STAGES
CONNECTING SCIENCE TO POLICY FOR HEALTHY SEAS

# SCIENCE POLICY BRIEF

## Future research needs to implement the MSFD

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# SCIENCE POLICY BRIEF: FUTURE RESEARCH NEEDS TO IMPLEMENT THE MSFD

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# STAGES PROJECT SUMMARY

STAGES is a Coordination and Support Action, which received funding from the European Union under the Seventh Framework Programme of Cooperation (FP7; Food, Agriculture and Fisheries). The partnership combined European/International organisations which represent a broad constituency of the Marine Strategy Framework Directive (MSFD) stakeholders, and national organisations with responsibility to support research and provide advice on the MSFD at Member State level.

The MSFD is designed to deliver "Good Environmental Status" (GES) in EU marine waters by 2020. This Directive requires that Member States with marine territories put in place measures to achieve and maintain GES within a defined timeframe and according to eleven key descriptors of environmental status. However, there is a significant knowledge deficit which may hinder full implementation of the MSFD and the achievement of GES in EU waters. The STAGES project was designed to directly address this knowledge deficit.

The STAGES project aimed to connect science to policy to help achieve GES in marine waters. To achieve this objective, the project worked towards bridging the MSFD science-policy gap and improving the availability of scientific knowledge to allow Member States to achieve GES. This involved:

- Identifying, extracting and synthesising the knowledge generated through EU and national research funded activities relating to the MSFD, and making this information widely accessible to policy makers and MSFD stakeholders.
- Providing pragmatic and ready-to-use recommendations to establish an effective European science-policy platform to support GES research and implementation of the MSFD.
- Establishing where further research needs to be conducted to improve the scientific knowledge underpinning implementation of the MSFD.

# KEY OUTPUTS OF THE STAGES PROJECT

The primary outputs of the STAGES project are focused around the main objectives and ambitions of the project and were distributed across WP2, WP3 and WP4 as follows:

**Work Package 2 "Identify, Extract, Analyse and Synthesize the Knowledge"** was designed to gather relevant knowledge from marine environment research at EU and national level, and ensure it was made readily available for use by policy makers and the wider MSFD stakeholder community. This process of identification, collection, analysis and synthesis of research projects and associated knowledge relevant to the MSFD and its implementation was the foundation of the STAGES project. Project information and knowledge captured through the STAGES survey has informed the development of four distinct but complimentary products:

- Upgraded Marine Knowledge Gate
- STAGES Thematic State of the Art reports
- STAGES MSFD Research Visualisation Tool
- STAGES Wiki

As well as these products, three relevant and distinct reports were generated from the effort and results of this Work Package, namely:

- Harnessing MSFD-related research: An overview of potentially relevant European and national research by the STAGES project
- Research Harnessing Recommendations: A way to enhance access to European and national public funded research with relevance for MSFD implementation
- Harnessing MSFD-related research: An insight into country participation in potentially relevant European and national research by the STAGES project

**Work Package 3 "Knowledge Gaps Assessment & Foresight"** enabled a consultative process with a broad range of marine stakeholders to produce an in-depth analysis of research needs for achieving GES across the EU. The results of this process are contained within the following reports:

- Science Policy Brief: Future Research Needs To Implement the MSFD
- Workshop report on "The identification of research needs with regard to the implementation of Monitoring programmes", 13-15 May, 2013, Brussels.
- Workshop report on "The identification of research needs with regard to the Pressures and their Impact on Marine Ecosystems", 4-5 September, 2013, Rome.
- Workshop report on "The identification of research needs with regard to the socio-economic analysis under the Marine Strategy Framework Directive", 9-11 October, 2013, Ispra.

**Work Package 4 "Building A Science-Policy Interface To Support MSFD Implementation"** investigated stakeholder needs and optimum modalities to facilitate the access of policy makers charged with implementing the MSFD to relevant and up-to-date scientific advice. WP4 examined best practice in the development and operation of an effective science-policy interface, relevant to complex environmental/ marine policies and produced the following key outputs:

- Science Policy Brief: Future research needs to implement the MSFD
- Proposal and Recommendations for a Science-Policy Interface (SPI) to support the MSFD

All of the STAGES key outputs can be found on the STAGES website (www.stagesproject.eu) and can be requested from the project coordinator, Marisa Fernandez (mfernandez@cetmar.es) or the Dissemination manager in AquaTT (stages@aquatt.ie).

# INTRODUCTION



This document outlines the results of a broad stakeholder consultation process carried out by the STAGES project to identify the needs for further research to improve the scientific underpinning for the implementation of the MSFD, i.e. to improve the scientific answers to the following key questions:

- What are the key pressures on marine environments?
- What are the impacts on marine ecosystems and services resulting from these pressures?
- Where are the main accumulations of impacts and major needs for response identified?
- How should the interactions between ecosystems and socio-economic activities be addressed?

For the sake of simplicity and in agreement with EC DG ENV, MSFD Themes within STAGES are groupings of GES Descriptors as follows:

| | **Theme name** | **GES Descriptors** |
|---|---|---|
| 1 | Biodiversity | Biological Diversity |
| | | Non-Indigenous Species |
| | | Food Webs |
| | | Sea-Floor Integrity |
| 2 | Commercially exploited fish | Commercial Fish |
| 3 | Contaminants & Nutrients | Eutrophication |
| | | Contaminants in Fish and other Seafood |
| | | Contaminants and Pollution Effects |
| 4 | Hydrographical conditions | Hydrographical Conditions |
| 5 | Disturbances | Marine Litter |
| | | Underwater Noise/Energy |

These thematic groupings are represented in the State of the Art reviews generated by the STAGES project, as outlined previously.

Three workshops were convened in order to: i) share state-of-the-art knowledge on pressure-impact relations and on accumulation of impacts; and ii) identify knowledge gaps and uncertainties which presently make the design of efficient and well accepted pressure control measures for progress towards GES impossible. Taking into account regional considerations, anthropogenic impacts and drivers will be identified and analysed in light of natural drivers affecting changes in ecosystems.

The workshop participants included a selection of independent experts, drawn from the four marine regions (the Baltic Sea, the northeast Atlantic, the Mediterranean Sea and the Black Sea) and a broad range of relevant scientific expertise.

The three workshops organised and facilitated by the STAGES project are as follows:

1. The identification of research needs with regard to the implementation of Monitoring Programmes, 13-15 May, 2013, Brussels.

2. The identification of research needs with regard to the Pressures and their Impact on Marine Ecosystems, 4-5 September, 2013, Rome.

3. The identification of research needs with regard to the socio-economic analysis under the Marine Strategy Framework Directive, 9-11 October, 2013, Ispra.

The aim of the workshops was to highlight where specific knowledge gaps occur for the five Thematic Groups - Biodiversity, Contaminants & Nutrients, Disturbances, Commercially Exploited Fish, and Hydrographical Conditions. Results from the workshops are presented thematically, highlighting where specific knowledge gaps occur and providing short-term, medium-term and long-term recommendations for further research which can inform future research programmes, as well as managers and decision makers.

The workshops resulted in this synthesis of knowledge gaps and related (and updated) recommendations and priorities for further research.

The three workshop reports can be downloaded from the STAGES website.

# UNDERSTANDING THE EXISTING SCIENTIFIC KNOWLEDGE BASE FOR MSFD

STAGES surveyed marine public research with EU and national funding across Europe so as to develop an inventory of MSFD-relevant projects and results, which are now hosted in the Marine Knowledge Gate - a major open access online repository of marine research in Europe upgraded through the STAGES project. This inventory provides the most extensive look into MSFD related research to date, which may continue to evolve and develop past the lifetime of the STAGES project.

A non-comprehensive statistical overview of MSFD-related research in Europe, based on the STAGES inventory was developed, as well a set of recommendations to overcome major barriers found.

Throughout this study conducted by EurOcean, all figures represent only the information provided to the STAGES survey and therefore cannot be regarded as a complete overview of the work being carried out in any of the regions covered.

This study compared MSFD-related research relevant to existing GES Descriptors also grouped into MSFD Themes (see annex 1) among Marine Regions, as identified by the STAGES survey. It showed there was a similar proportion of research across GES Descriptors in the northeast Atlantic Ocean and Mediterranean Sea, which was always significantly higher than in the Baltic Sea and the Black Sea, except for GES Descriptor 5 in Eutrophication, where the proportion of research dealing with the Baltic is higher than in the Mediterranean.

