Joint European Research Infrastructure network for Coastal Observatory – Novel European eXpertise for coastal observaTories - **JERICO-NEXT**

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Table of Contents

List of Figures

List of Tables

Key Acronyms

BODC:	British Oceanographic Data Centre
CEFAS:	Centre for Environment, Fisheries and Aquaculture Science
CEMP:	Coordinated Environmental Monitoring Programme
CCW:	Countryside Council for Wales
DAERA:	Department of Agriculture, Environment and Rural Affairs (Northern Ireland). Previously DOE NI.
DIN:	Dissolved Inorganic Nitrogen (nitrate + nitrite + ammonium)
DIP:	Dissolved Inorganic Phosphorus
EA:	Environment Agency
FP7-JERICO	The FP7 funded JERICO project (2011-2015)
GES:	Good Environmental Status
HD:	Habitats Directive
HELCOM:	Baltic Marine Environment Protection Commission, also known as Helsinki Commission
ICES:	International Council for Exploration of the Sea
JERICO-RI	the JERICO Research Infrastructure
JRA:	Joint Research Activity
JRAP:	Joint Research Activity Project
MERMAN:	Marine Environment Monitoring and Assessment National Database
MSFD:	Marine Strategy Framework Directive
MSS:	Marine Scotland Science
NA:	Networking Activities
ND:	Nitrates Directive
NRW:	Natural Resources Wales (Previously EA Wales, CCW and Forestry Commission)
OSPAR:	Oslo Paris Convention for the Protection of the Marine Environment of the North-East Atlantic
POP:	Persistent organic pollutant
RI:	Research Infrastructure
SEPA:	Scottish Environment Protection Agency
TOxN:	Total Oxidised Nitrogen (nitrate + nitrite)
UWWTD:	Urban Waste Water Treatment Directive
WFD:	Water Framework Directive
WP:	Work Package

Executive Summary

The objectives of JERICO-NEXT are to address the challenge of observing the complexity and high variability of coastal areas at Pan-European level, within the context of the EU Water Framework Directive and Marine Strategy Framework Directive, and operational marine services. The JERICO-NEXT project aims to extend the EU network of coastal observations developed in FP7-JERICO by adding new innovative infrastructures while integrating biogeochemical and biological observations. An important target of JERICO-NEXT is to provide the research community with continuous and more valuable coastal data coupling physical and biological information. The ultimate objectives are to maximise the value and impact of the JERICO research infrastructure (JERICO-RI) and provide key recommendations for the further development of the infrastructure in terms of sampling capabilities, representativeness of coastal processes, support to services, among others.

Work Package 1 (WP1) focuses on producing a long-term strategy for the development and integration of coastal observatories in Europe, including observations of the physical, chemical and biological compartments, with the objective of addressing key scientific questions and meeting the societal challenges related to coastal regions. This report (WP1, Task 1.1, D1.1) summarises the outcome of a review of the environmental threats in European waters, and gaps in programmes for monitoring these risks. The approach included a summary of recent studies, analysis of the results of two dedicated questionnaires which were filled in by national representatives within JERICO-NEXT and other European competent organisations, and an in-depth discussion of the question of observation scales. Findings from this report will underpin the future JERICO-NEXT monitoring strategy, and support JERICO-RI in providing high-value datasets for addressing key challenges at European level.

This study consolidates the main conclusions from the Dobris Assessment (EEA 1995) and more recent studies (EEA, 2008a, b and the EU-DEVOTES project), highlighting the need for improved monitoring of environmental threats in European coastal environment. Clear assessment and possible perspective on key challenges related to the observation of essential coastal variables is presented.

Participation in the JERICO-NEXT questionnaire was not exhaustive, but responses provided new insights into the gaps between the environmental pressures or threats and their impacts, and the monitoring of these impacts. In total, 36 national representatives, scientists and monitoring authorities from 12 European countries completed the questionnaire, and 38 monitoring programmes were reported. Responses were received from the United Kingdom, Greece, France, Spain, Malta, Finland, Germany, Ireland, Italy, Norway, Poland, and Sweden. Many respondents were JERICO-NEXT partners, but some were also from relevant organisations outside the consortium.

The main policy drivers of monitoring in the coastal ocean were identified as the EU Marine Strategy Framework Directive (MSFD) and the Water Framework Directive (WFD). The findings highlighted that policy drivers may change over time but overall purposes largely remain the same or similar. Regional Seas conventions (OSPAR and HELCOM) were also identified as key policy drivers of monitoring programmes.

The most commonly identified threats to the marine environment were: fishing, marine litter, shipping and contaminants. Regime shift and ocean acidification were noted as pressures with large potential for widespread harm. The majority of respondents identified habitat loss or destruction as an impact of human activities on the marine environment, with more than 50% identifying contamination, invasive species, population change/depletion of standing stocks, underwater noise disturbance and changes in community composition as key impacts. **Linkages between threats and impacts are complex, due to cumulative effects of multiple pressures**.

Most respondents considered current monitoring of threats to be partially adequate or not adequate. The majority of responses were related to spatial and/or temporal scales at which monitoring takes place, and inadequate monitoring of parameters. The implications of these findings were discussed and demonstrated using a case study for the central part of the Bay of Biscay.

A number of suggestions for improved monitoring programmes were highlighted, which focussed on improved design, increased monitoring effort and better linkages with research and new technologies. **These monitoring programme should be fit-for-purpose, through working with policy end-users. However, they should also underpin longer-term scientific objectives which cut across policy and other drivers, and consider cumulative effects of multiple pressures.**

The JERICO-RI is not presently contributing to national monitoring programmes but has a high potential to fill in some of the observation gaps, especially related to physical and biogeochemical parameters, and the coupling between biology and physics across scales needed for integrative understanding. **Through the JERICO-NEXT project, the JERICO-RI could become a major contributor towards future coastal monitoring programmes**. The science strategy for JERICO-RI under elaboration will pave the way to a better integration of physical, chemical and biological observations into an ecological process perspective. **The particular challenge of simultaneously observing physical, chemical and biological parameters for assessments of complex coastal processes remains an open issue in relation to the temporal scale of sampling. This will be studied and thoroughly discussed in deliverable 1.2 of the JERICO-Next project.**

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1. Introduction

In the last decades, marine observing systems have been implemented in coastal and shelf seas around Europe. Their purpose is mostly to answer local/regional monitoring and oceanographic research demands, but heterogeneity of monitoring methods and geographical dispersion often limit development of a coherent network. Indeed, observations are often driven through short-term research projects, therefore the sustainability of observing systems is not guaranteed.

One of the main challenges for the European marine research community is now to increase the consistency and the sustainability of these dispersed networks and infrastructures by integrating their future within a shared pan-European framework.

1.1. The JERICO-NEXT vision:

The JERICO-NEXT community emphasizes that one cannot comprehend the complexity of the coastal ocean if the coupling between physics, biogeochemistry and biology is not understood. Reaching such a level of understanding requires new technological developments allowing for the continuous monitoring of a larger set of parameters. It also requires an *a priori* definition of the optimal sampling strategy in view of coupling diverse data monitored over very different spatial and temporal scales. Therefore JERICO-NEXT: (1) will focus its main effort on the assessment of the interactions between physics, biogeochemistry and biology, and (2) will not be restricted to pure technological aspects but will also include fundamental scientific considerations within its networking activities (NA); the two being tightly tied within the joint research activities (JRAs).

1.2. Objectives of JERICO-NEXT

The objectives of JERICO-NEXT are to address the challenge of observing the complex and highly variable coastal areas at Pan-European level, in the framework established by European Directives (such as the Water Framework Directive, WFD, and the Marine Strategy Framework Directive, MSFD) and the operational marine services. The aim of JERICO-NEXT, as a network of coastal observatories, is to ensure regular and standardized observations to provide long term time-series of high-quality data.

The JERICO-NEXT project aims to extend the EU network of coastal observations developed in the FP7-JERICO project by adding new innovative infrastructures while integrating biogeochemical and biological observations. The main target of JERICO-NEXT is to provide the researchers with continuous and more reliable coastal data coupling physical and biological information.

Furthermore, the project aims to demonstrate the adequacy of the observing technologies and monitoring strategies to provide the information necessary to address a selected set of major environmental issues, for example: (1) direct and indirect requirements for assessment of Good Environmental Status required by the MSFD (see Annex 1), and (2) global environmental change impacts on coastal ecosystems.

The overall project structure is presented in Figure 1-1.

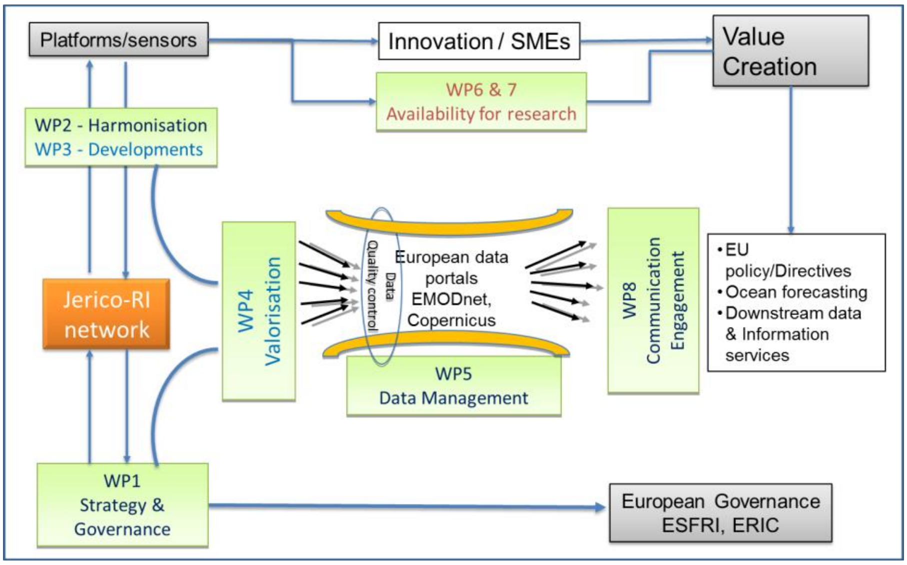


Figure 1-1: Project structure, showing the link between WP4 and WP1, as well as the link to value creation.

Work Package 1 (WP1, Integrated Science Strategy and Governance from local to European Scales) provides a framework for the implementation of the project work plan and for the long-term sustainability and impact of the research infrastructure (RI) on research and on the implementation of the relevant European policies. It focuses on producing a long-term strategy for the development and integration of coastal observatories in Europe, including observations of the physical, chemical and biological compartments, with the objective of addressing present and future scientific questions and meeting the societal challenges related to coastal regions.

The WP tackles key scientific questions about how best to observe physical, chemical and biological parameters in European waters (task 1.2 – scientific strategy), and the adequacy of present observation strategies to meet key scientific and societal challenges in the coastal ocean (task 1.1). In order to enhance the integration of marine biology with physical and chemical oceanology, some specific interactions are planned with other relevant European and international ocean observing systems and infrastructures that provide complementary observations of biological (task 1.3) and /or physical, chemical (task 1.4) parameters. This WP will also look at long-term financial and legal governance structures for the sustainable implementation of JERICO-NEXT infrastructures (task 1.5 – Governance strategy).

1.3. Objectives of this report

By the end of FP7-JERICO, a comprehensive analysis of the monitoring capability of the JERICO-RI, was presented, which included a status, a gap analysis and recommendations for a way forward (FP7-JERICO D1.11 http://www.jerico-ri.eu/download/filebase/jerico_fp7/deliverables/D1.11%20Achievements%20and%20Strategy%20for%20the%20Future.pdf). This analysis was considering the JERICO-RI as a standalone infrastructure, accounting neither for ongoing national monitoring programs nor the scientific relevance of the RI.
The objective of this report is to provide a complementary review of the main environmental problems and threats currently taking place within the European coastal oceans, the monitoring programmes that address these threats, and any gaps in monitoring. Particular attention was devoted to existing monitoring under the WFD and programmes to be adopted or, if required, developed for implementation of the MSFD or dedicated climate change monitoring programmes. These findings underpin the future JERICO-NEXT monitoring strategy, and support JERICO-RI in providing high-value datasets for addressing these key challenges at a European level.

The current status of knowledge is reviewed, and the findings from key publications and reports on recent projects are summarised (Section 2). Views of WP1 partners and collaborators on present and future environmental threats and monitoring requirements were also reviewed, and are the focus of Sections 3 and 4.

2. Literature Review

This section summarises existing assessments of environmental threats in European coastal zones, as well as ongoing monitoring programmes. The main sources of information were the 4th DOBRIS assessment conducted by the EEA in 2007 (EEA 2008a, b) and the results from the recent EU-DEVOTES project (see Patrício et al. 2013, 2014, 2016).

2.1. Environmental threats in European coastal regions

In 1995, the Dobris Assessment (EEA, 1995) listed 56 broad environmental threats, 19 of which were relevant to the coastal domain. This list has been further shortened into key environmental impacts:

- Physical modifications due to urban development, industry, location of centres of energy production, military activities, fisheries and recreation
    - Coastal erosion
    - Habitat loss and degradation
- Contamination and coastal pollution
    - Catchment management
    - Wastewater disposal
    - The fate and impact of nutrients and organic matter
    - Environmental impact of chemical contaminants
    - Marine Litter
- Loss of biodiversity and genetic resources

In the past two decades, EU policy drivers and action from regional sea conventions have led to improvements in water quality in the western seas (Baltic Sea, North Sea, Celtic Sea, Bay of Biscay). New EU directives imposing the ecosystem-based approach, such as the Marine Strategy Framework Directive, have largely been implemented into national policies by EU Member States. These directives offer an opportunity for the integration of existing measures.

Key messages from the 4th assessment of the European environment (EEA 2008) were as follows:

Eutrophication remains a problem in all enclosed seas and sheltered marine waters across the European Seas. There have been some improvements in the western seas, extending to the north-western shelf of the Black Sea, as a result of large cuts in point sources of nutrient pollution from industry and wastewater by EU Member States. However, diffuse nutrient sources, particularly from agriculture, remain a major obstacle for recovery and need increased control throughout Europe.

