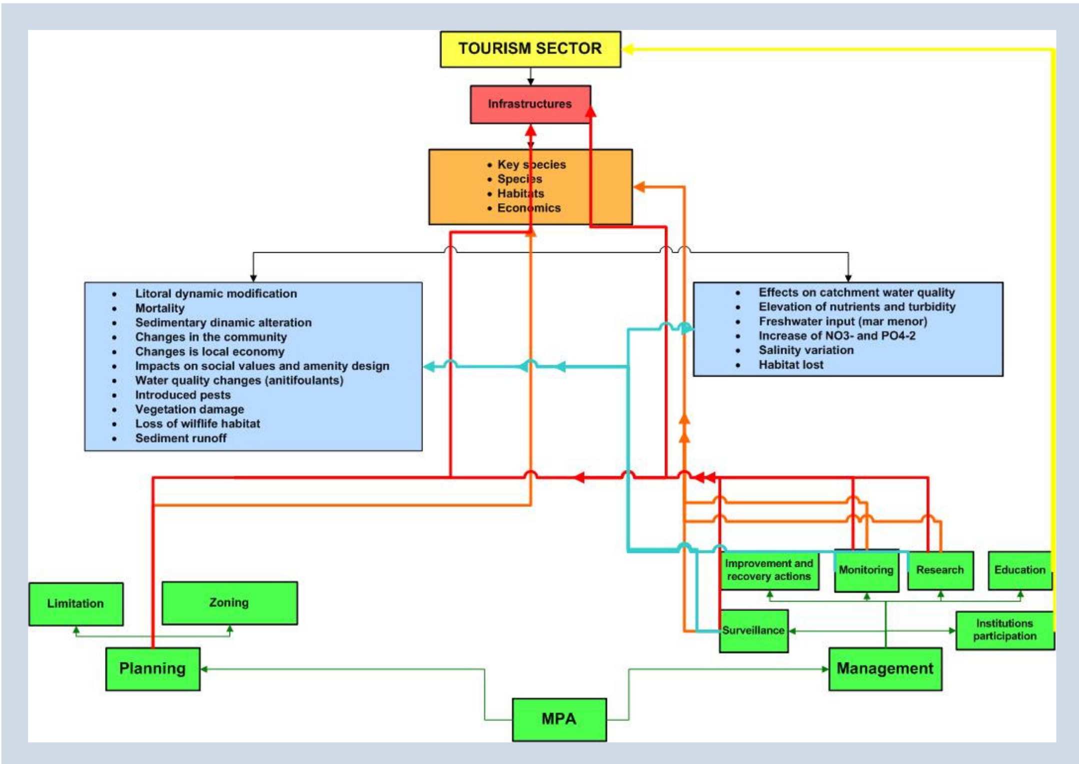
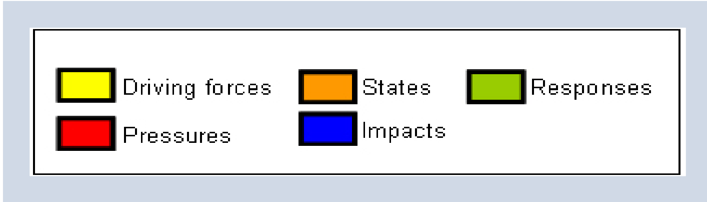


Figure 6.10. Infrastructure demand responses



C- Summarized whole diagram

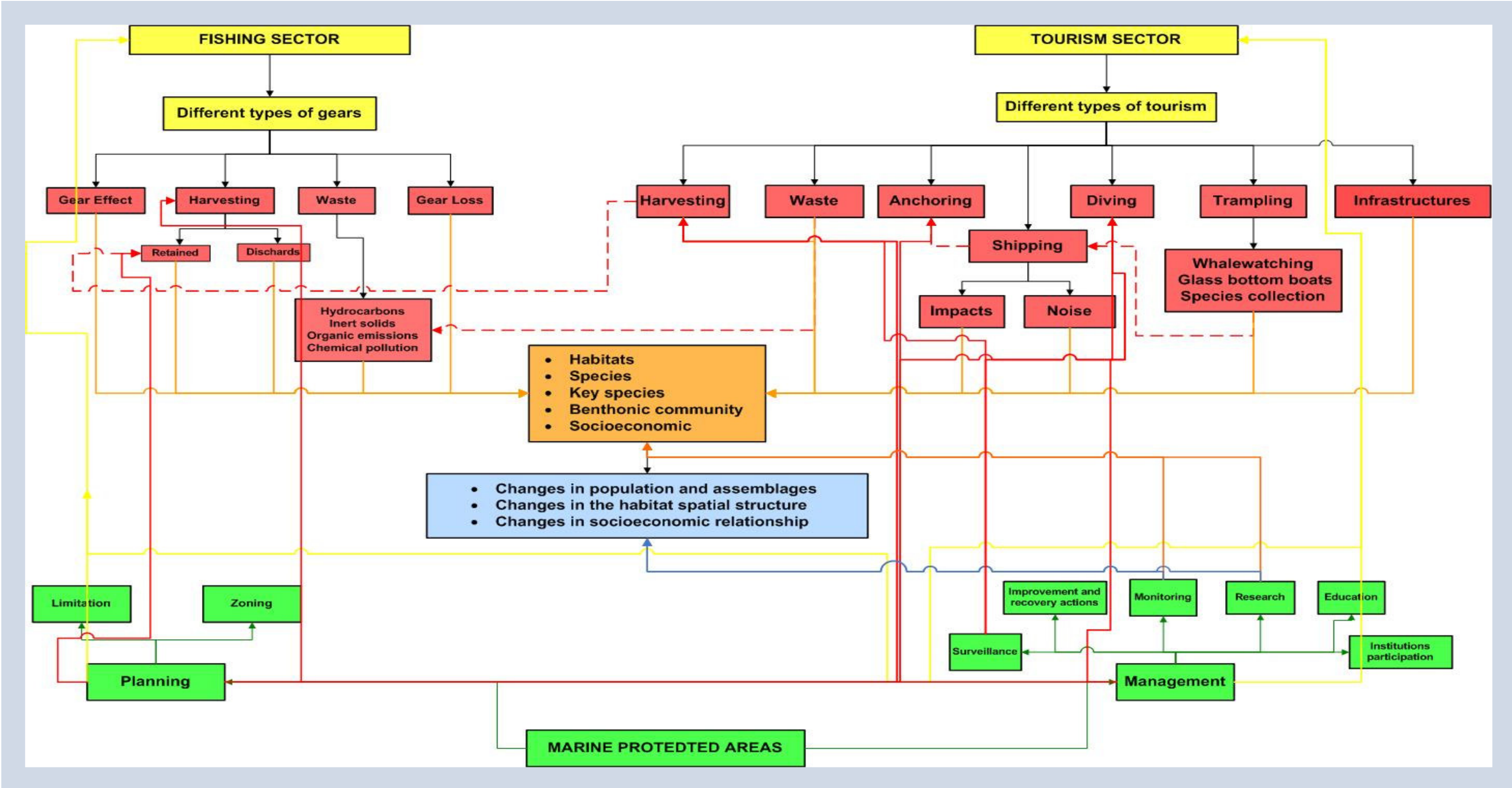


Figure 7. Summary of the whole conceptual model.