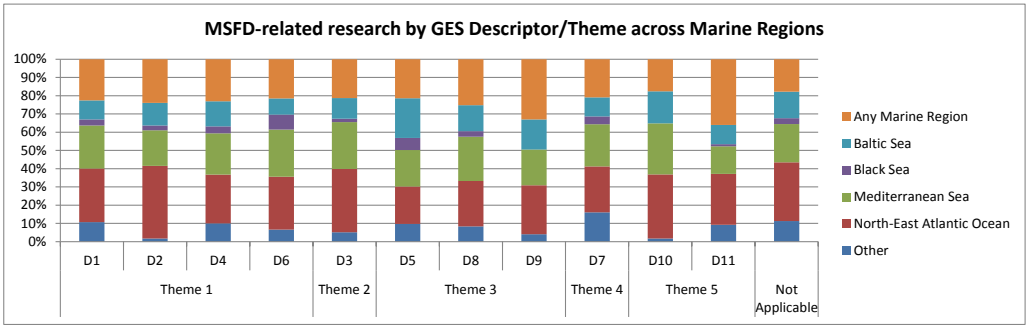



*Figure 1.Distribution of GES Descriptors/MSFD Themes across Marine Regions*

Theme 1 in Biodiversity (D1, D2, D4, D6) appeared to dominate across Marine Regions, followed closely by Theme 3 in Contaminants & Nutrients (D5, D8, D9). Theme 5 in Disturbances (D10, D11) appeared in the lowest proportion across Marine Regions, especially in the Black Sea.

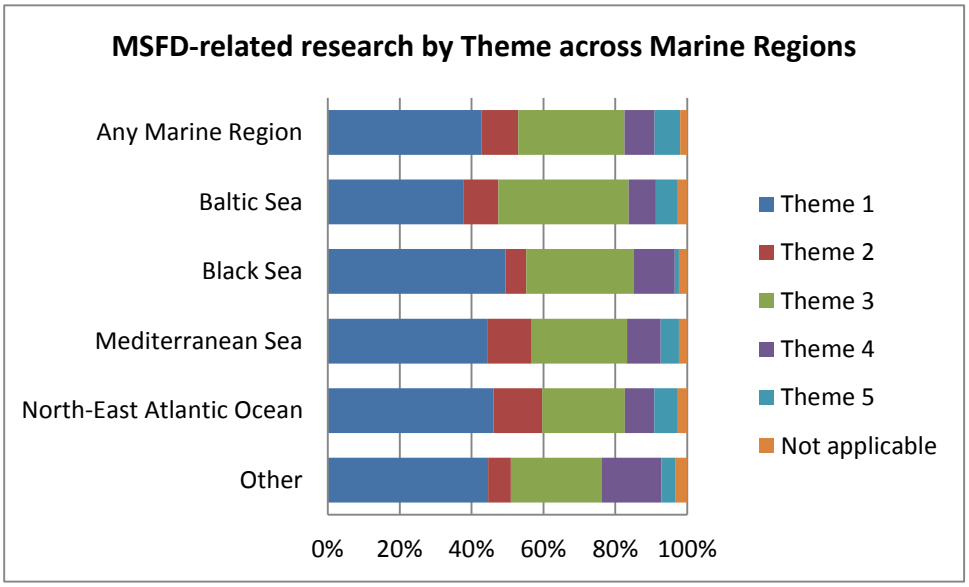



*Figure 2.Distribution of MSFD Themes across Marine Region*

# BIODIVERSITY

DEFINITION

*"Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions."*

- *"Maintained"* equates to:
  - no further loss of the diversity within species, between species and of habitats/communities and ecosystems at ecologically relevant scales,
  - any deteriorated attributes of biological diversity are restored to and maintained at or above target levels,
  - where intrinsic conditions allow, and where the use of the marine environment is sustainable.
- Habitats and species are key attributes of biological diversity; the term *"habitats"* in the descriptor is interpreted as including their associated communitiesof species.

The ICES/JRC task-group report on biological diversity defined this term as *"the variability among living organisms from all sources including, inter alia, [terrestrial,] marine [, and other aquatic ecosystems,] and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems."*

## RESEARCH NEEDS IDENTIFIED

The overriding purpose of research needs under D1 is to operationalise the MSFD indicator of GES on biological diversity, including considerations of appropriate scales for management. There is a need to make the structural indicators of biodiversity operational, with emphasis on the need to develop new methods to support species distribution and abundance. Recognising the benefits of Integrated Monitoring Networks, similar to those

DESCRIPTOR 1

provided by EuroGOOS (http://eurogoos.eu), will have direct benefits for the effective interpretation of multiple datasets between Member States in regional seas.

Knowledge gaps focus on the lack of basic understanding of "responsiveness" of the biological indicators and the little knowledge on nano- and microbiology. Processes and functional relationships in the marine environment need to be improved, taking into account differences in temporal and spatial scales, as well as information on the causes of long-term changes.

## GENERAL RESEARCH NEEDS

- Develop and validate operational habitat definitions.
- Develop and validate ecologically relevant thresholds between levels of conservation status, taking account of natural variability, structure and function, and species abundance and distribution.
- Develop projects and studies on benthic and pelagic habitats, their identification, mapping, and urgently needed analysis of their structure and functioning.
- Develop and apply new technologies for rapid biodiversity discovery, especially environmental genomics and other omics technologies, for improved understanding of functional biodiversity.

## RESEARCH NEEDS FOR THE PRESSURES AND THEIR IMPACTS ON THE MARINE ECOSYSTEM

- Develop methods for integrating long-term monitoring studies that account for pressures on biodiversity and integrate these into regional sea marine observation systems.
- Develop methods for considering synergistic, cumulative, and antagonistic effects of human pressures on biodiversity.
- Develop methods to account for long-term consequences of human pressures on marine ecosystems, especially considering climate change, and the implications of ocean acidification on ecosystems.

## RESEARCH NEEDS FOR THE IMPLEMENTATION OF THE MONITORING PROGRAMME

### Short-term

- Automatic analysis methods for plankton samples, to carry out an objective analysis (not influenced by expertise in taxonomic identification) of certain plankton attributes, such as size structure and taxonomic composition.

### Medium-term or requiring moderate investments

- Innovative monitoring tools to provide real-time information such as, e.g., remote sensing for plankton composition, use of ferry boxes, ROV (Remotely-Operated Vehicles), acoustic, and molecular approaches.
- For routine implementation, molecular-based methods for population and species diversity assessment should be developed.
- Studies on population genetics (DNA barcoding/Metagenetics, Short Nucleotide Polymorphisms)

### Long-term research or large investments

- Development of 'business models' for upscaling and operationalisation of biodiversity monitoring.
- Anticipating the development of technologies for next-generation sequencing.

# NON-INDIGENOUS SPECIES (NIS)

## DEFINITION

*"Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems."*

- *"Invasive alien species"* (IAS) are a subset of established NIS which have spread, are spreading or have demonstrated their potential to spread elsewhere, and have an adverse effect on biological diversity, ecosystem functioning, socio-economic values and/or human health in invaded regions. Species of unknown origin which cannot be ascribed as being native or alien are termed cryptogenic species. They also may demonstrate invasive characteristics and should be included in IAS assessments.
- *"... levels that do not adversely alter the ecosystems"* is described as the absence or minimal level of *"biological pollution"*. The latter is defined as the impact of IAS at a level that disturbs environmental quality by effects on: an individual, a population, a community, a habitat or an ecosystem. The biological and ecological effects of bio-pollution may also cause adverse economic consequences.

The ICES/JRC task-group report on NIS defined this term as species, subspecies or lower taxa introduced outside of their natural range (past or present) and outside of their natural dispersal potential. Their presence in a given region is due to intentional or unintentional introduction resulting from human activities. Natural shifts in distribution ranges (e.g. due to climate change or dispersal by ocean currents) do not qualify a species as a NIS.

# RESEARCH NEEDS IDENTIFIED

## GENERAL RESEARCH NEEDS

- The distribution of marine non-indigenous species in relation to environment for many areas, bottom types and organism groups
- The range of natural variability in spatial and temporal distribution and abundance of most species and communities.

## RESEARCH NEEDS FOR THE PRESSURES AND THEIR IMPACTS ON THE MARINE ECOSYSTEM

- Development of risk-based criteria to highlight key pathways of NIS introduction, hot spot areas and secondary spread in order to assess effectiveness of management measures.
- Development of methods to measure the magnitude of bio-invasion impacts on the marine ecosystem and ecosystem services, including considerations for threshold reference points.
- The role of NIS in assessments of GES by modifying the performance of existing indicators, such as those describing benthic quality.

## RESEARCH NEEDS FOR THE IMPLEMENTATION OF THE MONITORING PROGRAMME

### Short-term

- Development of tools to achieve faster and more accurate identification of habitat/biotopes present in different marine environments (from shallow to deep sea, soft to hard bottom).

### Medium-term or requiring moderate investments

- Studies on the changes in the functioning of marine ecosystems subjected to an impact of invasive alien species.
- Molecular-based methods for routine implementation of NIS identification.

### Long-term research or large investments

- Relevant hydrodynamic models for understanding the processes of natural dispersion.
- Studies on mechanisms of this natural dispersion of each invasive species.