Destructive fishing practices continue, though it is hard to assess their extent. Bottom trawling keeps benthic ecosystems in a juvenile stage with low biodiversity. This also affects fish and the whole marine ecosystem negatively. By-catch and the discard of non-target fish, birds, marine mammals and turtles also contribute to the large-scale impacts of fisheries on the ecosystem. Many exploited fish and macro-invertebrates that utilize the coastal zone have declined, and the causes of these declines, apart from overfishing, remain largely unresolved. Degradation of essential habitats has resulted in habitats that are no longer adequate to fulfil nursery, feeding, or reproductive functions, yet the degree to which coastal habitats are important for exploited species has not been quantified (Seitz et al., 2013.).

Measures taken to reduce concentrations of some well-known **hazardous substances**, such as heavy metals and certain persistent organic pollutants (POPs), have generally been successful in the western seas. Sparse data indicate high levels of hazardous substances, particularly POPs, in the Black Sea. POPs, which can have serious detrimental effects on marine organisms, are transported over long distances and can be found even in the remote Arctic.

Major accidental **oil spills** have generally decreased in European seas. However, oil discharges from regular activities, such as transport and refineries, are still significant along major shipping routes and at certain hot spots along coasts. Without effective countermeasures, the expected increase in oil transport, especially in the Arctic, Baltic, Black and Mediterranean Seas, will add significantly to the risk of regional oil pollution.

Alien species are a major threat to biodiversity and continue to invade European seas, mainly via ships' ballast water. A new regulation from IMO has led to drastic reduction of this issue. The highest numbers of invasive species are found in the Mediterranean Sea.

Population densities along the coasts of the European continent are high and continue to increase — with built-up areas growing at the expense of agricultural, semi-natural and natural land in all EU Member States. Tourism has played a crucial role, in particular along the Mediterranean coast, and is becoming a driver of development on the Black Sea coast.

Climate change will very likely cause large scale alterations in sea temperature, sea level, sea-ice cover, currents and the chemical properties of the seas. Observed biological impacts include altered growing seasons, and community shifts in terms of species composition and distribution. Further impacts could also include the loss of marine organisms with carbonate shells due to ocean acidification.

Lack of comparable data across all seas still presents a major obstacle for pan-European marine assessments, even of well-known problems such as eutrophication. More and better data are needed to develop a pan-European marine protection framework that addresses environmental issues in a cost-effective way.

The Black Sea is generally in a poorer state than western seas. This is partly due to its natural vulnerability and partly because modern environmental policies have not been sufficiently introduced, adopted or implemented. The neighbouring countries have environmental opportunities to benefit from, as many of their coastal ecosystems remain unaffected by tourism, and water quality is not always under as much pressure from nutrient-intensive agricultural practices as in the EU.

2.2. Monitoring of the European coastal regions

A general statement on the quality of the information collected at European level through the national monitoring programmes was given in EEA reports (2008a, b), and summarized in Table 2-1.

Table 2-1: Strengths and weakness of information collected through monitoring programmes in Europe (EEA, 2008a & b).

Information strengths	Information weakness
Comprehensive surveillance of microbiological bathing water quality in EU waters	Very little comparable data on water quality and biology available for the Black Sea and the Barents Sea
Harmonised and efficient monitoring programs for water quality, land-based emissions, and sea food contamination exist for a few seas, including the Baltic Sea and the North Sea, as a result of implementation of international conventions.	Estimates of pollutant loads from different human activities and natural sources in general not available
	Unified procedures for estimating land-based emissions to seas missing
	Comparison of contaminant load estimates between different seas is difficult
	No pan-European marine water quality database exists

	Reporting schemes differ markedly between seas

The assessment of biogeochemical monitoring networks in regional seas that has been conducted through the OPEC project (wwww.marineopec.eu) concluded that Ferrybox plays a major role in monitoring of surface chlorophyll-a and dissolved oxygen in all regions. It is however only partially used as an accepted data source in national monitoring. The Baltic has the most comprehensive coverage, but sub-surface phosphate has large monitoring gaps. There is a gap area in the northern North Sea. While the temporal coverage in the Aegean Sea is too small, as daily measurements are necessary for understanding the variability of the biochemical processes in the region.

The integrated assessment of the marine biodiversity status is and has been problematic compared to, for example, assessments of eutrophication and contamination status, mostly because monitoring of marine habitats, communities and species is expensive, often collected at an inappropriate spatial scale and/or poorly integrated with existing marine environmental monitoring efforts (Andersen et al. 2014).

A comprehensive analysis of the current situation, structure, spread and coverage of monitoring programmes identified as suitable to address the good environmental status (GES) of the MSFD descriptors D1 (biodiversity), D2 (non-indigenous species), D4 (food-webs) and D6 (seafloor integrity) has been conducted by the EU-DEVOTES project. The DEVOTES catalogue does not address the adequacy of monitoring, only which descriptors/pressures are addressed. The main outcomes are summarised hereafter for the four Regional Seas (i.e. North Eastern Atlantic, Baltic Sea, Mediterranean Sea and Black Sea, Figure 2-1 to Figure 2-3) and in the Sea of Marmara (non-EU marine waters connecting the Mediterranean Sea with the Black Sea, Figure 2-5).

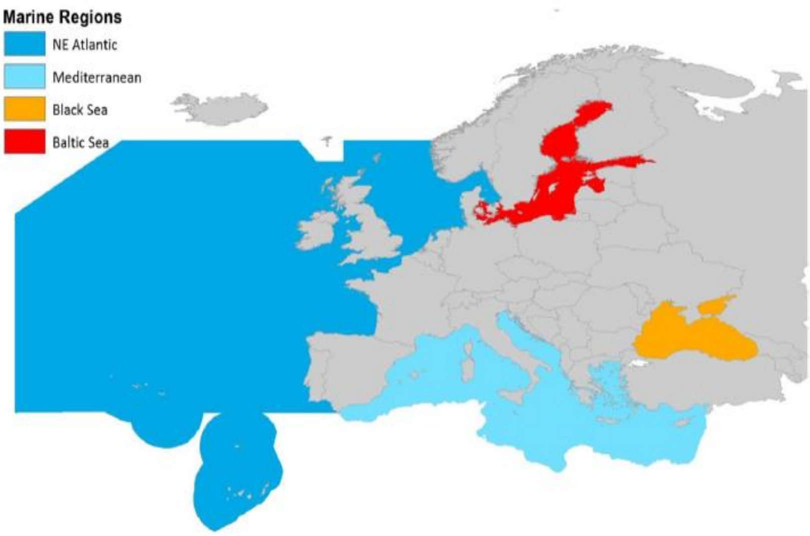


Figure 2-1: Marine regions as used in DEVOTES

The DEVOTES report conducted a “strengths, weaknesses, opportunities, and threats” (SWOT) analysis of the monitoring programmes per regional seas, which are summarised in the following sections.

2.2.1. North Eastern Atlantic

The NEA region is currently divided into four sub-regions (Figure 2-2):

- The Greater North Sea, including the Kattegat, and the English Channel;
- The Celtic Seas;
- The Bay of Biscay and the Iberian Coast;

- The Macaronesian biogeographic region, being the waters surrounding the Azores, Madeira and the Canary Islands.

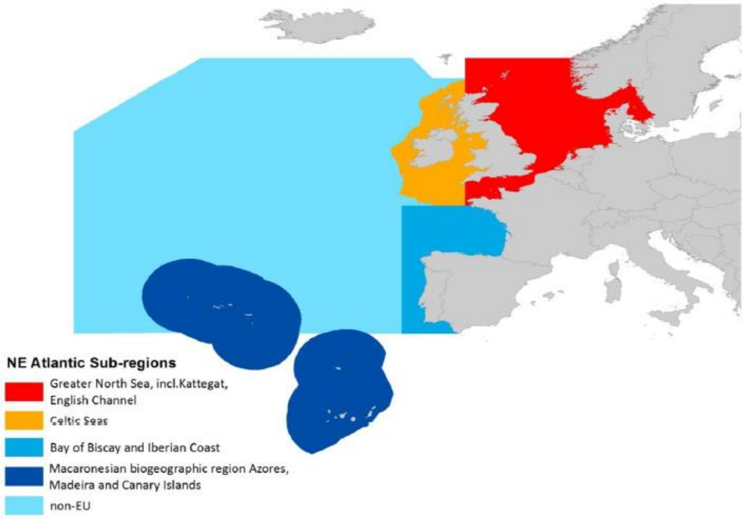


Figure 2-2: North Eastern Atlantic marine sub-regions used in DEVOTES.

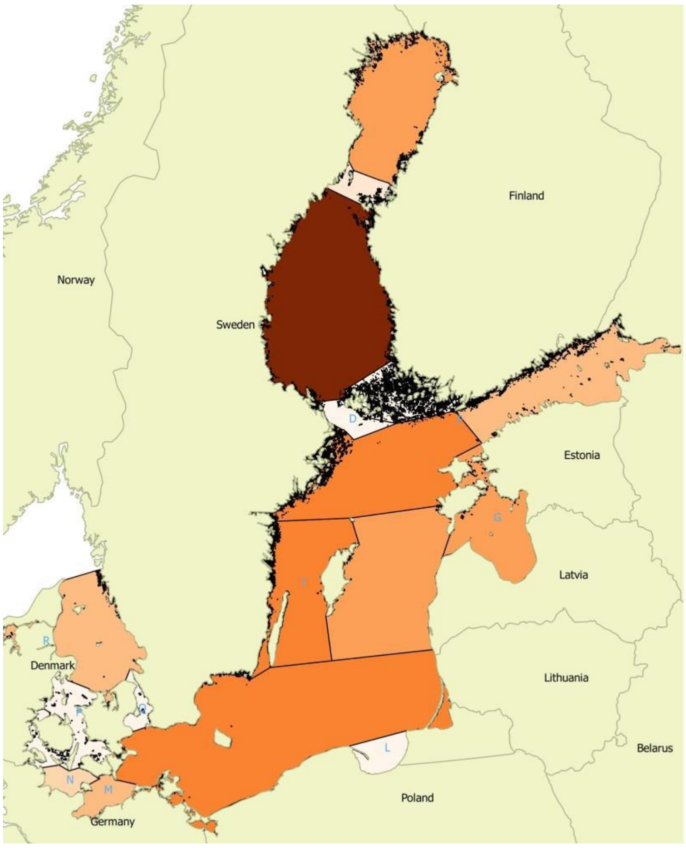
In the North East Atlantic, most descriptors (D) are covered to some extent, but there is spatial variability, and monitoring for D1 and D6 is more limited. Monitoring in southern sub-regions Atlantic (i.e. Bay of Biscay and Iberian Coast, and specially the Macaronesian biographic region) is limited compared to northern sub-regions, (i.e. Greater North Sea and Celtic Seas) though less is known about sampling intensity. Monitoring stations are unevenly distributed and often address a specific pressure so while most pressures are addressed at a sub-region level, there may be gaps when examined at a smaller scale. All monitoring programmes address more than one descriptor, some address 18-20 pressures at once and many monitoring programmes collect physicochemical and biodiversity data concurrently. However, certain indicators, descriptors, pressures, habitats and even sub-regions have limited monitoring programmes; such gaps may impede progress towards achieving GES.

There is an opportunity for improvement of monitoring programmes in the region, so that they become more efficient and wider in scope. In particular, the need for monitoring programmes to integrate several biological components through simultaneous observations has been identified. All water column types and most seabed habitats are monitored. However, several biological essential parameters are poorly monitored, and QA standards for these components are still to be improved. The most obvious and significant challenge to monitoring is budgetary constraints within the EU Member States concerned with the North Eastern Atlantic Region (e.g. several programmes have recently been cancelled). Furthermore, the long history of national monitoring which has been expanded, modified and developed over time, together with methodological differences between nations, results in difficulties for the integration and holistic assessment of the data (at a regional sea level). The JERICO-RI, which aims at reducing fragmentation in coastal observations and monitoring in European coastal seas, may contribute to solving some of these challenges and gaps.

2.2.2. Baltic Sea

The Baltic Sean is currently sub-divided into ten sub-regions, as shown in Figure 2-3.

All monitoring programmes address more than one descriptor, and almost all descriptors and biological components are addressed within the region. They are targeted towards reporting to HELCOM requirements. Collection of different data types simultaneously is a common practice. Monitoring in the region covers all water types and most seabed habitats, but some benthic habitats (e.g. sublittoral rock) are not reported to be monitored. Monitoring is particularly strong for eutrophication and extraction of living resources. Similarly to the North-Eastern Atlantic, an uneven distribution of sampling sites means monitoring may in reality not cover whole sub-regions, with gaps in space and time. Standardisation of sampling methodology and QA procedures between countries and sub-regions could be improved towards higher compatibility between datasets, and consolidation of knowledge about the impact of pressures. Some pressures which have not been well monitored (e.g. litter and noise) are the focus of research activities which could be used to develop monitoring. A database for the monitoring of non-indigenous species is being developed which could be very useful for risk assessments of invasive species and policy decisions. The monitoring programmes are not fully harmonized among the Baltic countries, most likely due to the differences in size of national budgets, assigned to marine monitoring. This challenge may remain in the future, highly depending on the national policy and/or economic status.



Basin	Sub_basin	code_1	stations
Belt Sea	Kattegat	R	71
Baltic Proper	Southern Baltic Proper	K	111
Baltic Proper	Gulf of Gdansk	L	14
Baltic Proper	Western Gotland Basin	I	111
Baltic Proper	Eastern Gotland Basin	J	103
Gulf of Riga	Gulf of Riga	G	92
Gulf of Bothnian	Bothnian Bay	A	91
Gulf of Bothnian	Bothnian Sea	C	214
Gulf of Bothnian	The Quark	B	38
Gulf of Bothnian	Archipelago Sea	E	19
Gulf of Bothnian	Åland Sea	D	2
Gulf of Finland	Gulf of Finland	F	80
Baltic Proper	Northern Baltic Proper	H	110
Belt Sea	Great Belt	P	11
Belt Sea	Little Belt	O	15
The Sound	The Sound	Q	9
Belt Sea	Bay of Mecklenburg	M	72
Belt Sea	Kiel Bay	N	45

Figure 2-3: Categorized (map) and exact (table) number of marine monitoring stations (where biological parameters are measured) per Baltic Sea sub-region. Data source is HELCOM MORE (2013).

2.2.3. Mediterranean Sea

The Mediterranean Sea is divided into four main sub-regions, as shown in Figure 2-4.

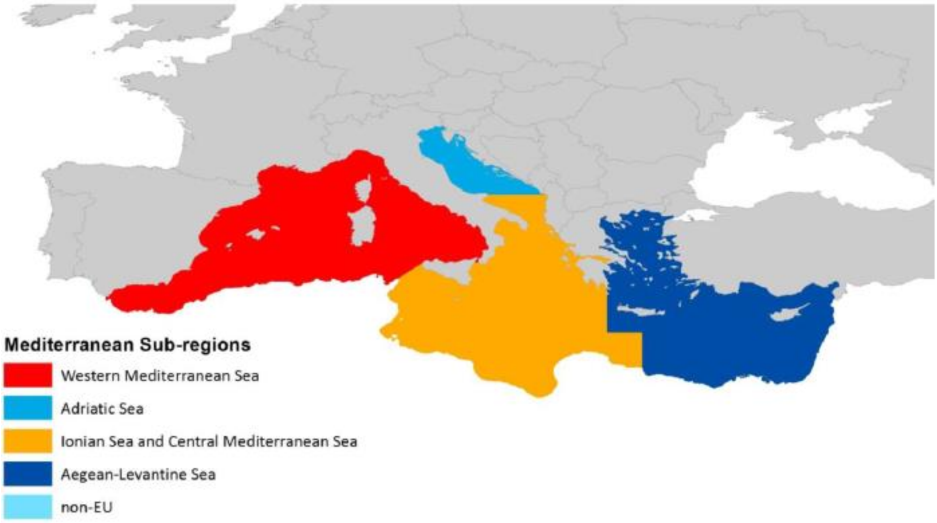


Figure 2-4: Mediterranean Sea marine sub-regions used in DEVOTES.

In the Mediterranean Sea, marine monitoring is enhanced by prior experience gained through the WFD, especially for D1 and D6. Coordination between policy instruments (i.e. MSFD, UNEP MAP) and between countries enhances monitoring capabilities. However, there is a limited capability to detect GES because of the few ecosystem components monitored, biodiversity indicators are still under development, monitoring is not standardized in terms of methods of sampling, policy and use of the available data require optimization. In the Mediterranean, NGOs and citizen science schemes have a larger role in monitoring. It can be seen as a strength in term of densifying the observations, but it is also a great weakness when it relates to the reporting and access to the data. Data for most descriptors are spatio-temporally limited, and mismatches of scale between data collection and pressures is a problem. Since monitoring has not necessarily been designed to address specific pressures, there is currently insufficient information to adequately address pressure-impact relationships. A sustainable funding scheme and a rapid response/intervention framework are necessary for a successful monitoring scheme. Increasing multidisciplinary is becoming a strength through the addition of additional parameters such as marine litter to fisheries surveys.

2.2.1. Black Sea and the Sea of Marmara

Only a limited part of the Black sea is included in EU waters (see Figure 2-5).

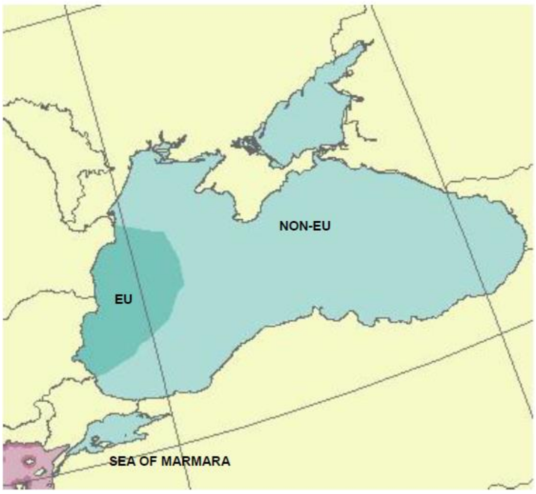


Figure 2-5: Black Sea (EU, non-EU waters) and the Sea of Marmara: (Source: Connor, 2012).

The Black Sea has good cooperation between countries through the Bucharest convention. Descriptor 1 is well covered in all areas, and nutrient enrichment is appropriately addressed. Descriptor 4 is not covered in the Black Sea and D2 and D6 are not covered in all sub-regions. While some programmes monitor three or more biodiversity components simultaneously, many programmes only address a single descriptor, so there is opportunity for expanding their scope. There has been significant progress in developing standard sampling and analysis protocols, with zoobenthos and phytoplankton already developed. Regional databases are in development but require further updates. Geographical coverage of monitoring is limited, and not all water column and seabed habitats are monitored, especially in non-EU waters. Biological oceanography in the region is underdeveloped, and could be significantly improved through infrastructure improvements, continued development of the Black sea GOOS, participation in Copernicus, and adoption of new technologies such as remote sensing and ships of opportunity. A challenge particular to the Black sea is the size of the catchment drainage area, which included countries without Black sea coastlines that must be considered when addressing inputs to the region. The Black Sea also has a high proportion of non-EU member states, for whom compliance with the MSFD is not obligatory but only desirable, which presents a challenge for the monitoring activities in the region.

3. Current environmental threats and monitoring: approach and key findings

3.1. Approach

To review current environmental threats and gaps in monitoring (task 1.1), the approach agreed at the kick-off meeting in October 2015 was to develop and distribute two questionnaires to obtain the views of WP1 partners and collaborators, and information on environmental threats and adequacy of monitoring programmes, respectively. All participants in WP1 were expected to act as national representatives and support this approach and contribute to the development of the JERICO-RI science strategy.

The questionnaires were developed by Cefas, COVARTEC, CNRS and Ifremer and distributed to national representatives, who were asked to take responsibility for responding to the questionnaire or to collect answers from responsible monitoring authorities within their countries. National representatives were also asked to forward the questionnaire to the relevant authorities in countries which are not partners within JERICO-NEXT.

Threats to the marine environment were considered in terms of 'pressures' and 'impacts'. Pressures were described as the human activities which have impacts on ecosystems or parts thereof (DPSIR model). It was recognised that some pressures may be considered as threats if they lead to significant negative impacts. An attempt was made to link these impacts back to the source of the impact (pressures). Checklists of pressures and impacts were given, and multiple options could be selected. Other pressures and impacts could also be added, with options to provide explanation/s.

3.1.1. <u>Format of questionnaires</u>

The questionnaire was developed using Google Forms, and consisted of two main parts. The first part was focussed on the participants, with the aim of obtaining the views of all participants on the environmental threats in European waters and the adequacy of current monitoring programmes. The second part was focussed on building a meta-database of monitoring programmes, with the aim of obtaining a summary of what was measured and where. In addition, a spreadsheet was provided, to obtain georeferenced information on monitoring stations.

The structure of the questionnaires is shown below (with hyperlinks to the questionnaire itself).

Questionnaire 1: Environmental Threats and Monitoring

1. Participant Details:
    a. Name and contact details
    b. Institute/Affiliation
2. Region of interest (see Annex 2)
    a. Country
    b. Region
    c. Sub-Region
3. Review of threats per region
    a. Pressures: What are the main pressures from human activities that are affecting the environment in this area?
    b. Impacts: What are the impacts resulting from the pressures identified above?
4. Policy Purposes: What are the main policies or other drivers behind the monitoring programme/s in each region or sub-region? These may be international conventions, EU Directives, national policies, or other requirements.
5. MSFD Descriptors: The MSFD includes 11 qualitative descriptors. Please link the threats identified to these descriptors, or any others which may be relevant in the area.
6. Names of relevant monitoring programmes:

7. Adequacy of existing monitoring programmes: are they sufficient to assess the effects of the environmental threats in the considered area?
    a. How are they deficient?
    b. How could they be improved to better address the threats?

Questionnaire 2: Monitoring programmes

1. Country
2. Monitoring programme name
3. Is the program statutory/official or unofficial?
4. Variables measured
5. Platform types
6. Number of stations
7. Is monitoring regular or ad hoc?
8. Monitoring frequency
9. Start date
10. End date
11. End reason, if not ongoing
12. Monitoring stations (in separate spreadsheet).
13. Comments
14. Data access restrictions
15. Responsible organisation
16. Responsible person and details
17. Data source institute
18. Database to which the data are submitted
19. Are data flows to central databases up to date?
20. Web links to data

3.1.2. *Distribution and responses to the questionnaires*

The request to complete the questionnaires was circulated to all partners in JERICO-NEXT in June 2016 (see Table 3-1) and subsequently forwarded to wider contact networks. All respondents were asked to complete and submit the questionnaires online by 15 September 2016.

Due to delays in the completion and submission of the online questionnaires, the deadline was extended three times (see Table 3-1). The request was also publicised via the JERICO-NEXT website, twitter, EuroGOOS and OSPAR. The questionnaire was closed to new responses on 30 November 2016.

Table 3-1 Timelines of questionnaire development and responses

Action	Date	Deadline
First draft of questionnaires	April 2016	
Questionnaires finalised	21 June 2016	
Questionnaires circulated to partners and WP8 contacts	29 June 2016	15 September 2016
Deadline extended		12 October 2016
Deadline extended		1 November 2016
Questionnaires circulated to broader partner audience	25 October	1 November 2016
Deadline extended		30 November 2016
Questionnaires closed to new responses		30 November 2016

3.1.3. *Analysis of responses*

Responses to the questionnaires were analysed in order to:

i. identify the main environmental problems and threats within European coastal waters
ii. gather a (meta)database on current monitoring programmes operated in Europe for the purposes of the WFD and MSFD
iii. identify gaps in the monitoring process

3.2. Environmental threats in European coastal waters

3.2.1. Participants

In total, 36 responses were received via Google forms from institutes in 12 countries across Europe (Table 3-2). The most responses (14 in total, 42%) were received from the UK (Figure 3-1), and these covered regional seas as well as territorial and EEZ or national waters. Most other responses were received for regional seas (e.g. the Baltic or Mediterranean) or their sub-regions. Five responses were received from Greece (15%), three from France (9%, by sub-region), two from Spain and Malta (6%, Figure 3-1). Many respondents were JERICO-NEXT partners, but some were also from the wider European monitoring network.

Table 3-2: Summary of respondents to the environmental threats questionnaire. Regions and sub-regions given in the questionnaire are shown in Annex 2

Institute/affiliation	Country	Region	Sub-Regions
OSPAR	United Kingdom	North East Atlantic	
FINNMAI	Finland	1Baltic Sea	1.1 Gulf of Bothnia, 1.2 Gulf of Finland, 1.4 Baltic Proper
EuroGOOS	Sweden	1Baltic Sea	1.4 Baltic Proper
IMGW	Poland	EEZ/National Waters	
Plymouth university	United Kingdom	IV North Sea	IVa Northern North Sea, IVb Central North Sea, IVc Southern North Sea
Marine Scotland	United Kingdom	IV North Sea	IVa Northern North Sea
MCS	United Kingdom	IV North Sea	IVa Northern North Sea, IVb Central North Sea, IVc Southern North Sea, Celtic sea
CEFAS	United Kingdom	IV North Sea	IVa Northern North Sea, IVb Central North Sea, IVc Southern North Sea
MMO	United Kingdom	EEZ/National Waters	
SEPA	United Kingdom	EEZ/National Waters	
Marine Scotland	United Kingdom	EEZ/National Waters	
SAHFOS	United Kingdom	EEZ/National Waters	
JNCC	United Kingdom	EEZ/National Waters	
Scitus Management Ltd	United Kingdom	EEZ/National Waters	
JNCC	United Kingdom	EEZ/National Waters	
EA	United Kingdom	Territorial Waters (12nm)	
Covartec	Norway	EEZ/National Waters	
IFREMER	France	Territorial Waters (12nm)	

CNRS	France	VII Celtic Seas	VIIh Celtic Sea South, VIIe Western English Channel, VIId Eastern English Channel
MI	Ireland	VII Celtic Seas	VIIa Irish Sea, VIIb West of Ireland, VIIc Porcupine Bank, VIIg Celtic Sea North, VIIj SW of Ireland - East, VIIk SW of Ireland - West, VIa and VI b
Bangor university	United Kingdom	VII Celtic Seas	VIIa Irish Sea
CNRS	France	VIII Bay of Biscay	VIIIb Bay of Biscay - Central, VIIIa Bay of Biscay - North
AZTI	Spain	VIII Bay of Biscay	VIIIb Bay of Biscay - Central, VIIIc Bay of Biscay - South, VIIId Bay of Biscay-Offshore
EcoLaguna	Germany	IX Portuguese Waters	IXa Portuguese Waters - East, IXb Portuguese Waters - West
HCMR	Greece	Mediterranean Sea	22 Aegean Sea
HCMR	Greece	Mediterranean Sea	19 Western Ionian Sea, 20 Eastern Ionian Sea, 21 Southern Ionian Sea, 22 Aegean Sea, 23 Crete Island
HCMR	Greece	Mediterranean Sea	19 Western Ionian Sea, 20 Eastern Ionian Sea, 21 Southern Ionian Sea, 22 Aegean Sea, 23 Crete Island, 24 North Levant
HCMR	Greece	Mediterranean Sea	20 Eastern Ionian Sea, 21 Southern Ionian Sea, 22 Aegean Sea, 23 Crete Island, 24 North Levant, 25 Cyprus Island, 26 South Levant, 27 Levant
HCMR	Greece	Mediterranean Sea	20 Eastern Ionian Sea, 22 Aegean Sea, 23 Crete Island
CNR-ISMAR	Italy	Mediterranean Sea	17 Northern Adriatic Sea
University of Malta	Malta	Mediterranean Sea	15 Malta Island, 16 South of Sicily
University of Malta	Malta	Mediterranean Sea	15 Malta Island, 16 South of Sicily
UPC	Spain	Mediterranean Sea	6 Northern Spain