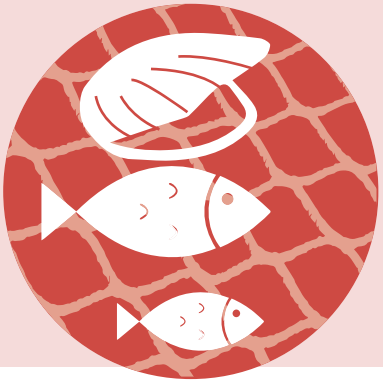
# COMMERCIALLY EXPLOITED FISH AND SHELLFISH POPULATION

## DEFINITION

*"Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock."*

- *"Commercially exploited populations"* applies to all living marine resources targeted for economic profit. Fish and shellfish represent all marine vertebrate and invertebrate taxa including bone-fish, elasmobranches, starfish, crayfish, bivalves, molluscs (including cuttlefish, squid) and jellyfish.
- *"...within safe biological limits..."* means that a stock should be (1) exploited sustainably consistent with high long-term yields and (2) have full reproductive capacity; those two attributes are used to assess the stocks.
- *"...exhibiting a population age and size distribution that is indicative of a healthy stock":* The general consensus is that the health of the stock increases as the age and size distribution consists of a greater number of older fish.

The ICES approach to fisheries advice integrates a precautionary approach, maximum sustainable yield (MSY), and an ecosystem approach into one advisory framework. Fisheries affect fish stocks through the fishing mortality rate (F) that is applied to different sizes of fish (selectivity). Production of a fish stock is the sum of the population weight (biomass) augmented by recruitment and growth minus the loss from natural mortality. Production can be highly variable but, on average, it is related to stock size (often expressed as spawning-stock biomass (SSB)), which in turn depends on F. The relationship between F, production, and stock size is called the production function. Surplus production is the catch that can be harvested without changing the stock size. The peak of the production function is MSY, and the fishing mortality generating this peak is FMSY.



# RESEARCH NEEDS IDENTIFIED

## GENERAL RESEARCH NEEDS

Fishing can be considered as a major pressure in most European seas, meaning that D3 cannot be considered separately from the additional impacts of fishing pressure on GES. It is clear from the national initial assessments that little consideration has been given to determining GES with regards to locally managed shellfish or stocks for which data is limited. Whilst some bodies (STECF, ICES) are making progress on assessing finfish stocks with limited data, there are few national or international bodies determining methods for shellfish.

- Determining targets and reference points for data-limited fish stocks in relation to set descriptors (including more stock assessments) especially for shellfish.

## RESEARCH NEEDS FOR THE PRESSURES AND THEIR IMPACTS ON THE MARINE ECOSYSTEM

Effective fisheries management measures require information about the spatial distribution of fishing pressures and impacts. The experience of the EFIMAS and FIMPAS projects has shown that management measures need such knowledge to be effective. Impact of fishing pressure on other descriptors was a point raised in the questionnaires. The pressure managed through the Common Fisheries Policy (CFP) impacts widely across European seas. This needs to be accounted for throughout many of the other descriptors. The by-catch of protected, endangered or threatened species (PETS) was included due to social objectives to conserve those organisms.

- Modelling spatial pressures of fishing in relation to ecosystem sensitivities and the structure of stocks.
- The impact of fishery by-catches on PETS.
- Consequences for fisheries management of changes in exploited marine population distributions and productivity.
- Developing methods to quantify fishing pressure from small-scale and recreational fisheries, including the impact of discarded fishing gear.

## RESEARCH NEEDS FOR THE IMPLEMENTATION OF THE MONITORING PROGRAMME

One main problem could be that data refer to landings, not catches. Moreover, there is a lack of data for some stocks and primary or secondary indicators are only available for a few stocks. Reference points and targets consistent with spawning stock biomass required to produce MSY (SSBMSY) are lacking for stocks with only secondary indicators. The

number of species considered in the assessments is too small and the data on by-catches are either not available or are quite insufficient.

### Short-term

- Determining a method to select the scale of monitoring and response to the dynamics of fish populations for all exploited populations, dominant populations and dominant fisheries.
- Impact of discard bans on monitoring.
- Establishment of consistent reference points, as well as the development of additional indicators, related to mixed-fisheries characteristics for examples.
- Studies to obtain information on fishing mortality rates and biomass indices for fish populations for which there is little information, such as deep-sea fish. Shellfish are another group with scarce data.
- Assessment of transboundary monitoring needs to be clarified.
- Monitoring of the exploited invasive species, such as Manila clam, king crab, snow crab or Pacific oysters.
- Improving the collating of information on by-catches.

### Medium-term or requiring moderate investments

- Studies must be made on integrating criteria and indicators of biological disturbance from fishing, which are related to the level of fishing pressure, particularly ensuring fishing mortality (F) at or below the MSY, in complex situations such as mixed fisheries and cases of significant ecosystem interactions.
- An analysis should be undertaken to assess whether SSBMSY would be achieved simultaneously for all stocks, taking into account the interactions between them.
- More studies on the impacts of selectivity on stocks are needed.

### Long-term research or large investments

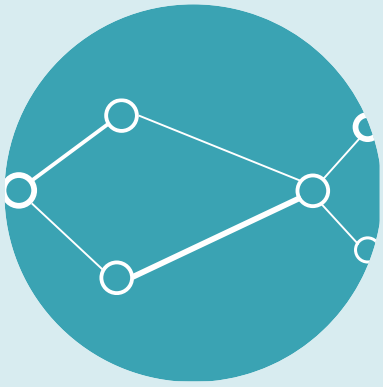
- New genomic methods should be developed (e.g. short nucleotide polymorphism (SNP)).
- One way to identify which populations should be surveyed and resources prioritised could be achieved by developing and adapting the “productivity and susceptibility” approach (PSA).

# MARINE FOOD WEBS

DEFINITION

*"All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity."*

- *"Food webs"* are networks of feeding interactions between consumers and their food. The species composition of food webs varies according to habitat and region, but the principles of energy transfer from sunlight and plants through successive trophic levels are the same. This descriptor addresses the functional aspects of marine food webs, especially the rates of energy transfer within the system and levels of productivity in key components.
- *"All elements"* is described as all components of food webs which have been considered, i.e. all trophic and functional groups, comprising either one or several species. This potentially includes all living organisms and non-living organic components.
- *"... to the extent that they are known":* While examination of food webs should in principle include "all elements", for practical purposes it would include only those food web components that can effectively be sampled by established robust methods of monitoring.
- *"... normal abundance and diversity and at levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity."* This provides guidance on the reference points and/or target values selected to correspond to good environmental status. Full reproductive capacity refers to the maintenance of fertility and avoidance of reduction in population genetic diversity.



DESCRIPTOR 4

## RESEARCH NEEDS IDENTIFIED

Research into food web ecology is complex and demanding, and there are many aspects of trophic interactions that require further study, so it is important that recommendations for research needs fill specific gaps related to MSFD implementation. The main knowledge gaps deal with the difficulty in obtaining the productivity of the top predators (such as sharks or marine mammals). It is also difficult to extend the valuation to the medium and lower trophic levels.

## GENERAL RESEARCH NEEDS:

- Develop practical methods to quantify the role of key components (fish, plankton) in food web interactions, in terms of both structure and function.
- Disentangling the effects of human activities from those of climate change in order to apply practical management measures.
- Emphasis on understanding the functions of key structural fauna.
- Understanding the effects of broader environmental conditions on food webs, e.g. those caused by nutrient loading in regional seas and climatic factors.
- Development of techniques to support the implementation of structural food web indicators and those describing productivity of key parts of the food web.

## RESEARCH NEEDS FOR THE PRESSURES AND THEIR IMPACTS ON THE MARINE ECOSYSTEM:

- Develop methods that discriminate between effects on food webs caused by pressures of human activities and those caused by change in system carrying capacity through climatic effects.
- Develop methods that describe consequences of coastal shelf seas biogeochemistry for plankton communities, especially nutrient fluxes, to inform the application of indicators of food web production ratios.
- Study of the consequences for food web structure and function of fishing all stocks at MSY and consider the impacts of changes in fishing selectivity.
- Develop methods to identify change in food web structure. These will be used to quantify fundamental threats and risk to ecosystem functioning and the provision of ecosystem services.

## RESEARCH NEEDS FOR THE IMPLEMENTATION OF THE MONITORING PROGRAMME

### Short-term

- Adapt the existing monitoring programmes to food web characteristics.
- Increase the study of energy flows: e.g. between benthic invertebrates and waterbirds, carbon remineralisation by the bacterioplankton, etc.
- Increase the study of marine predators feeding areas and feeding strategies.
- Develop/improve methods to measure or to estimate the productivity of key components.

### Medium-term or requiring moderate investments

- Develop indicators:
  - To describe communities from a structural point of view: e.g. the size spectrum, or the proportion of piscivores in the community.
  - That are integrative for trophic connections and energy fluxes: e.g. productivity of key parts of the food webs, carbon recycling indexes, Primary production required (PPR), sources or prey quality, etc.
- Improve models of food webs by incorporating new understanding from research in order to improve operationality.
- Use models to optimise monitoring programmes: genetic and isotopic based research to understand trophic position and relationships and to assess group-specific and community-specific indicators.