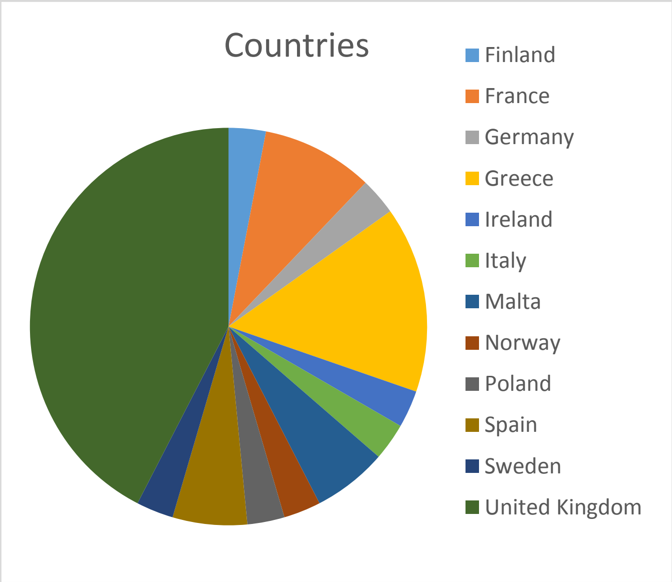


Figure 3-1: Proportion of responses from each European country

3.2.2. Pressures from human activities that are affecting the environment in this area

Fishing was the most commonly identified pressure, with 84% of the responses, followed by marine litter (76%), shipping (68%) and contaminants (68%, Figure 3-2). Pressures could be broadly arranged into four groups: activities affecting seafloor integrity such as trawling, dredging, and extraction; localised pressures related to shipping and construction; pressures from land such as nutrient enrichment and litter; and climate change related pressures. Pressures were generally spread throughout the regions, with respondents having different focuses depending on their knowledge and expertise. Respondents noted that the pressures affecting coastal and offshore areas were not the same. Climate change related pressures were most prevalent in the Baltic and Mediterranean. Although the focus of the responses was on localised pressures, climate change related pressures (regime shift and ocean acidification) were considered to have large potential for widespread harm and in all regions at least one respondent marked regime change as an important pressure. Some pressures were noted to be reduced, e.g. contaminants in the UK.

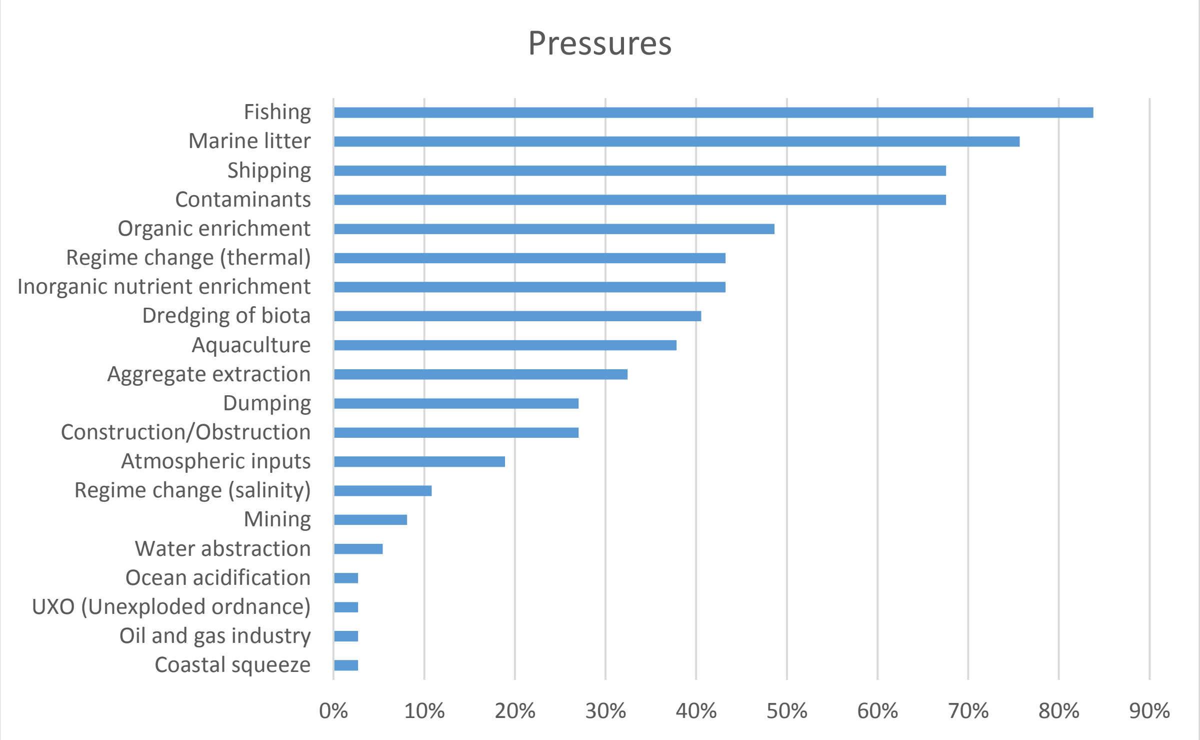


Figure 3-2: Frequency of responses on pressures affecting the marine environment

3.2.3. Impacts resulting from the pressures identified

The majority of respondents (70%) identified habitat loss or destruction as an impact of human activities or pressures on the marine environment (Figure 3-3). More than 60% of respondents identified contamination (68%) and invasive species (62%) as impacts. More than 50% identified population change/depletion of standing stocks (54%), underwater noise disturbance (51%) and changes in community composition (51%). Other impacts were related to physical damage (49%), changes in species ranges (46%), undesirable disturbances (43%), changes in primary production (41%), mortality of marine life (38%), changes in the physical or chemical attributes of the water (19-38%, such as substrate composition, turbidity, light availability and hydrology) and biofouling (19%). The scale of impacts varies widely (see Section 4), with some activities, such as construction of a wind farm having a potentially high impact on a small area, whereas activities such as fishing are more widespread. The impact of human activities also depends on the vulnerability of the habitat in question. For example, in the southern Celtic Sea there are fragile benthic habitats such as cold water corals which are highly impacted by sea floor activities. Some impacts, such as noise disturbance, depend on the intensity of the activity, these will be concentrated in areas with high shipping activity, or in periods of construction.

One participant in the survey was concerned about impacts of unexploded ordnance (UXO), with respect to contamination (for example, with harmful substances) and mortality of marine life. The participant highlighted that these UXOs are imminent threats and that there is very little proactive and concerted action to find, identify and eradicate subsea stockpiles of old munitions.

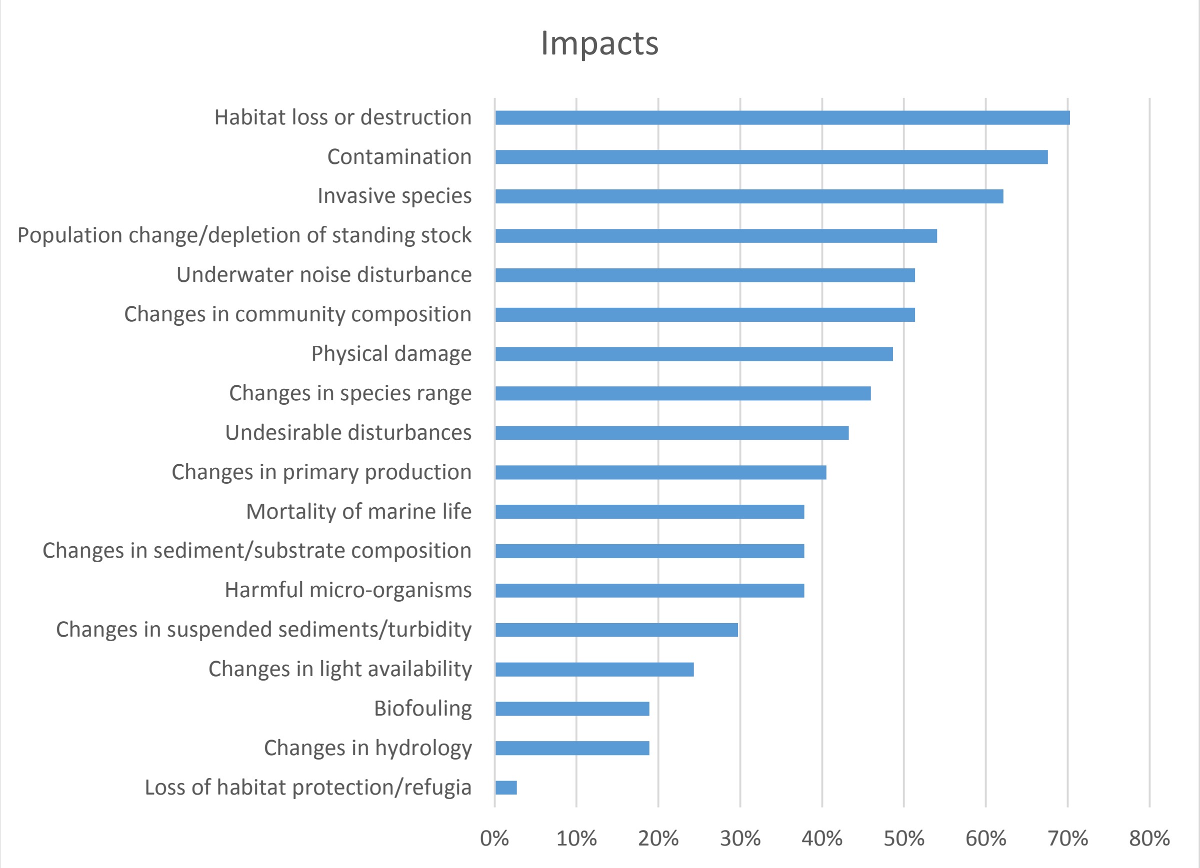


Figure 3-3: Frequency of responses on environmental impacts affecting European coastal seas.

3.2.4. Linkages between threats and impacts

In the questionnaire, threats were described as the human activities (pressures) which have significant negative impacts on ecosystems or parts thereof (see Oesterwind et al 2016[1]). The majority of pressures were directly due to human activities such as fishing and organic and inorganic nutrient enrichment. However, some pressures, such as regime changes (reflected in changes in salinity and/or water temperature) are the indirect effects of human activities (such as emissions to the atmosphere), largely due to climate change. Respondents were given an opportunity to provide free text if they felt that the questionnaire structure did not meet all their needs to express their concerns.

Linkages between threats (pressures leading to significant negative impacts) and impacts can be complex, as impacts may be the cumulative effect of multiple pressures. For the five impacts that received the highest percentage of responses (Figure 3-3), potential links to the pressures identified in the questionnaire are demonstrated in Figure 3-4. Habitat loss or destruction, for example, may be due to fishing activity, aquaculture, aggregate extraction, dumping, dredging, mining, construction/obstruction and/or regime changes. Similarly, invasion by non-indigenous species (such as plankton or fish) may be due to fishing activity, aquaculture,

[1] ***Pressures*** *can be described as 'a result of a driver-initiated mechanism (human activity/natural process) causing an effect on any part of an ecosystem that may alter the environmental state'.* ***Impacts*** *can be defined as 'consequences of environmental state change in terms of substantial environmental and/or socio-economic effects which can be both, positive or negative'.*

shipping and regime shifts, where warming water temperatures and changes in ocean circulation enable species to expand their ranges.

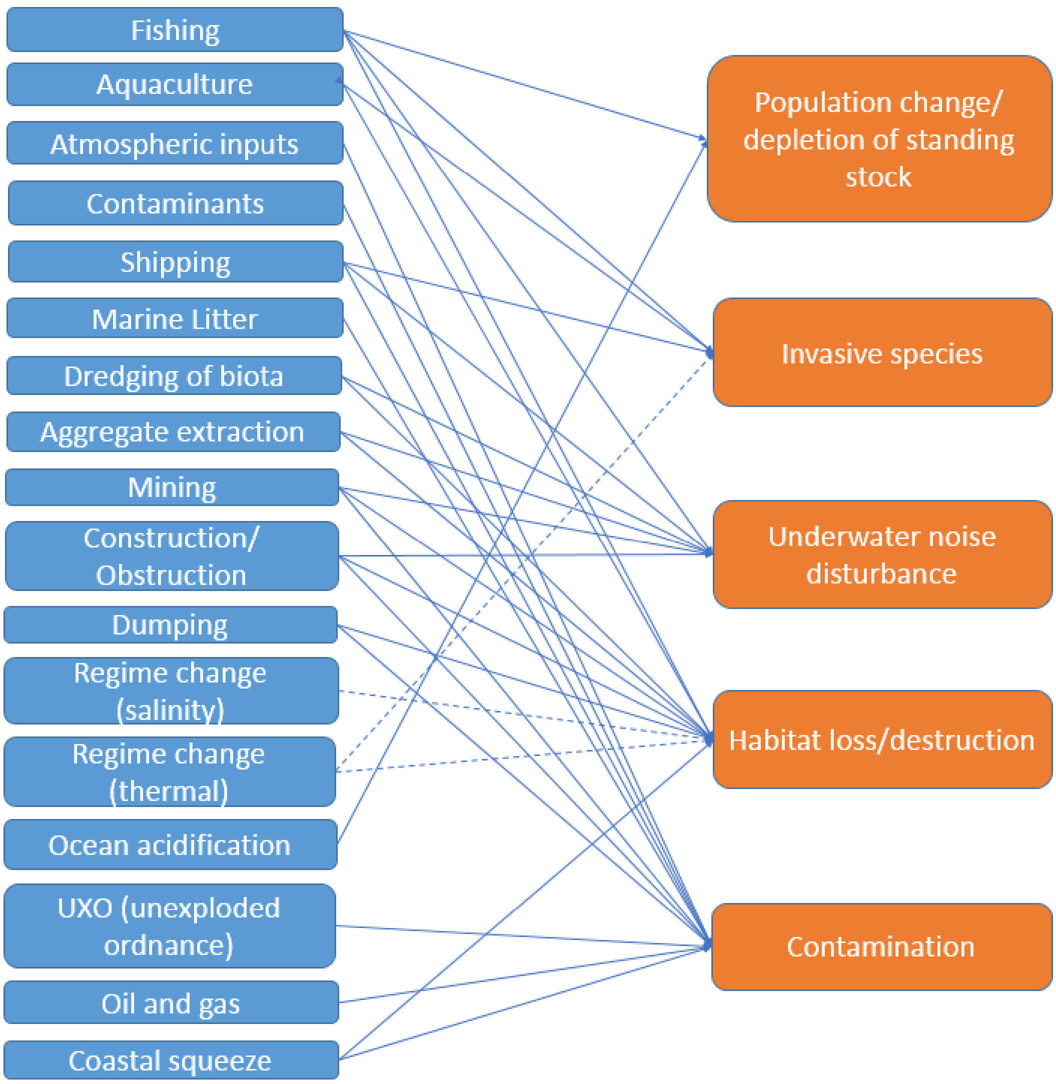


Figure 3-4 Links between threats (pressures in blue) and the five impacts with the greatest percentage of responses in the questionnaire. Dotted lines indicate indirect impacts.

3.2.5. Policy purposes

The respondents to the questionnaire identified the main drivers of monitoring of coastal and offshore waters as the implementation of the EU Marine Strategy Framework Directive (MSFD, EU 2008) and the Water Framework Directive (WFD, EU 2000, Figure 3-5). Other EU directives identified included the Urban Waste Water Treatment Directive and Nitrates Directive (EC 1991a, b); the proportion of respondents identifying these as policy purposes was relatively low (<30%, Figure 3-5), presumably because a lot of monitoring towards these older directives is now included in WFD monitoring programmes implemented under River Basin Management Plans of Member States. These results highlight that policy drivers may change over time but overall purposes may remain the same or similar. Regional Seas conventions were also identified as key policy drivers of monitoring programmes, with a greater proportion of responses for OSPAR than for HELCOM. These results are likely to have been influenced by the larger proportion of respondents from the UK compared to other contracting parties. Local policy drivers were identified by almost 30% of respondents, but no details were given.

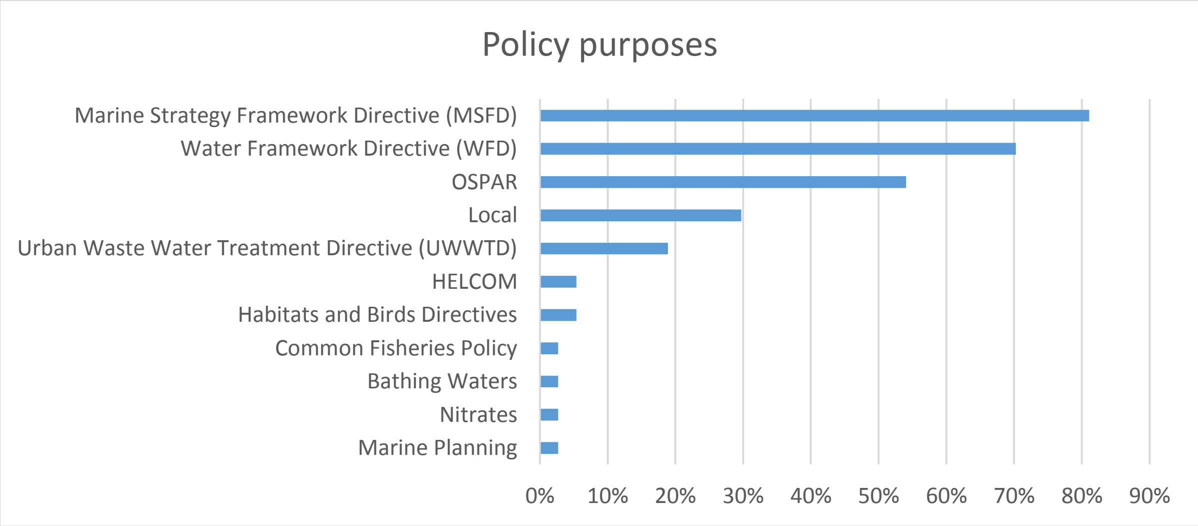


Figure 3-5: Main policy or other drivers for marine monitoring

All environmental threats in European waters could be linked to the descriptors in the MSFD. Responses indicated that most threats (76%) could be linked to the biodiversity descriptor (D1, Figure 3-6), closely followed by the marine litter descriptor (D10, 73%), contaminants (D8, 65%), non-native species (D2, 59%) and fish (D3, 59%), eutrophication (D5, 57%), sea floor integrity (D6, 54%) and food webs (D4, 51%). Links between threats and the remaining descriptors (D7, D9 and D11) were also reasonably high, with 35% to 38% of respondents supporting these links.

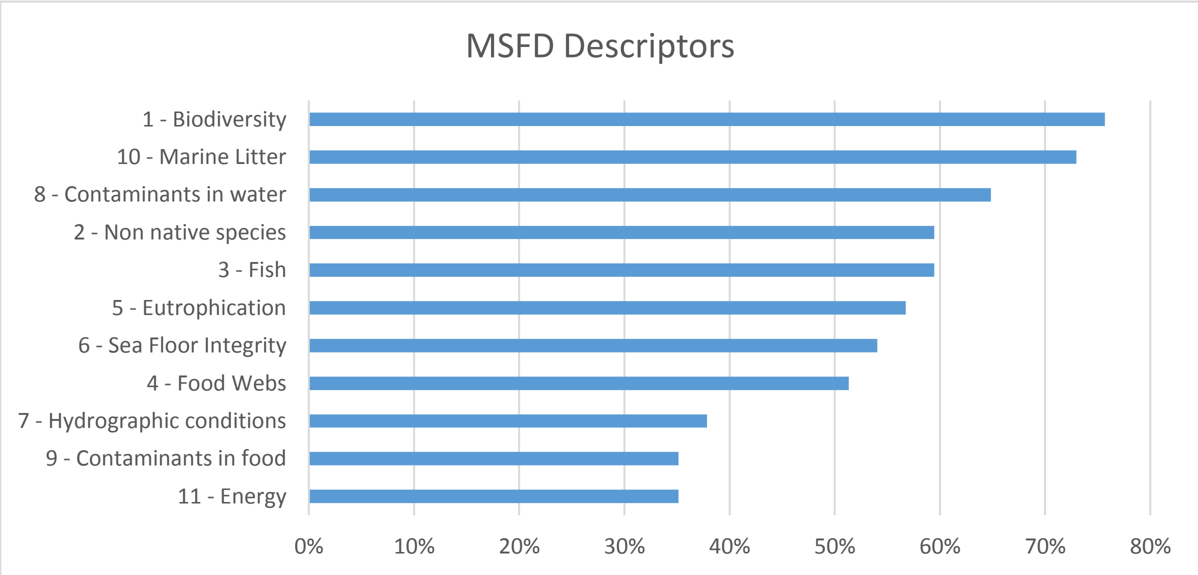


Figure 3-6: MSFD Descriptors linked to environmental threats. The left axis shows the descriptor number and name.

Complex linkages between pressures and impacts and the cumulative effects of multiple pressures are not currently addressed by any of the key policy drivers. The MSFD was intended as a holistic approach to assessments, but currently follows an approach where descriptors are dealt with separately. Developments are underway to move assessments towards a more integrated cross-disciplinary approach (e.g within OSPAR), which will require more co-ordinated monitoring across descriptors, and a focus on acquiring long-term data sets (Tett et al. 2013). Long-term data sets are also highly relevant to assessments under the MSFD, which focusses on trends in pressures and impacts. For both OSPAR and MSFD assessments, levels of confidence in the data and in the assessments and an evaluation of the representativeness of the data in both time and space are key elements. This requires sufficient data (by assessment region and over the assessment period) and information on assessment thresholds per indicator. For indicators agreed by the European Commission and for indicators under development, issues of geographical and temporal scales will need to be addressed (see Section 4).

3.3. Monitoring Programmes

In response to the questionnaire, 38 monitoring programmes were reported (Table 3-3). This is not a complete inventory of monitoring in Europe, but provides examples of a variety of monitoring programmes. Entries for the UK, Ireland and Greece are believed to be relatively comprehensive.

Table 3-3: List of monitoring programmes reported by respondents to the questionnaire

Country	Name of monitoring program
Belgium	Measurement net Flemish banks
Finland	Finnish national monitoring programme
France	REPHY
France	French benthic monitoring
France	SOMLIT
Greece	POSEIDON
Greece	WFD monitoring
Greece	Coastal area monitoring
Ireland	Advanced Mapping Services
Ireland	National Tide Gauge Network
Ireland	Irish Weather Buoy Network
Ireland	SmartBay Observatory
Ireland	Residues in Farmed Finfish
Ireland	National biotoxin and phytoplankton monitoring programme
Ireland	Irish Maritime Development Office (IMDO)
Ireland	Marine Licencing Authority
Ireland	Nutrient Monitoring Programme
Ireland	Trace Metals Monitoring Programme
Ireland	Water Framework Directive (WFD)
Ireland	Fish Health
Ireland	Oceanographic Services
Ireland	Euro-Argo
Italy	PALOMA station time series
Italy	PALOMA elastic beacon time series
Poland	Monitoring of the Baltic Sea in the Polish EEZ in 2014-2017

Spain	Basque monitoring network
Spain	SOCIB; Balearic Islands multi-Platform Observing System
Spain	Monitoring of costal water in Catalonia
Spain	Obsea Project
United Kingdom	CSEMP, Dredge Disposal, Litter and Fish Biological Monitoring
United Kingdom	Continuous Plankton Recorder survey
United Kingdom	CSEMP - contaminants
United Kingdom	MCS Beachwatch
United Kingdom	Scottish Groundfish Surveys
United Kingdom	Scottish Inshore Ecosystem Monitoring
United Kingdom	Scottish Offshore Ecosystem Monitoring
United Kingdom	Scottish Coastal Observatory

3.3.1. *Monitoring: variables, platforms and frequency*

Most monitoring programmes (approximately 60%, Figure 3-7) were reported to measure temperature and salinity. Nutrients, chlorophyll and dissolved gases were also measured in a large proportion (39-45%) of programmes, although it should be noted that not all parameters are measured at all stations in a monitoring programme. Many variables, such as marine litter, toxins, seabirds and mammals are only measured in specific monitoring programmes designed for the purpose. Some variables were monitored in surprisingly few national programmes, such as sea level and contaminants, but this may just be a reflection of the selection of responses received. Responses to the questionnaire indicated that marine monitoring programmes provide less coverage of biological parameters (e.g. plankton 32%, benthos 18%, fish 18%, macroalgae 11%, birds 3%) than physical water column parameters (e.g. temperature, salinity, 58-61%) and chemical parameters (e.g. nutrients, dissolved gases, 45% and 39%).

The FP7-JERICO report on fixed platforms (deliverable D3.3 http://www.jerico-ri.eu/download/filebase/jerico_fp7/deliverables/Fixed%20platforms%20report21.pdf) reviewed which parameters are measured at which stations (Collingridge et al. 2013). It was found that physical oceanography parameters (such as sea level, temperature, and waves) were measured at many JERICO-RI platforms whereas biogeochemical parameters such as nutrients and chlorophyll were only measured at a handful of platforms. Complementary between monitoring programs and JERICO-RI observations is therefore expected.