### Long-term research or large investments

- Technological development and miniaturisation of sensors are needed to increase the automatic data collection.

# EUTROPHICATION

## DEFINITION

*"Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algal blooms and oxygen deficiency in bottom waters."*

- *"Eutrophication"* is a process driven by enrichment of water by nutrients, especially compounds of nitrogen and/or phosphorus, leading to: increased growth, primary production and biomass of algae; changes in the balance of organisms; and water quality degradation. The consequences of eutrophication are undesirable if they appreciably degrade ecosystem health and/or the sustainable provision of goods and services.
- *"Oxygen deficiency"* can result from the sinking and decomposition of the excess organic matter produced as a result of eutrophication.
- *"Ecosystem degradation"* is understood as an undesirable disturbance to the structure, vigour in function, resistance to change and resilience in recovery of ecosystems, i.e. to ecosystem health.
- *"Harmful algal bloom"* (HAB) is a broad term that embraces many phenomena. Links between HABs and nutrient enrichment have been much debated. The Thematic Group noted that HABs should be treated as part of the undesirable consequences of eutrophication only if their frequency or amplitude increases in correspondence with increased nutrient input or with changes in nutrients ratios. capacity." This provides guidance on the reference points and/or target values selected to correspond to good environmental status. Full reproductive capacity refers to the maintenance of fertility and avoidance of reduction in population genetic diversity.

# RESEARCH NEEDS IDENTIFIED

## GENERAL RESEARCH NEEDS:

- Research on HABs: Identification of the role of mechanisms such as upwelling relaxation events, cyst formation, in HAB formation, and the extent to which these events are manageabe;
- Research value, resilience and recovery of marine ecosystems: This includes research exploring potential recovery pathways from eutrophic to non-eutrophic states.

## RESEARCH NEEDS FOR THE PRESSURES AND THEIR IMPACTS ON THE MARINE ECOSYSTEM

The gap which needs to be fulfilled deals with the relative role of pressures (including transboundary impacts), the links between pressure (e.g. atmospheric input) and state, including reversibility pathways and targets.

- Study of the natural background nutrient enrichment compared to human-related sources, through development/application of land-ocean models, taking into account point and diffuse sources, ocean boundaries, and atmospheric contributions.
- Study of the effects of nutrient loads and ratios, together with physical factors, on species composition, with emphasis on harmful algae, with the aim of broadening the range of eutrophication symptoms that can be successfully modelled and improving knowledge on reversibility, given the likelihood of baseline shifts and regime changes.
- Develop rapid methods for phytoplankton species identification, origin, early detection, and prediction of HABs, e.g. by improved remote sensing and by molecular methods.

## RESEARCH NEEDS FOR THE IMPLEMENTATION OF THE MONITORING PROGRAMME

### Short-term

- Develop methods to include other characteristics in addition to Chlorophyll a, such as changes in community composition, occurrence of nuisance and toxic species that result from changes in nutrient ratios, and increased duration and frequency of blooms which result from increases in nutrient loads.
- Develop new phytoplankton assessment tools that account for shifts in species composition and frequency of blooms in the status assessment scoring.
- Support evolving monitoring strategies aimed at optimal integration of various monitoring tools.

### Medium-term or requiring moderate investments

- Develop regional algorithms that reduce the uncertainty in the calculation of satellite chlorophyll from global algorithms.

### Long-term research or large investments

- Develop algorithms for phytoplankton composition identification using remote sensing and satellite modelling.
- Develop metagenomics in species identification microarrays.
- Develop biological trait analysis for phytoplankton, species analysis, and analysis of harmful toxins.

# SEA FLOOR INTEGRITY

DEFINITION

*"Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected."*

- *"Sea Floor"* includes both the physical structure and biotic composition of the benthic community.
- *"Integrity"* includes the functioning characteristic of natural ecosystem processes and spatial connectivity. Serious problems of sampling and measurement and high scientific uncertainty about aspects of benthic ecology and tolerances of benthic ecosystems to perturbations pose challenges to the application of GES.
- *"Bioengineers"* are organisms that change the structure of the seafloor environment in ways not done by geophysical processes alone, by reworking the substrate or by providing structures that are used by other species. Bioengineers may serve functions such as: providing shelter from predation or substrate for other organisms, reworking of sediments, transporting interstitial pore water, and facilitating material exchange at the sediment-water interface.

# RESEARCH NEEDS IDENTIFIED

## GENERAL RESEARCH NEEDS

The lack of open access to data describing the location of human activities, especially the Vessel Monitoring System data describing the location of European fleets, limits the progress that can be made with pressure-based descriptors. Understanding characteristics of the benthic community is central to implementing D6, and the practicality of generating detailed maps, while limiting the economic cost of doing so, highlights the importance of using combined modelling approaches, appropriately ground-truthed with physical and biological data. Such benthic models are expected to have wider applicability to the MSFD, particularly for other biodiversity descriptors in D3.

## RESEARCH NEEDS FOR THE PRESSURES AND THEIR IMPACTS ON THE MARINE ECOSYSTEM

- Develop methods to evaluate the risk of the spatial and temporal distribution of human activities (trawling, mining, renewable energy, etc.) on sensitive and vulnerable benthic habitats and species. This can only be undertaken with broader access to satellite location of international fleets.
- Integrate seafloor habitat sampling and biological/physical models, with appropriate ground-truthing, to allow Member State to identify areas under greatest risk as a priority for management.

## RESEARCH NEEDS FOR THE IMPLEMENTATION OF THE MONITORING PROGRAMME

### Short-term

- Define agreement on habitats description (EUNIS).
- Study relations between pressures and microbiology.

### Medium-term or requiring moderate investments

- Develop new devices and data transmission for the observation and study of deep sea habitats.

### Long-term research or important investments

- Integrate information from different sources and surveys.

# HYDROGRAPHICAL CONDITIONS

## DEFINITION

*"Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems".*

Large-scale human activities such as coastal defence works, damming of large rivers, land reclamation projects, and structures in coastal or open sea, such as wind farms, offshore airports, ocean energy device arrays and large scale aquaculture facilities may permanently influence the "hydrographical regime of currents", waves and sediments. Such changes to currents and waves can in turn induce further changes to sediment transportation, bed forms, salinity and temperature which might lead to further positive or negative impacts on fauna as a result of changes to their immediate dynamic environment or through food chain effects. Changes in currents and salinity can also influence the spreading pattern of larvae and breeding and spawning areas.

This descriptor is meant to address *"permanent alterations in hydrographical conditions".* Therefore, it is important to differentiate between permanent and temporary changes – potential for recovery, and the timescales involved need to be factored in. The Thematic Group recommendeds that constructions lasting for more than eight years should be considered to be permanent. In this context, the term *"permanent alteration"* must be explicitly defined to give Member states a common framework. The cumulative effects of the impact should be included when studying this descriptor.

# RESEARCH NEEDS IDENTIFIED

## GENERAL RESEARCH NEEDS:

Knowledge must be improved in defining permanent alteration of the state of hydrographic conditions or species and habitats due to pressure caused by major developments, especially where there are likely to be transboundary implications. This is needed to ensure consistency in assessing the spatial extent of hydrographical alterations of habitats and their functioning.

Studies on changes in currents can influence the migration of pelagic fauna and can change the salinity, in turn influencing both pelagic and benthic fauna.

## RESEARCH NEEDS FOR THE PRESSURES AND THEIR IMPACTS ON THE MARINE ECOSYSTEM

- Develop a relevant and harmonised definition of "permanent alteration" both in terms of hydrographic conditions and species and habitats to ensure consistency in assessing impacts of major projects.
- Models to predict alterations in hydrographical conditions are needed so as to ensure that thorough assessment of proposed major projects can be undertaken prior to their approval. This requires knowledge about the sensitivity of ecosystems and their functioning on a broad scale, as well as the identification of the parameters needed to model changes in hydrographical conditions (e.g. shear stress) on a similar scope.
- Define the parameters needed to model the bottom shear stress in such a way that the effect of hydrodynamic changes on benthic fauna can be predicted.
- Knowledge on benthic fauna populations' sensitivity to changes in the dynamic environment, focusing on the relationship between bottom-shear stress and benthic fauna.
- Define the parameters needed to model the long-term current changes in such a way that the effect of hydrodynamic changes on larvae and juvenile fish can be predicted.
- Knowledge focused on sensitivity of larvae, juvenile fish, pelagic fish and top predators to changes in direction of migration.
- Define the parameters needed to model salinity changes in such a way

that the effect on marine fauna can be predicted.

- Knowledge focused on marine fauna populations' sensitivity to changes of salinity.
- Define the parameters needed to model the change in temperature in such a way that the effect of temperature changes on marine fauna can be predicted.
- Knowledge focused on marine fauna populations' sensitivity to changes of temperature.