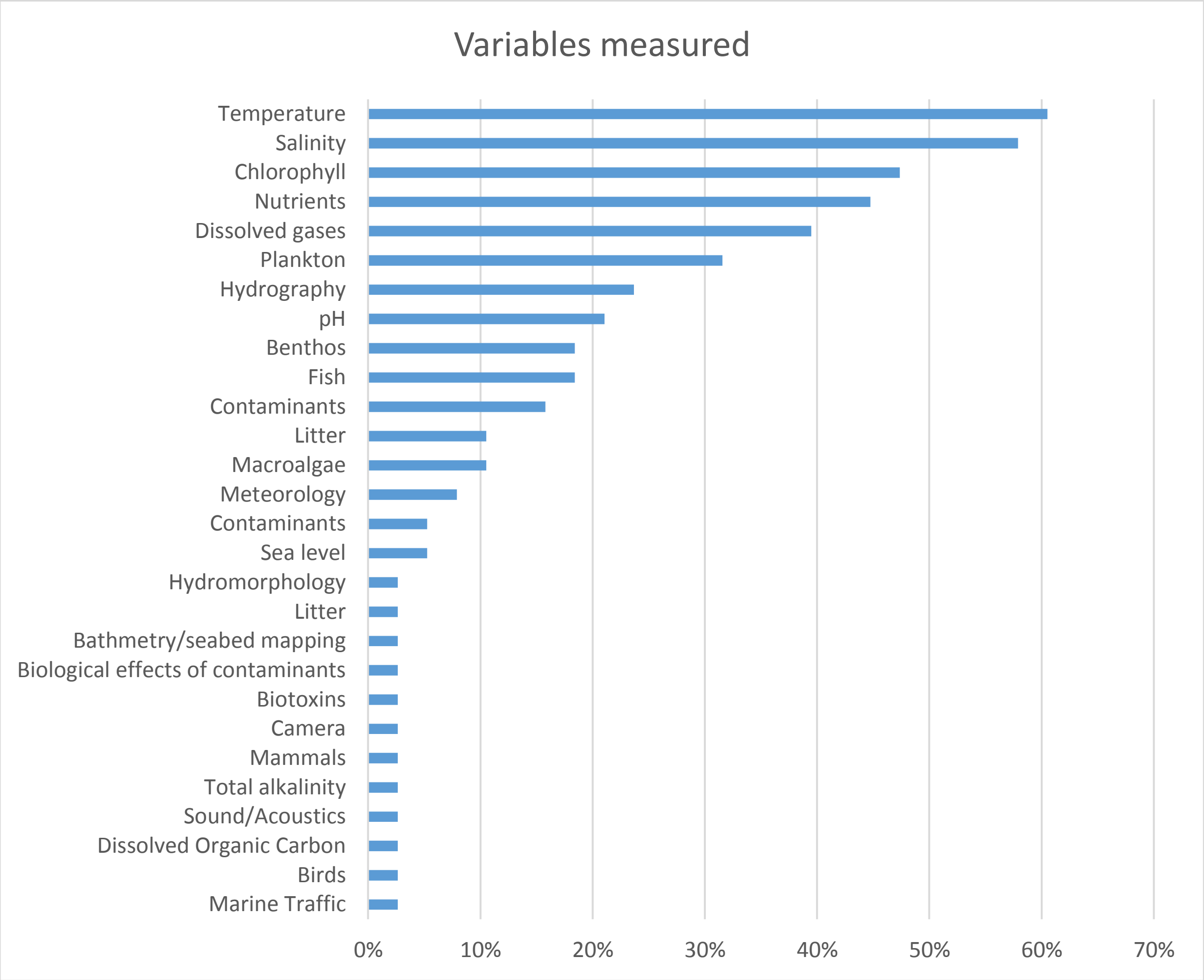


Figure 3-7: Variables measured in marine monitoring programmes

Most monitoring programmes were reported (76%, Figure 3-8) to use some sorts of vessel, mostly a research vessel or small boat for more inshore monitoring. Shore based monitoring was also common (39%). The use of fixed platforms was indicated by 34% of respondents, including Belgium, Greece, Ireland, Italy, Spain and the UK. The use of remote sensing as a monitoring platform was reported by 21% of respondents (Figure 3-8), although it is likely to complement other types of monitoring, rather than to replace it. Other innovative and emerging technologies, such as autonomous vehicles and profiling floats were included in 11% of the responses. The use of Ferryboxes on fixed transects or cruises of opportunity was also low (<10%, Figure 3-8).

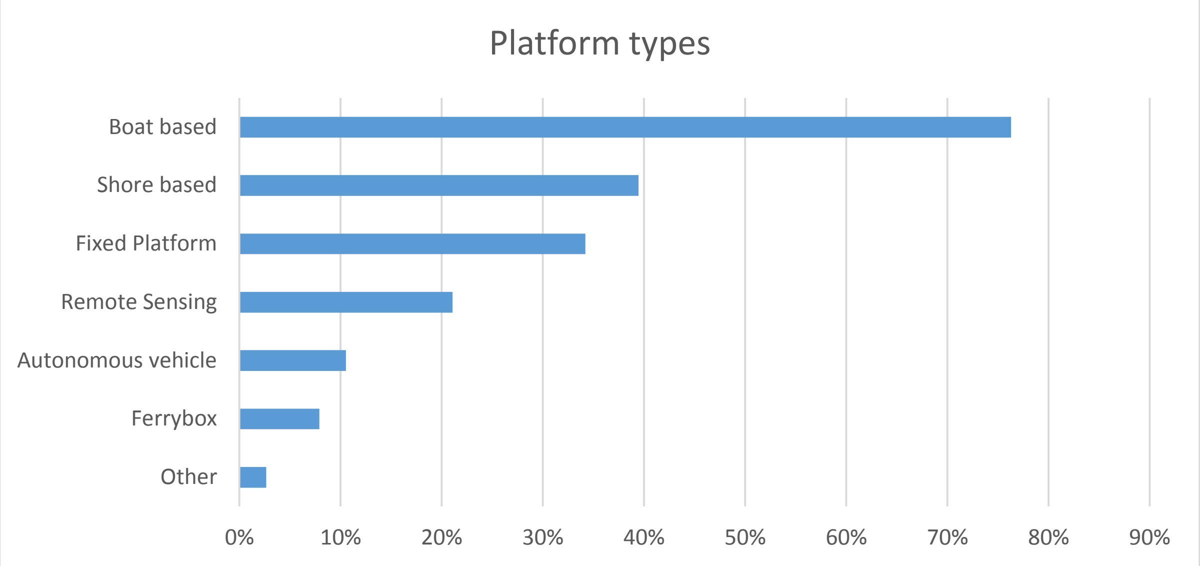


Figure 3-8: Platform types used in marine monitoring.

Responses to the questionnaire indicated that the frequency of monitoring (Figure 3-9) is highly variable. Results are shown separately for all options given in the questionnaire (Figure 3-9), and grouped into three categories (regular, continuous, intermittent, see inset in Figure 3-9). All responses to regular/routine sampling (annual, seasonal, quarterly, bimonthly [six times a year], monthly, fortnightly, weekly, and hourly) were combined into one category labelled 'regular'. Results shown separately for each platform indicate the highest proportion of responses (34%) were for continuous monitoring (e.g. from fixed platforms, moorings or gliders), whereas monitoring on other 'regular' time-scales (monthly, annual etc) made up the greatest proportion of responses (73%), when combined into one category. Several monitoring programmes had only annual monitoring but monitoring was comprehensive in terms of parameters and spatial coverage. Monitoring programmes incorporating fixed platforms or gliders were more restricted in spatial scope.

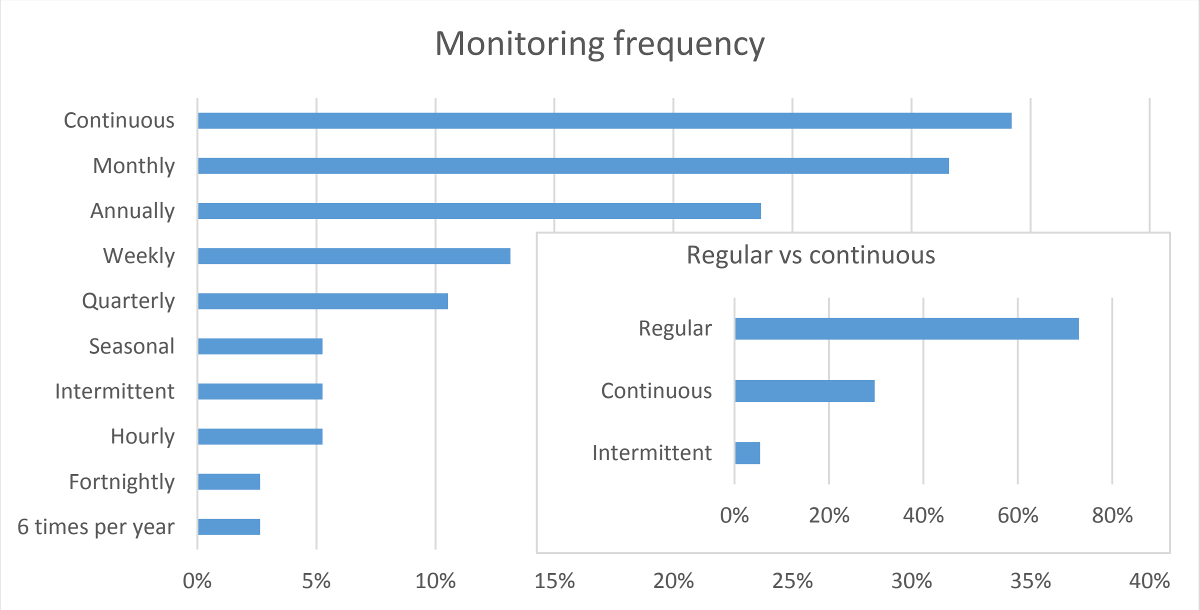


Figure 3-9: Frequency of monitoring. The main graph shows results for all options given in the questionnaire. The inset combines these into three categories: continuous and intermittent are the same as in the main graph, regular = all other categories combined

3.3.2. Sustainability and frequency of monitoring programmes

Questionnaire responses showed that 68% of the monitoring programmes have been running for more than 10 years, which would enable the detection of temporal trends in the data. The longest running monitoring programme was the continuous plankton recorder survey run by the Sir Alister Hardy Foundation for Ocean Science (SAHFOS), which has been running since 1931. Several of the French and Scottish monitoring programmes have been running for approximately 30 years. Long-term monitoring programmes such as these provide valuable long-term data sets which are highly relevant to present-day policy drivers (see Section 3.2.5), particularly for addressing cross-cutting issues such as climate change and ocean acidification. Furthermore, they highlight the importance of overall scientific objectives underpinning monitoring programmes to meet the purposes of policy drivers, which change over time. One respondent to the questionnaire included a monitoring programme which had ended due to lack of funding, but it is likely there were many more which were not reported.

More than half of the monitoring programmes reported were official or statutory ones, but a significant proportion were unofficial or project based. This indicates challenges and risks to the sustainability of monitoring, as there is no guarantee that unofficial monitoring based on short term projects will be continued.

3.3.3. Data access

Many respondents (71%) reported that their monitoring programmes had no restrictions on data access, presumably reflecting public funding of the programmes. Where data access was restricted, most programmes do make the data available on request, subject to information on the intended purpose or a review of the use of the data, signing a licence agreement, and/or requirements to acknowledge the source of the data, for example through the use of a DOI. Three respondents did not specify what the restrictions were.

Respondents who answered the questions on data access, reported that data were submitted most commonly to local/national databases, but also frequently to ICES databases, EMODNet or Copernicus. However, for the majority of programmes, data flows to these central databases were not up to date, indicating that not all monitoring data are available centrally.

It is important to notice that no restriction to access does not mean that the data are easily accessible.

3.4. Monitoring Stations

Some participants in the questionnaire provided georeferenced information on monitoring stations in their regions, using the spreadsheet template which was provided. The aim of this section of the questionnaire was to determine where sites are sampled during monitoring programmes. Maps of the locations of monitoring stations, by platform type (Figure 3-10) and programme name (Figure 3-11) are likely to reflect stations which are sampled routinely as part of monitoring programmes. What they do not show are the sites and stations which are sampled during ship-based surveys conducted for other purposes, but provide data on the same variables as the monitoring programmes, and therefore make a valuable contribution to available data sets. Many of these data are generated by research projects or programmes and are available through data portals such as the European Marine Observation and Data Network (*EMODnet*, see Figure 3-12), or international databases such as the ICES, OBIS (Ocean Biogeography information system) and GBIF (Global Biodiversity Information facility) databases (see Figure 3-13). However, data flows to these data bases are often not kept up to date (see Section 3.3.3). The full extent of data availability for the Mediterranean remains unclear, as data are not available from ICES. A review of monitoring stations associated to the JERICO-RI can be found in FP7-JERICO deliverable D1.11 (http://www.jerico-ri.eu/download/filebase/jerico_fp7/deliverables/D1.11%20Achievements%20and%20Strategy%20for%20the%20Future.pdf).

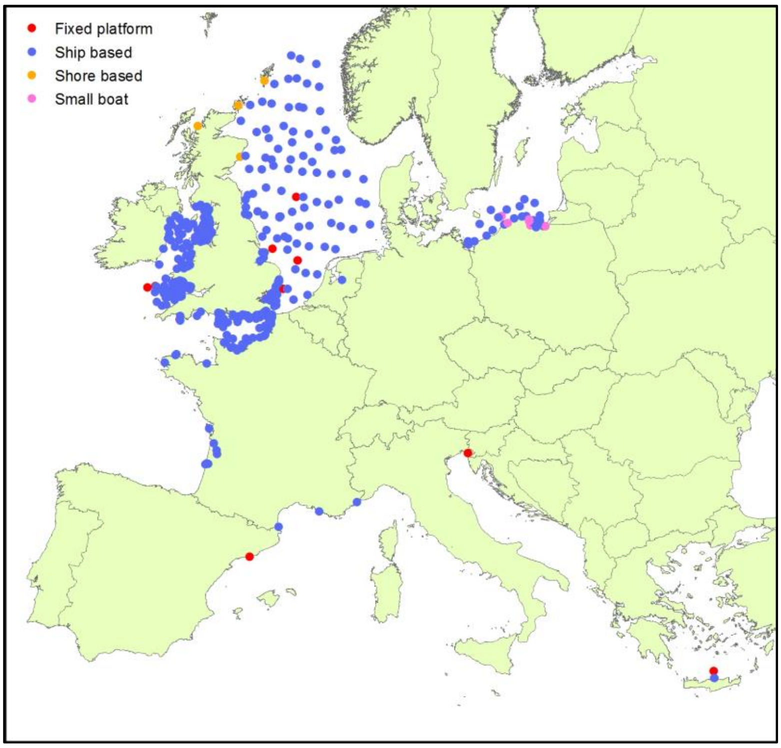


Figure 3-10: Locations of monitoring stations, shown by platform type - fixed platforms, ship-based sampling, shore-based sampling and sampling from small boats.