## RESEARCH NEEDS FOR THE IMPLEMENTATION OF THE MONITORING PROGRAMME:

### Short-term

- Studies are required to develop monitoring methods using remote-sensing satellite techniques, high frequency radar systems, and supports for instrumentation such as tide gauge, oceanographic cruises, uplooking Acoustic Doppler current profiler (ADCP), mooring systems, ships of opportunity, gliders and floats.
- Connection between monitoring and modelling needs to be improved.

### Medium-term or requiring moderate investments

- Adapt available methodologies to offshore conditions.
- Determine targets and limits.

### Long-term research or large investments

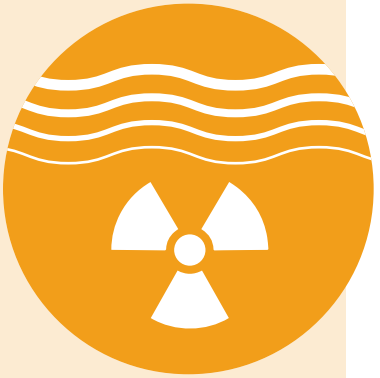
- Develop operating models to characterise the hydrographical conditions on short scales and infer if these can be affected by infrastructure development.
- Develop cumulative effects assessment methodologies for geomorphologically complex situations.
- Study regional scale modelling.
- Develop models of possible anthropogenic activities.

# CONTAMINANTS IN MARINE ENVIRONMENT

DEFINITION

*"Concentrations of contaminants are at levels not giving rise to pollution effects."*

The pressures considered are inputs of contaminants into the marine environment. These derive mainly from land-based sources via rivers and coastal run-off and/or from atmospheric sources. Contaminant inputs can also result from anthropogenic activities in the sea, which cause continuous and/or accidental release of contaminants. The Thematic Group proposed that the pressures exerted through the input of contaminants can be quantified as loadings expressed in pollutant weight per time transferred into the marine environment. For environmental management purposes, the control of loads and thus pressures can be a useful tool to determine whether measures are having an effect.



## RESEARCH NEEDS IDENTIFIED

### GENERAL RESEARCH NEEDS

Current knowledge of pollution effects in marine biota at various levels of ecological organisation is insufficient. For MSFD GES assessments, there is a need to determine threshold levels associated to biological responses, taking into account natural processes and the ecological structure and functioning of the ecosystem (e.g. food web transfer).

Moreover, knowledge about pollution pressures on the wider marine environment (deep/open sea) and a more systemic source-to-sink perspective remain insufficient. They are needed in order to obtain better information on total sources of hazardous substances of interest and on total loads via water and the atmosphere to the marine environment.

## RESEARCH NEEDS ON THE PRESSURES AND THEIR IMPACTS OF MARINE ECOSYSTEM

- Determination of thresholds/target/assessment levels for GES and biological effects/responses evaluation:
  - Transfer of contaminants through marine food webs and their effects at different trophic levels (taking into account bio-accumulation/bio-magnification/bio-transformation/natural ecological processes).
  - Development of methodologies and techniques for biological effects assessment including contaminant mixture actions and effects on genetic variability of populations.
  - Assessment of anthropogenic pressure: determination of regional specific background concentrations derived taking into account the geochemical and oceanographic variability between regions; also allowing assessment of pollution trends and setting environmental indicators.
- Assessment of pollution pressures on wider marine environment scales:
  - Development of baseline studies on fate and effects of pollution in deep and open European seas.
  - Assessments of large-scale fluxes of priority hazardous substances from the WFD: at sub-regional, oceanic basin-wide scales and at air-sea and water-sediment interfaces.
  - Development of cost-effective new strategies and techniques for pollutant monitoring at wider marine environment scales.

## RESEARCH NEEDS FOR THE IMPLEMENTATION OF THE MONITORING PROGRAMME

Monitoring coverage of open sea and deep-sea environments is generally less dense than in the coastal environment. Coverage varies between the different marine regions. In these environments, technical advice is lacking for offshore monitoring including sampling and analytical methodologies and the selection of appropriate matrices.

Information is also needed about groups of pollutants other than those of the WFD that may be relevant to the marine environment.

### Short-term

- Develop methods to quantify contaminants fluxes and inputs.
- Develop tools to monitor marine ecotoxicology data, including for emerging contaminants.
- Study bioavailability and effects of emerging contaminants.
- Develop integrated surveillance programmes including, at least, different compartments of the ecosystem for the study of pollutant concentrations and associated biological responses.
- Develop projects to study how to include new groups of contaminants and tissue-level biomarkers, as well as embryo-larval bioassays in sediment pollution monitoring.
- Study higher trophic level contamination.

### Medium-term or requiring moderate investments

- Develop new passive samplers to increase pre-concentration of samples at sea.
- Develop adaptation of marine monitoring strategies for 'ubiquitous' contaminants.
- Better understand the ecological relevance and relationship between early warning signals at molecular level and the alteration of physiological functions like reproduction, immunotoxicity and fitness.
- Better understand how contaminants are transferred across trophic levels.

### Long-term research or large investments

- Develop new genomic and transcriptomics methods in ecotoxicological studies.
- Better understand the links with microplastics and whether this acts as an additional exposure vector for contaminants.

# CONTAMINANTS IN SEA FOOD

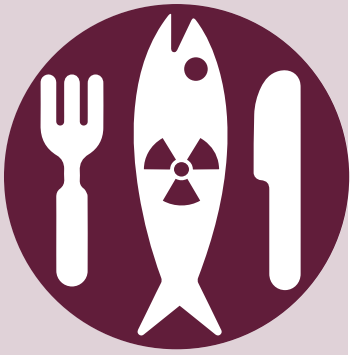


## DEFINITION

*"Contaminants in fish and other seafood for human consumption do not exceed levels established by Community legislation or other relevant standards."*

- The term ***"contaminants"*** is interpreted as "hazardous substances present in fish and shellfish as a result of environmental contamination and human activities for which regulatory levels have been set for human consumption or for which the presence in fish is relevant". In this interpretation, hazardous substances are substances (i.e. chemical elements and compounds) or groups of substances that are toxic, persistent and liable to bio-accumulate, and other substances or groups of substances which give rise to an equivalent level of concern.
- The terms *"fish and other seafood"* are interpreted as only wild caught fish, crustaceans, molluscs, echinoderms, roe and seaweed harvested in the different (sub)regions, all destined for human consumption.
- *"Levels established by Community legislation"* are considered to be the regulatory levels set in community legislation for public health reasons.
- *"Other relevant standards"* could be other national and international standards and recommendations set for fish and other seafood which are not in contradiction with the EU legislation.

Although regulatory levels have been set for marine biotoxins, they would not be considered as contaminants. Their presence in fish and seafood is not always linked to human activities. HAB events are often due to climatic and hydrographical circumstances, although human-induced eutrophication from domestic, industrial and agricultural wastes can stimulate HABs. Therefore, there is no always-consistent link between the levels of marine biotoxins in fish and seafood and the environmental status of the marine environment. In addition, the threat from marine biotoxins is managed in a different manner than other regulatory levels in seafood, prompting controls on harvesting.



# RESEARCH NEEDS IDENTIFIED

## GENERAL RESEARCH NEEDS

Specific regulations for emerging contaminants, some edible parts of organisms, and selected pathways (top predators, oily fish and shellfish) are missing and should be implemented.

## RESEARCH NEEDS ON THE PRESSURES AND THEIR IMPACTS OF MARINE ECOSYSTEM

- Collaborative work with D8, D4 and D5 on pathways of contamination, toxicokinetics and ecotoxicology, with emphasis on substances where limits are set (i.e. mercury, cadmium and PCBs).
- Studying variability in concentrations of relevant substances in different edible parts of seafood.
- Long-term monitoring of dioxins and dioxin-like PCB levels in marine fats and oils as well as oily fish.
- Epidemiological studies on emergent contaminants.
- Studying the link between the levels of marine biotoxins in seafood and the environmental status.

## RESEARCH NEEDS FOR THE IMPLEMENTATION OF THE MONITORING PROGRAMME

Although some standards do exist, there is a need for baseline studies to establish an accurate reference of the levels of undesirable substances in seafood. Several substances, such as organic chemical contaminants or pharmaceutical substances are not well known for many species. Better understanding of the life cycle of contaminants between water and fish is required. The traceability of seafood is not efficient enough. Tools to predict improvement effects of measures taken and to thus assess the efficiency of these measures would be useful.

### Short-term

- Develop specific and on-going monitoring of the concentrations of contaminants in fishery products traceable to their source.
- Analyse additional contaminants, sampling in a wider range, and including more marine commercial species.

### Medium-term or requiring moderate investments

- Develop monitoring programmes outside coastal area monitoring of seafood contamination.

### Long-term research or large investments

- Study of effects of worldwide pollution and long-range transport

# MARINE LITTER

## DEFINITION

*"Properties and quantities of marine litter do not cause harm to the coastal and marine environment."*

- *"Marine litter"* is any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment. It consists of items that have been made or used by humans and deliberately discarded or unintentionally lost into the sea and on beaches, including such materials transported into the marine environment from land by rivers, drainage or sewage systems or winds: e.g. plastics, wood, metals, glass, rubber, clothing, paper.
  - This definition does not include semi-solid remains of, for example, mineral and vegetable oils, paraffin and chemicals that sometimes litter sea and shores.
- *"Harm"* can be divided into three general categories:
  - Social (reduction in aesthetic value and public safety)
  - Economic (e.g. cost to tourism, damage to vessels, fishing gear and facilities, losses to fishery operations, cleaning costs)
  - Ecological (mortality or sublethal effects on plants and animals through: entanglements; captures and entanglement from ghost nets; physical damage and ingestion including uptake of microparticles (mainly microplastics) and the release of associated chemicals; facilitating the invasion of alien species; and altering benthic community structure)

# RESEARCH NEEDS IDENTIFIED

## GENERAL RESEARCH NEEDS

Research should support the development of a geographic information system (GIS) platform and a large-scale EU-wide model for river/surface/water column/sea floor litter transport by currents to enable the location/evaluation of sources, destinations (accumulation areas) and backtracking of litter. This will make it possible to have a Europe-wide common tool to better understand source/effect relationships and strongly support adequate measures and management schemes. It will also support the understanding of transport of alien/invasive/pathogens species that use litter as vectors (link with D2).

To understand the ecological impact of litter, including microplastics, on marine organisms and ecosystems, upstream research relating quantities and size of litter to specific lethal or sub lethal effects in relation to different environmental conditions is needed. Thus, one recommendation is related to establishing the specific environmental consequences, by type of litter/microlitter, from metabolism to ecosystem-level effects. This will enable science-based definition of threshold levels when measuring impacts and will therefore help to better define GES and targets.

Moreover, better understanding of processes and rates of degradation of the various types of litter in the environment is needed. The influence of external factors (temperature, depth, etc.) must be also considered. In fine, the detailed "biogeochemistry" of litter in the marine environment will be available and provide universal background information to assess trends and support directed measures for specific types of litter/components. There is also a need for research to support the development of additional monitoring tools and indicators for areas where there are currently gaps in the understanding of the pressure from marine litter, such as riverine litter and species for ecological impact indicators (shearwaters, turtles, etc.). This should include standards/baselines, data management/quality assurance, extension of monitoring protocols to all MSFD regions/sub regions.

## RESEARCH NEEDS FOR THE PRESSURES AND THEIR IMPACTS ON THE MARINE ECOSYSTEM

- Determine sources and fates of litter in the marine environment.
- Determinate degradation processes for marine litter and the impact on trend evaluation.

## RESEARCH NEEDS FOR THE IMPLEMENTATION OF THE MONITORING PROGRAMME

There are numerous gaps, such as the lack of data, especially in offshore areas. Litter made of intermediate size particles (0-2.5cm) and microplastics should be studied for their sources, distribution and impacts on ecosystems. Finding alternative species for ecological impact indicators where fulmars are not found in sufficient numbers is a also key point for the assessment of this descriptor.

### Short-term

- Develop conversion factors number/weight/volume.
- Determine litter degradation rates.
- Microplastics :
  - Increase knowledge about them: size to be specified and harmonised, inter-calibration protocols and harmonisation needed.
  - Quantify them in the environment (including sediments from submerged substrates and beaches, as well as surface water).
- Optimise information collection networks for impact indicators, to supplement existing scientific and technical bases.
- Develop designs which are statistically powerful enough.

### Medium-term or requiring moderate investments

- Develop monitoring plans using video or photo images, to assess litter on rocky and deep bottoms.
- Develop tools to assess the landscape and/or cognitive effects of litter on society, mainly affecting tourism and the development of water activities, in order to assess economic and social damage to affected areas.

### Long-term research or large investments

- Develop opportunistic data acquisition for deep areas/canyons (high cost of data acquisition), allowing long-term monitoring.
- Determine the possible origin of litter and dispersion vectors by studying their distribution and coupling with particle drift models or identifying characteristics of the waste.

# UNDERWATER NOISE



## DEFINITION

*"Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment."*

- *"Noise"* means anthropogenic sound that has the potential to cause negative impacts on the marine environment (which in this case includes component biota but not necessarily the whole environment).
- The term *"level"* as used in the MSFD descriptor is taken in a broad sense not only to describe sound pressure levels but also other features of sound.

A simplified means of assessing impacts from noise exposure on the marine environment is the basic "source-path-receiver" model, where "source" refers to the noise source of interest, "path" refers to the propagation of sound through the water, and "receiver" refers to the marine organism of interest.

It is likely that no factor alone is harmful enough to directly degrade marine life; yet, together they may create conditions leading to reduced productivity and survival in some cases. It is evident that potential impacts of sound have to be placed in a wider context, addressing the consequences of acoustic disturbance on populations in conjunction with other factors. The investigation of the overlap between sources and exposed organisms is crucial, as areas of high density might indicate a relatively high value of the habitat, and activities would impact a relatively high proportion of individuals of any given population.

## RESEARCH NEEDS IDENTIFIED

Ambient noise levels have increased over the past 50 years, mostly due to shipping activity. Chronic exposure to noise can permanently impair important biological functions and may lead to consequences that are as severe as those induced by acute exposure. Pressure/impact relations of increased ambient noise levels are not yet understood. Although much attention has been given to effects on marine mammals, relatively little attention has been given to the sensitivity of fish and other organisms, including marine invertebrates. The Commission Decision of 2010 describes sound in terms of (pressure) level, but fish and many invertebrates are probably sensitive to particle motion and not to sound pressure.

### RESEARCH NEEDS FOR THE PRESSURES AND THEIR IMPACTS ON THE MARINE ECOSYSTEM

- Determine population effects of low- and mid-frequency impulsive noise on marine life in order to establish targets (for 2018/2021 MSFD cycle).
- Determine the effects of increased ambient noise levels on marine life, in order to establish targets for future MSFD cycles.
- Determine other parameters (than currently used pressure parameters) is needed to characterise sound adequately.

### RESEARCH NEEDS FOR THE IMPLEMENTATION OF THE MONITORING PROGRAMME

The gaps in knowledge lie in the field of biology, effects of noise and actual levels of sound in the oceans. Some of these knowledge gaps will be addressed by the monitoring itself (because the proposed indicators will describe the pressure on the environment, i.e. the noise generated by impulsive sources will be recorded) and data on ambient noise levels and trends will become available as result of the monitoring programmes.

### Short-term

- Organise efficient data gathering (recording) for impulsive noise and measuring/data gathering for ambient noise, preferably at EU or regional scale.

### Medium-term or requiring moderate investments

- Develop sound maps, integrating acoustic models, source information and environmental parameters to describe current sound levels and trends.

### Long-term research or large investments

- Increase knowledge of direct effects of impulsive sounds (sonar and acoustic deterrents, seismic, piling, explosions). This should address behavioural effects (e.g., leading to avoidance or abandonment of preferred habitat, which may happen at low exposure levels and therefore may be relevant at the population/ecosystem level); injury may still be relevant for some activities.
- Effects of impulsive sounds at population/ecosystem level. There are proposals for frameworks to expand from direct/individual effects of disturbance to population/ecosystem level effects, e.g. the PCAD-model (population consequences of acoustic disturbance).
- Effects of increased ambient noise level, addressing masking potential but also other stress effects. Assessment of relevance of masking for population/ecosystem effects.
- Verify the most relevant parameters to describe sound (not restricting to presently used pressure parameters but also velocity parameters/particle motion): ultimately international standards would be needed.
- For future impact assessments/risk assessment, improved knowledge on seasonal presence and abundance of marine life may be needed.
- Mitigation potential, e.g. silencing technologies, including assessment of actual mitigation potential of such technologies:
  - Assessment of mitigation effectiveness, not limited to technological solutions but including evaluation of other current measures and exclusion zones/periods, passive acoustic monitoring, ramp-up, including a cost-benefit assessment.

# IDENTIFIED RESEARCH NEEDS FOR SOCIAL AND ECONOMIC ANALYSIS UNDER THE MSFD?

There is a clear knowledge gap with respect to the socio-economic effectiveness or impacts of existing measures, reflecting for several descriptors a poor understanding of ecosystem functioning and actual linkages between economic sectors – pressures – impacts – state, and how changes in the ecosystem (and its services) affect human welfare. Research on this topic within large multi-disciplinary projects is definitely necessary to support any quantitative economic analysis.

Member States also use a large variety of different approaches and methods to assess the cost of degradation and to meet the requirements for cost-effectiveness and cost-benefit analysis under the MSFD. This could cause difficulties in delivering consistent and comparable socio-economic assessments. Research would thus be needed to investigate potential harmonisation of these methods and their associated protocols, as well as the development, application and communication of alternative (less quantitative) methods used when monetary valuation is not possible or appropriate.