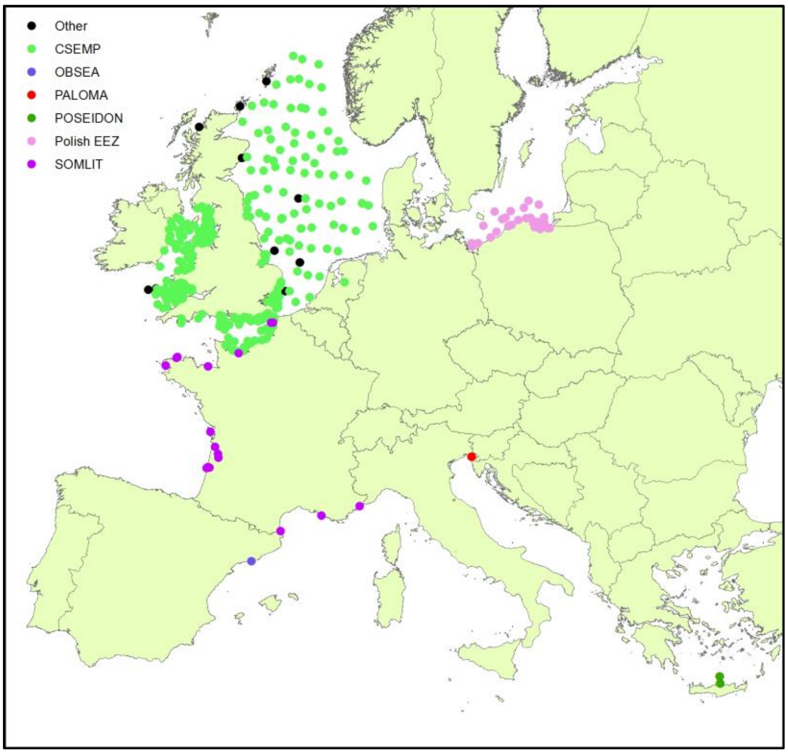


Figure 3-11: Locations of monitoring stations, shown by programme name (see Table 3-3).

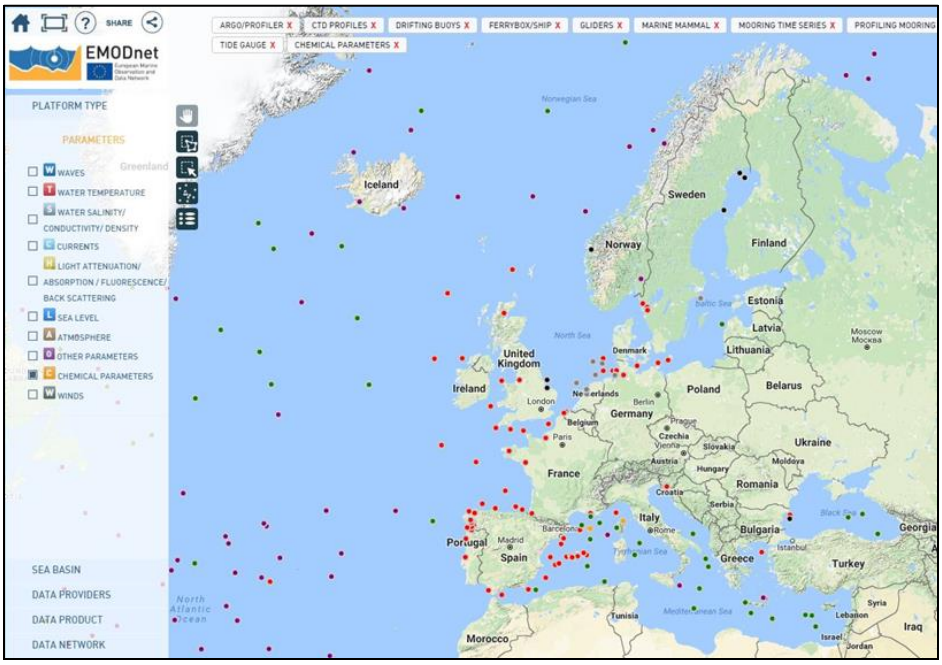


Figure 3-12: Map from EMODnet, showing locations of sampling for chemical parameters, for all stations reported to EMODnet.

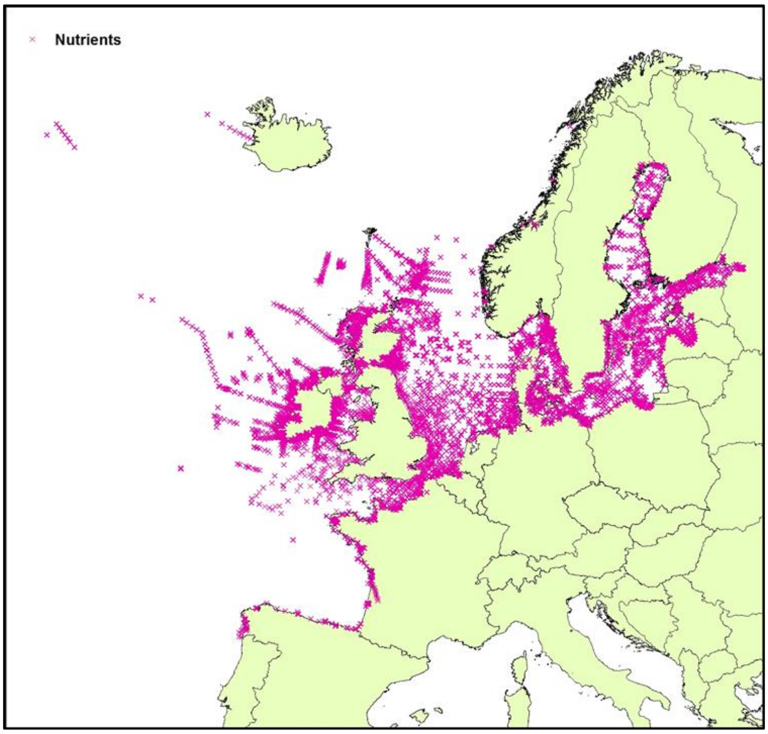


Figure 3-13: Map showing locations of nutrient sampling using data extracted from ICES (2006-2016). Data for Mediterranean regions were not available.

3.5. Gaps identified in current national monitoring programmes

Only 12% of the respondents to the questionnaire considered monitoring programmes to be adequate (Figure 3-14) in terms of providing the information required to monitor and address environmental threats, while one quarter (26%, Figure 3-14) of respondents considered monitoring programmes to be inadequate. The greatest proportion (62%, Figure 3-14) of respondents to the questionnaire considered monitoring programmes to be partly adequate for addressing environmental threats.

The questionnaire included comments boxes for free text, to enable respondents to give details on their views and responses. Views on why monitoring is not adequate or only partly adequate were given by some of the participants who gave one of these responses ('not' adequate or 'partly' adequate), as well as suggestions on how to improve the monitoring of environmental threats. Relatively little detail was given in these free text boxes, but the range of views that were given showed that a broad spectrum of participants responded to the questionnaire, and that their comments reflected different experiences in their areas of expertise and in their different countries. The free text responses are summarised below. Where examples were given, they have been included, to illustrate responses given. None of the examples gave much detail, but are useful for highlighting general principles. A more detailed case study is given in Section 4 of this report to further highlight the key issues.

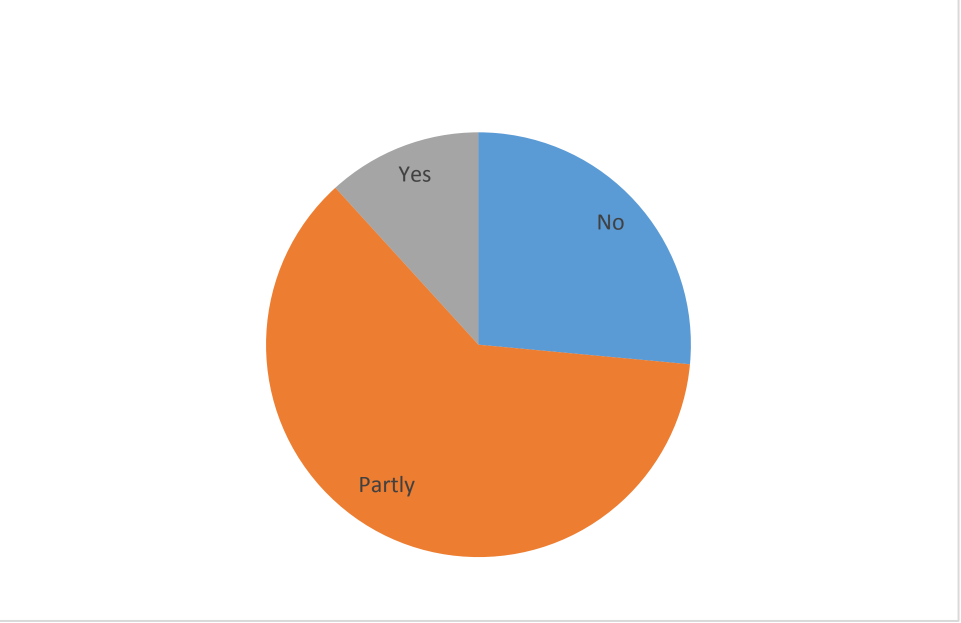


Figure 3-14: Proportion of respondents who considered monitoring programmes to be adequate (Yes), inadequate (No) or partly adequate (Partly)

3.5.1. Where monitoring is partially adequate

The greatest proportion of respondents (62%, 21 respondents) considered monitoring programmes in their countries to be only partly adequate for monitoring and addressing the impacts of environmental threats on the marine environment. The majority of these responses (48%, 10 respondents) were related to scales at which monitoring takes place, in terms of spatial and/or temporal resolution. Some respondents also felt that there was inadequate monitoring of particular parameters.

Countries such as the UK have adopted a risk-based monitoring approach, which was considered to result in fragmented monitoring. Examples of low spatial resolution were given for the CPR survey, one of the key plankton datasets, where spatial gaps exist throughout EU waters. Spatial resolution was also considered to be low for some habitats, as not all habitats are covered in monitoring. The same applies to marine litter and non-native species monitoring programmes.

In terms of spatial resolution, other responses indicated that not all parameters are monitored adequately. Responses included biochemical parameters, although no examples were given, and zooplankton. The WFD does not require zooplankton monitoring, but some indicators under the MSFD do require information on zooplankton. Although phytoplankton is monitored inshore, the data are disparate and mainly used to report on potential health issues due to toxin producing algae.

Examples of low temporal resolution were given for a number of threats. For example, for statutory monitoring of impacts such as those from dredging and disposal, where monitoring is often over time scales which are too short (2-5 years) to properly assess the impacts on the biological communities. Also, for seabirds and cetaceans. However, monitoring of seabirds and cetaceans is out of the scope of JERICO-Next. For some threats, which were not specified, monitoring of local impacts was considered to be deficient.

A number of respondents were of the view that there are many inadequacies in the monitoring programmes. For some of the descriptors, there is insufficient information. These included some biodiversity components, food-webs, marine litter, underwater noise, emerging contaminants, emerging pollutants, and micro-plastics. Coupling between physics and biology in response to environmental pressures is typically not included in monitoring programmes focussed on individual descriptors. One respondent indicated that methodologies and approaches were not state-of-the-art, for example, the focus during benthic sampling was on taxonomy instead of ecosystem functions and services.

The respondents gave several suggestions for improving monitoring programmes considered to be only partly adequate. These were focussed on improved design of monitoring programmes and increased effort, observations and research, as follows:

- Improved design of monitoring programmes:
    - Develop a coordinated programme to monitor biodiversity components not yet monitored
    - Integrate monitoring programmes, and include more stations
    - Systematically monitor marine litter and noise
    - Improve monitoring of the small plankton
    - Improve monitoring of beaches in some countries
    - Make better use of low cost biochemical sensors on low cost platforms
    - Secure funding for long-term monitoring programmes
    - Increase monitoring in high-risk areas
    - Increase monitoring of poorly covered habitats
    - Include flexible research/investigative monitoring to increase knowledge of specific impacts
- Increase observations in time but also in space. Include parameters that provide information on ecosystem functions.
- Increased and long-term monitoring of zooplankton. Better spatial coverage, including inshore.
- Develop monitoring programme that are fit-for-purpose, through working with policy end-users. For example, work planned in the Welsh sector of the Irish Sea to develop offshore renewables industries will result in considerable local impact. Appropriate monitoring needs to be installed to measure a range of physical and ecological variables in order to assess impact.
- To assess availability of information in relation to pressures. In Wales, for example, there is a recognition that there is incomplete information on the fishing pressure on inshore fisheries. Steps are being taken to

introduce inshore Vessel Monitoring Systems that will automate the process of gathering better information on fishing activity and seabed disturbance.

3.5.2. Where monitoring is not adequate

Approximately one quarter of respondents (28%, 10 respondents) considered monitoring programmes in their countries to be inadequate for monitoring and addressing the impacts of environmental threats on the marine environment. The majority of responses were similar to those given in Section 3.5.1, and were related to spatial and/or temporal scales (67%, 9 respondents) at which monitoring takes place, and inadequate monitoring of parameters.

Two respondents highlighted concerns about the links to policy drivers. One commented that monitoring programmes develop to respond to pressures and impacts. Another highlighted concern related to lack of political or commercial interest and provided an example for unexploded ordnance, for which there seems to be very little political or commercial interest in finding and making safe dumped munitions. It is only when a person or marine life is found with injuries or abnormal growth that this matter receives any active intervention.

Examples of monitoring programmes with low spatial resolution were given for sub-regions of Mediterranean Sea; point source monitoring of contaminant inputs, controls and improvements; benthic habitats for the wider environment, and deep sea areas. Examples of inadequate monitoring of parameters were given for the Mediterranean Sea: zooplankton, phytoplankton compositions, marine mammals, reptiles, birds, invasive species, marine litter, and contaminants in sediment and biota.

Respondents also gave a number of suggestions for improving monitoring programmes considered to be inadequate. These were also focussed on improved design of monitoring programmes and increased effort, observations and research, as follows:

Suggestions:

- Improve the design of monitoring programmes:
    - To meet policy needs, e.g. for spatial representativeness of data; benthic habitats in the wider environment (beyond MPAs)
    - Deployment of additional observatories will be necessary for the assessment of biodiversity and water quality. JERICO-RI may contribute to filling in the gap, especially for water quality and biodiversity of phytoplankton
    - To take into account regional or national specificities (e.g. sub-regions of regional seas)
    - Consistent and routine monitoring in fixed points (e.g. around the island, Malta island, south of Sicily)
    - To monitor also marine waters extending beyond the coastal zone and adding more biological and chemical parameters ex. zooplankton, microbes, marine mammal (e.g. Mediterranean Sea)
    - To develop a limited number of long-term monitoring sites in remote areas to monitor changes in baseline conditions (chemistry, ecotoxicology, and ecosystem structure) in response to climate change/acidification, and diffuse inputs; incorporation of newer threats (e.g. phosphorous-based flame-retardants, microplastics, noise) into regular monitoring
    - Implement systematic monitoring based on rigid baseline ecological assessment (at small local scales, e.g. Mediterranean Sea)
    - For unexploded ordnance (UXO), monitoring should indicate the stability of the UXO and toxic weapons and their likelihood of causing harm or changes in biota. What is the philosophy of monitoring if not to gather information for intervention? We must be more proactive.