Based on the lack of knowledge of ecosystem functioning, the marine water accounts approach is generally selected to assess the use of marine waters, to the detriment of the ecosystem services approach. Nevertheless, the valuation of marine/coastal ecosystem services has been discussed as an important and essential domain for research to achieve a true account of the benefits people can obtain from open ocean waters, coastal seas and near-shore systems. In particular, research is needed on the monetary valuation of external effects on ecosystem services and how these translate to loss and benefits in terms of social welfare.

Also, better knowledge about the relationship between each of the MSFD descriptors and ecosystem services would lead to an increasingly better capacity to design efficient Programmes of Measures. Under the EU Biodiversity Strategy to 2020, the on-going activities of the Working Group MAES (Mapping and Assessment on Ecosystems and their Services) are partly addressing this topic, establishing a consistent framework for ecosystem assessments through a coherent typology and mapping of ecosystem services. Based on the results provided by

this Group, a number of challenges remain to value ecosystem goods and services in the context of the MSFD, such as, for example: how to account for the variability in ecosystem functions, the transboundary nature of the European seas (i.e. benefits occurring outside the national assessment region where service is provided), or less tangible benefits (e.g. ecosystem resilience).

Some issues that may not directly call for extensive research programmes, but are of importance to efficiently perform the analyses, i.e. the paucity and the difficulty of access to maritime statistics. Also, considering the difficulty in performing a socio-economic analysis when GES is not properly defined or ecosystem knowledge is missing, or due to the lack of standard terminology in maritime economy and the lack of joint international efforts, sharing experiences might be very helpful for this type of issue, for example through WG ESA and Regional Sea Conventions. Other issues, such as whether EuroStat could provide information more fitted to MSFD socio-economic analyses, could be discussed at the Commission level, e.g. within the Marine Strategy Coordination Group. The financing of the MSFD's implementation is also a very important topic and therefore there is an expectation that the forthcoming discussions on cost effectiveness of measures and co-financing opportunities may be useful in this regard. In general, more investments in socio-economic research specific to maritime activities (statistics, methodology development) would be essential for Member States in the next phase of MSFD reporting.

# SCIENTIFIC RECOMMENDATIONS

## DATA COLLECTION/STORAGE/DISSEMINATION

- There is a need for 'simplified' natural science information, in a format that could be usable for socio-economic assessments; this would involve greater interaction between natural scientists and economists toward true interdisciplinary MSFD-related projects; recourse to 'toy models' can be useful to identify the most urgent data needs.
- Better data/information on production and costs to support the calculation of marine-related use values at policy-relevant levels, e.g. data on marine activities which may cause ecosystem deterioration or may be affected by policy.
- Ensure (e.g. at Eurostat level) a solid data architecture for marine and maritime activities based on consistent and comparable data collection and data methodologies. This includes effort to reduce the level of aggregation in official statistics (e.g. separating completely marine, mainly marine, and partially marine sectors ) and to provide free access to these data/statistics.
- Establish a common framework for organising information, integrating natural and socio-economic scientific knowledge that highlights the cost and benefits associated with the health of the marine environment (e.g. DPSWR approach ); possibly develop links with global initiatives such as the UN System of Environmental-Economic Accounting (SEEA) for producing comparable statistics on the environment and its relationship with the economy.

## ECOSYSTEM FUNCTIONING

- Research needed to get a proper understanding of the links between pressures (drivers), impact, state of the ecosystem and welfare, so that the benefits of any programmes of measures can be evaluated in quantitative terms and with an acceptable degree of uncertainty.
- Investigate and map the relationships between pressures associated with economic activities and descriptors (attributes, indicators, ecosystem services).
- Strengthen our ability to design efficient policy instruments and programmes of measures: research is needed to better understand the indirect drivers that give raise to environmental problems and the relation between possible measures and responses in terms of environmental state.

- Develop tools to model cause-effect relationships between pressures/ measures and environmental responses for a few critical issues, with a view to streamlining and harmonising methodologies for economic and social assessments

## METHODOLOGICAL ISSUES AND TOOLS

- Research (develop, systemise, disseminate) is needed for alternative (more qualitative) reliable and transparent methods of cost-benefit or cost-effectiveness analysis in cases where monetary valuation is not appropriate, e.g. approaches taking into account the decision-making procedure in water management (Procedural Approach as applied in Germany), the eco-point method for biodiversity assessment (applied in the Netherlands), or multi-criteria analysis to support decision-making process involving trade-offs.
- Cost-benefit and cost-effectiveness analyses used to evaluate the ecological and economic consequences of past interventions and plan future programmes of measures. These analyses require the development of numerical models that: i) integrate across social, economic, environmental and ecosystem dimensions; ii) cover entire regional seas; iii) are dynamic rather than static (i.e. account for delays in the impacts of measures; iv) are probabilistic rather than deterministic (i.e. account for uncertainties and missing data); v) are adequately detailed to predict long-term ecological and economic consequences of a given applied measure; vi) quantify interactions and trade-offs among ecosystem services.
- Standard and sound methodologies for aggregating benefits over space and time.
- Investigate methodologies to support socio-economic assessment and the design of a programme of measures when GES for a given descriptor/indicator is not clearly identified or when ecosystem knowledge is uncertain.
- Explore the use of Maritime Spatial Planning for economic analyses underMSFD to illustrate trade-offs.

## ECOSYSTEM SERVICES

- Research needed to better understand the relationship between marine and coastal services and the benefits they provide (i.e. some benefits derived from services should be clarified and commonly agreed); this type of research would also include a thorough analysis of spatio-temporal lags between the production of the services and the benefit to the area.
- Develop and harmonise better methodologies for the economic

valuation/monetary assessment of ecosystem services, considering issues of double-counting and cumulative effects of human uses. This research can be an integrated part of the impact assessment (cost-benefit analysis), as well as of cost-effectiveness analysis of different measures and policy instruments.

- Develop a standard typology of ecosystem services such that it can be universally (pan-European) applied.

## SOCIAL SCIENCES

- Research needed on non-use and non-market values linked to the marine and coastal environment, as well as valuation studies on cultural services; quantification of benefits for a few key pressures for which non-use benefits might be large and ignoring them might impact GES assessment.
- Identify relevant social indicators and guidelines/instruments to monitor and analyse social conduct and perception with respect to each of the MSFD descriptors.
- Research on behavioural aspects; explore the integration of more social/behavioural components in economic modelling, i.e. more accurate and dynamic representation of actors' behaviour.

## COMMUNICATION

- Work is needed to improve communication on societal benefits of marine protection in relation to economic activities; communicating the need for non-market valuation studies.
- Enhance the dialogue between natural scientists and economists; communicating with natural scientists about the missing link between natural scientific projects and economic analyses or models.
- Need for mechanisms to systematically review and share marine scientific knowledge, incl. socio-economic matters, possibly using existing EU platforms (e.g. marine WISE-RTD).
- Communicate the value of socio-economic assessment for policy decisions, i.e. how it positively influences policy development and/or implementation (success stories).
- A clear and common definition and terminology for marine/maritime economy should be developed so that both scientists and Member State authorities can discuss important implementation issues, based on similar grounds.

## HOW TO IMPROVE THE ACCESS TO MARINE SCIENTIFIC KNOWLEDGE TO IMPLEMENT THE MSFD?

One of the key outputs of STAGES will be a concept for a durable but flexible European Science Policy Interface (SPI) to support MSFD implementation in the long-term. This is being developed through extensive Stakeholder Consultation, analysis of best practice and dialogue with key potential actors. Many elements of the SPI are already largely in place, but currently lack the coherence and coordination required for MSFD stakeholders to fully benefit from advances in European science and technology and identification of future research needs.

A key component of a successful SPI is the harnessing of and improved access to marine scientific knowledge. Building on previous initiatives, the STAGES project has further demonstrated the potential of the Marine Knowledge Gate (http://www.kg.eurocean.org/), a major open access repository of marine research in Europe, by developing a specific MSFD search tool to filter by Marine Region and GES Descriptor.

By hosting the information in the Marine Knowledge Gate, STAGES ensures that knowledge from marine research with relevance to MSFD implementation is made easily available/accessible to a wide range of stakeholders that are, or might be, involved in the MSFD process. This inventory provides the most comprehensive look to date into MSFD-related research which may continue to evolve and develop past the lifetime of the STAGES project. The Marine Knowledge Gate is a stabilised but scalable online platform, which may be further upgraded to accommodate additional user needs.

The wider SPI will also require components to enhance the existing science advisory process, provide a synthesis of knowledge and identification of gaps, and increase the capacity for knowledge brokers as key players to facilitate the two-way dialogue between science and policy.

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## DESCRIPTOR 3


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ANNEX

## DESCRIPTOR 1

***Criteria 1.1 Species distribution***

*Indicator 1.1.1 Distributional range*

*Indicator 1.1.2 Distributional pattern within the latter, where appropriate*

*Indicator 1.1.3 Area covered by the species (for sessile/benthic species)*

***Criteria 1.2 Population size***

*Indicator 1.2.1 Population abundance and/or biomass, as appropriate*

***Criteria 1.3 Population condition***

*Indicator 1.3.1 Population demographic characteristics (e.g. body size or age class structure, sex ratio, fecundity rates, survival/mortality rates)*

*Indicator 1.3.2 Population genetic structure, where appropriate*

***Criteria 1.4 Habitat distribution***

*Indicator 1.4.1 Habitat distributional range*

*Indicator 1.4.2 Habitat distributional pattern*

***Criteria 1.5 Habitat extent***

*Indicator 1.5.1 Habitat area*

*Indicator 1.5.2 Habitat volume, where relevant*

***Criteria 1.6 Habitat condition***

*Indicator 1.6.1 Condition of the typical species and communities*

*Indicator 1.6.2 Relative abundance and/or biomass, as appropriate*

*Indicator 1.6.3 Physical, hydrological and chemical conditions*

***Criteria 1.7 Ecosystem structure***

*Indicator 1.7.1 Composition and relative proportions of ecosystem components*

## DESCRIPTOR 2

***Criteria 2.1: Abundance and state characterisation of non-indigenous species, in particular invasive species***

*Indicator 2.1.1 Trends in abundance, temporal occurrence and spatial distribution in the wild of non-indigenous species, particularly invasive non-indigenous species, notably in risk areas, in relation to the main vectors and pathways of spreading of such species*

***Criteria 2.2: Environmental impact of invasive non-indigenous species***

*Indicator 2.2.1 Ratio between invasive non-indigenous species and native species in some well studied taxonomic groups (e.g. fish, macroalgae, molluscs) that may provide a measure of change in species composition (e.g. further to the displacement of native species)*

*Indicator 2.2.2 Impacts of non-indigenous invasive species at the level of species, habitats and ecosystem, where feasible*

## DESCRIPTOR 3

***Criteria 3.1: Level of pressure of the fishing activity***

*Indicator 3.1.1. Fishing mortality (F)*

*Indicator 3.1.2. Ratio between catch and biomass index (hereinafter 'catch/biomass ratio')*

***Criteria 3.2: Reproductive capacity of the stock***

*Indicator 3.2.1. Spawning Stock Biomass (SSB)*

*Indicator 3.2.2. Biomass indices*

***Criteria 3.3: Population age and size distribution***

*Indicator 3.3.1. Proportion of fish larger than the mean size of first sexual maturation*

*Indicator 3.3.2. Mean maximum length across all species found in research vessel surveys*

*Indicator 3.3.3. 95 % percentile of the fish length distribution observed in research vessel surveys*

*Indicator 3.3.4. Size at first sexual maturation, which may reflect the extent of undesirable genetic effects of exploitation*

## DESCRIPTOR 4

***Criteria 4.1: Productivity (production per unit biomass) of key species or trophic groups***

*Indicator 4.1.1. Performance of key predator species using their production per unit biomass (productivity)*

***Criteria 4.2: Proportion of selected species at the top of food webs***

*Indicator 4.2.1. Large fish (by weight)*

***Criteria 4.3: Abundance/distribution of key trophic groups/species***

*Indicator 4.3.1. Abundance trends of functionally important selected groups/species*

## DESCRIPTOR 5

***Criteria 5.1 Nutrient levels***

*Indicator 5.1.1 Nutrient concentration in the water column*

*Indicator 5.1.2 Nutrient ratios*

***Criteria 5.2 Direct effects of nutrient enrichment***

*Indicator 5.2.1 Chlorophyll concentration in the water column*

*Indicator 5.2.2 Water transparency related to increase in suspended algae*

*Indicator 5.2.3 Abundance of opportunistic macroalgae*

*Indicator 5.2.4 Species shift in floristic composition such as diatom to flagellate ratio, benthic to pelagic shifts, as well as bloom events of nuisance/toxic algal blooms caused by human activities*

***Criteria 5.3 Indirect effects of nutrient enrichment***

*Indicator 5.3.1 Abundance of perennial seaweeds and sea grasses adversely impacted by decrease in water transparency*

*Indicator 5.3.2 Dissolved oxygen, i.e. changes due to increased organic matter decomposition and size of the area concerned*

## DESCRIPTOR 6

***Criteria 6.1 Physical damage, having regard to substrate characteristics***

*Indicator 6.1.1 Type, abundance, biomass and areal extent of relevant biogenic substrate*

*Indicator 6.1.2 Extent of the seabed significantly affected by human activities for the different substrate types*

***Criteria 6.2 Condition of benthic community***

*Indicator 6.2.1 Presence of particularly sensitive and/or tolerant species*

*Indicator 6.2.2 Multi-metric indexes assessing benthic community condition and functionality, such as species diversity and richness, proportion of opportunistic to sensitive species*

*Indicator 6.2.3 Proportion of biomass or numbers of individuals in the macrobenthos above some specified length/size*

*Indicator 6.2.4 Parameters describing the characteristics (shape, slope and intercept) of the size spectrum of the benthic community*

## DESCRIPTOR 7

***Criteria 7.1. Spatial characterization of permanent alterations***

*Indicator 7.1.1 Extent of area affected by permanent alterations*

***Criteria 7.2. Impact of permanent hydrographical changes***

*Indicator 7.2.1 Spatial extent of habitats affected by the permanent alteration*

*Indicator 7.2.2 Changes in habitats, in particular the functions provided, due to altered hydrographical conditions*

## DESCRIPTOR 8

***Criteria 8.1 Concentration of contaminants***

*Indicator 8.1.1 Concentration of the contaminants mentioned above, measured in the relevant matrix in a way that ensures comparability with the assessments under Directive 2000/60/EC*

***Criteria 8.2 Effects of contaminants***

*Indicator 8.2.1 Levels of pollution effects on the ecosystem components concerned, having regardto the selected biological processes and taxonomic groups where a cause/effect relationship has been established and needs to be monitored*

*Indicator 8.2.2 Occurrence, origin (where possible), extent of significant acute pollution events and their impact on biota physically affected by this pollution*

## DESCRIPTOR 9

***Criteria 9.1 Levels, number and frequency of contaminants***

*Indicator 9.1.1 Actual levels of contaminants that have been detected and number of contaminants which have exceeded maximum regulatory levels*

*Indicator 9.1.2 Frequency of regulatory levels being exceeded*

## DESCRIPTOR 10

***Criteria 10.1 Characteristics of litter in the marine and coastal environment***

*Indicator 10.1.1 Trends in the amount of litter washed ashore and/or deposited on coastlines, including analysis of its composition, spatial distribution and, where possible, source.*

*Indicator 10.1.2 Trends in the amount of litter in the water column (including floating at the surface) and deposited on the seafloor, including analysis of its composition, spatial distribution and, where possible, source*

*Indicator 10.1.3 Trends in the amount, distribution and, where possible, composition of micro-particles (in particular micro- plastics)*

***Criteria 10.2 Impacts of litter on marine life***

*Indicator 10.2.1 Trends in the amount and composition of litter ingested by marine animals (e.g. stomach analysis)*

## DESCRIPTOR 11

***Criteria 11.1 Distribution in time and place of loud, low and mid frequency impulsive sounds***

*Indicator 11.1.1 Proportion of days and their distribution within a calendar year over areas of a determined surface, as well as their spatial distribution, in which anthropogenic sound sources exceed levels that are likely to entail significant impact on marine animals measured as Sound Exposure Level (in dB re 1 Pa 2 .s) or as peak sound pressure level (in dB re 1μPa peak ) at one meter, measured over the frequency band 10 Hz to 10 kHz*

***Criteria 11.2 Continuous low frequency sound***

*Indicator 11.2.1 Trends in the ambient noise level within the 1/3 octave bands 63 and 125 Hz (centre frequency) (re 1μPa RMS; average noise level in these octave bands over a year) measured by observation stations and/or with the use of models if appropriate*

# NOTES

# PROJECT PARTNERSHIP

The **STAGES** partnership has been constructed to ensure effective delivery of the ambitious project objectives. It comprises European and international organisations such as ICES and JRC, who were fundamental in developing MSFD Scientific Task Groups, as well as national organisations (IMR, IFREMER, CETMAR) that are responsible for supporting research and providing advice on MSFD implementation at Member State level. The partnership also includes AquaTT and EurOcean, both very experienced in marine science information management and knowledge transfer, and the European Marine Board as a primary marine science-policy think tank in Europe.

## PROJECT PARTNERS

- Centro Tecnologico del Mar – Fundacion (CETMAR)
- European Center for Information on Marine Science and Technology (EurOcean)
- Institut français de recherche pour l'exploitation de la mer (Ifremer)
- AquaTT UETP Ltd (AQUATT)
- International Council of the Exploration of the Sea (ICES)
- Joint Research Centre (JRC)
- European Marine Board (MB-ESF)
- Institute of Marine Research (IMR)

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