4. The scale issue: implications for monitoring

Among the 30 answers to the "threats questionnaire" stating that monitoring programs were not (or only partially) sufficient to accurately assess the effects of the mentioned main environmental threats acting in the considered areas, 16 raised important issues relevant to the spatial and/or temporal scales at which current monitoring programs are carried out. The issue of scales emerges as essential in establishing a future pan-European monitoring program. It is nevertheless interesting to underline that the importance of this question is clearly dependent on monitored parameters and threats. It is for example clearly more important in biological than in physical oceanography. There are several rationales for that:

(1) The number of biological data that can be automatically or semi-automatically acquired remains very low despite recent technological developments (including those achieved within FP7-JERICO and JERICO-NEXT), which limits the spatio-temporal coverage of biological/biogeochemical data sets
(2) Miniaturization of sensors allowing for their implementation on mobile carriers such as AUVs and floaters has been mostly achieved for physical and chemical ones, which results in better spatial and synoptic coverage
(3) Scaling-up from "point" observations to wider areas most often relies on modelling. Corresponding models are clearly more advanced for physical than for biogeochemical and further more biological ones, which also contributes to increase the importance of scales for biological observations.

Based on these considerations, the following discussion will be mainly based on biological considerations, since this scientific domain is likely to be the one with greatest challenge related to scale dependency.

4.1. General considerations on scale-issues

For biological monitoring, the question of scale is linked to several aspects: (1) the conversion of observations to Ecological Quality status (EcoQ), where the concepts of the Essential Environmental Variables (EEVs) and Essential Biodiversity Variables (EBVs) provide lots of potential for a reliable and inter-calibrated estimation of the EcoQ, (2) the nature/dynamics of monitored threats/disturbances and the scale associated with reporting within European (Water Framework Directive and Marine Strategy Framework Directive).

4.2. Conversion of observations to EcoQ

The observation-to-EcoQ conversion will be discussed based on the example of the monitoring of biological communities. The approach put forward by the WFD is shown in Figure 4-1. In this approach, the assessment of EcoQ involves the comparison of the value of a biotic index between the site to be characterized and a reference one, which is considered in a good EcoQ. This leads to the computation of an Ecological Quality Ratio (EQR), which is then converted in an "absolute" EcoQ using a pre-defined conversion scale.

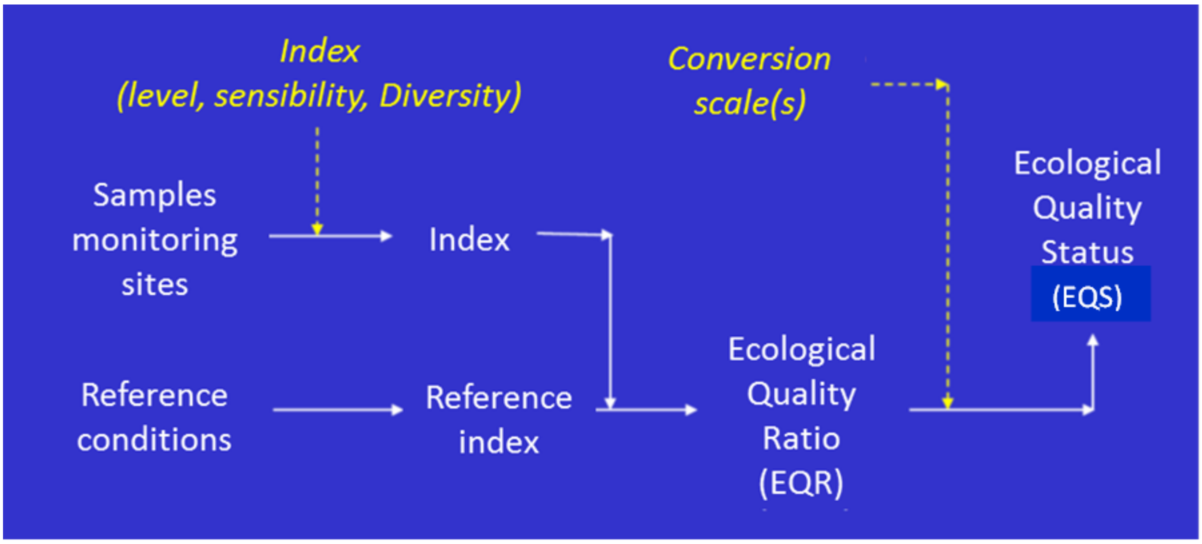


Figure 4-1: Schematic diagram of the establishment of the Ecological Quality Status (EQS) from monitoring programs data under the WFD policy.

In practice, this approach presents three main difficulties:

(1) **Reference sites must be located in the same habitat as characterized sites**. As far as Europe is concerned, and because of the generalization of anthropogenic effects, they prove difficult to find, as demonstrated within the BIOMARE research project during which 12 near to pristine site have been defined within European waters (Warwick et al 2003), mostly associated with islands, which constitute specific entities from a biogeographical standpoint.

(2) The **use of historical data as references is hazardous** because differences in EcoQ between the sampling dates of the reference and the site to be characterized may result from its “natural” temporal dynamics and not necessarily from a change in EcoQ due to a specific threat/disturbance. Resulting EQR may indeed reflect changes due to both a (presumed) threat/disturbance and natural long-term dynamics, impeding our understanding of the real underlying driver of change. This is especially noticeable in coastal marine environments, which are highly dynamic and subject to different natural temporal climatic cycles influencing the structure of biological communities (Auber et al 2015, Dipner and Kröncke 2003, Labrune et al 2007). Finally, time series data are primarily collected from disturbed or severely impacted habitats in coastal areas while the reference stations are placed far away from the impacted stations.

(3) **Conversion scales are difficult to establish** and some of them (i.e., the isometric ones) appear largely subjective (Rosenberg et al 2004).

The above-listed sources of uncertainty have proven very difficult to overcome, which explains why the MSFD has introduced the concept of “trajectory” (or temporal sequence of states Figure 4-2), which assesses either an improvement or a degradation of the EcoQ at a given site as compared to its previous temporal status. This clearly solves the question of the conversion scale, which simply becomes no longer necessary. The questions linked to the reference site can also be handled by monitoring several sites in a given habitat and comparing their trajectories. This approach however remains based on temporal comparisons and thus potentially subjected to interferences with natural temporal dynamics and their interface with threats/disturbances acting at different spatial/temporal scales. One way to overcome these issues is to monitor a set of stations per habitat and assessing the effect of threats/disturbances based on either the deviation of a subset of stations (i.e., outliers) from the other ones (case of local threats/disturbances) or the occurrence of regime shifts in the long-term trajectory of the whole set of stations (case of threats/disturbances acting over a large spatial scale). In this later case, this would require the acquisition of long-term time series to document the temporal dynamics of the monitored habitat as stated by the Finnish representative in answering the questionnaire.

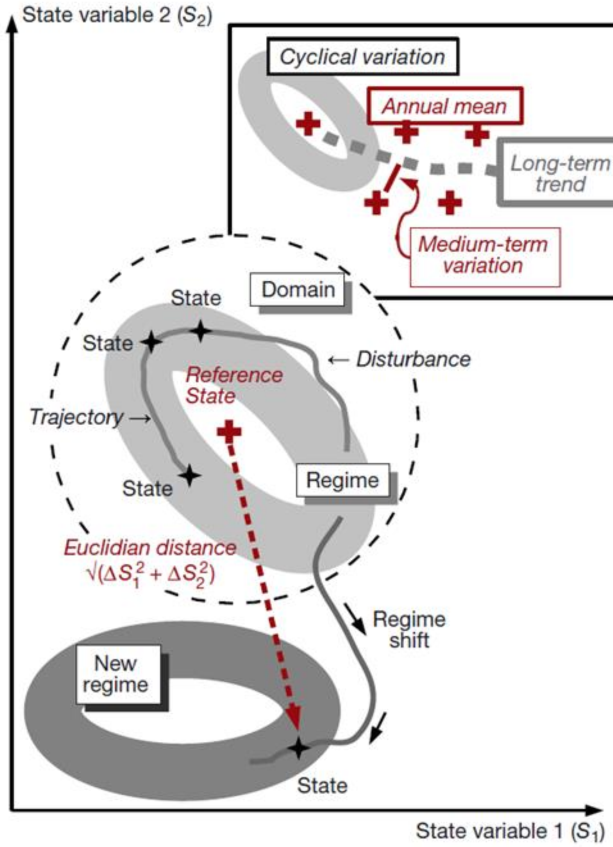


Figure 4-2: Definitions relating to system state variable space, exemplified for 2 axes, but generalizable to any number of dimensions. A state is represented by a point in state space; a trajectory is a (temporal) sequence of states; a regime is a coherent bundle of trajectories, such as those arising from seasonal cycles; a domain is a region in state space. The Euclidian distance gives the (shortest) scalar distance between 2 points in a state space of any dimensionality (Tett et al., 2013).

4.3. Nature/dynamics of monitored threats/disturbances and reporting

4.3.1. Small scale threats/disturbances

Environmental threats can first act at a relatively small spatial (and then most often temporal) scales. This is for example the case of the accumulation of marine litter, the development of green tides (due to nutrient overloading) or the spatial expansion of non-native species, which all mainly rely on the location of the point source pollution and on the characteristics of the abiotic and biotic components of the environment. In this case, there is no apparent discrepancy in spatial scales between monitoring and threats/disturbances. However, the number of monitored habitats clearly remains too low. This was apparent in the responses to our questionnaires through the expression of the need for more specific habitats (i.e. beaches in relation to marine litter) to be monitored and the mentioning of the occurrence of spatial geographical gaps in monitoring programs with for example a clear widespread European lack of offshore (i.e., beyond 1 nm) monitoring. Overall, 16 responses to the questionnaires mentioned fragmented spatial coverage and/or the existence of geographical gaps in current monitoring programs. Such a gap was also underlined for biogeochemical monitoring in the Rockall Trough (Ireland).

Furthermore, it should be underlined that the monitoring effort must be high enough both from a spatial and temporal standpoint to: (1) detect the effects of new threats/disturbances acting in different locations within the same habitat, and (2) assess the consequences of an identified threat/disturbance at larger scales (i.e., those associated with the considered habitat and furthermore the reporting area). This implies the necessity of monitoring a sufficient sample of sites within each habitat in order to assess the uncertainty in their EcoQ values, which highlights the weakness of most current monitoring programs and supports the above proposed sampling approach in response to MSFD requirements.

Finally, monitoring programs are often single threat- and/or compartment-focused, which limits their use to assess the effect of other type of arising threats/disturbances. Moreover, the clear discrepancy between the small spatial scales at which these threats are acting and the large spatial scale of the reporting for WFD and MSFD purposes (water body masses and/or regional) points out the question of the real significance of reporting the effects of these threats/disturbances at such large spatial scales.

4.3.2. Large-scale threats/disturbances

Other environmental threats act over large spatial scales, such as thermal regime change or ocean acidification. In this case, there is a clear apparent discrepancy between the (large) spatial extent of the threat/disturbance and the (small) scale at which the monitoring is performed (station). However, this drawback is in theory largely overcome by (1) the use of non-point mobile monitoring techniques such as Ferryboxes allowing for a covering of a large geographical area on a limited time-scale when focusing on the planktonic compartment, and (2) the fact that only a small number of fixed monitored sites is required to monitor this kind of threat disturbance. Several points must nevertheless be taken into account:

(i) Different biological communities may not be affected in the same way by the same level of a given (widespread) environmental pressure. As an example, Grémare et al (1998), and Labrune et al (2007) clearly showed that in the Gulf of Lion, the compositions of the two shallowest communities (i.e., littoral fine sands and littoral sandy muds) are most affected by climatic oscillations. A sound assessment of large-scale threats/disturbances at the reporting scales should therefore not rely on the sampling of a single, or even a limited number of habitats. Conversely, the monitoring strategy of large scale threats/disturbances should ideally encompass all the habitats present in the reporting area.

(ii) The representability of the monitoring is most often only partial. For example, highly mobile fauna (e.g. marine mammals or birds) are often used as proxies for large scale threats/disturbances because they can be found over large spatial scales and because, as for predators, their ecophysiology and/or population dynamics tolerate a large set of ecological processes. The probability of these organisms to be sampled is directly proportional to the deployed sampling effort and to their relative accessibility. It was for example stressed in the questionnaire responses that the current monitoring resources currently deployed in the UK do not have the power to detect trends in all seabird and cetacean species or identify the drivers of their population change. Along the same line, only the most accessible marine bird nests are currently monitored as part of the of the Maltese seabird monitoring program, which makes its results questionable.

4.3.3. The real world: a mixture of threats/disturbances at small and larger scales

When generalizing to global coastal marine ecosystems, it is obvious that several environmental pressures act simultaneously, each having its own spatial resolution and temporal dynamics. According to Halpern et al. (2008) and Crain et al. (2009), no fewer than five pressures overlap anywhere in the world's oceans. Such an overlapping was also clearly apparent in the responses to our questionnaire. It induces potential cumulative and/or interactive effects, which clearly complicate the definition of the modalities of an optimal monitoring strategy. Based on all above-mentioned considerations, one can nevertheless conclude that these modalities should include the following points:

(i) The elementary unit of monitoring should be the habitat since this is the largest spatial entity within which the comparisons of community compositions are sound.
(ii) The monitoring of each habitat should include a number (sample) of sites large enough to allow for the detection and the variability in the distinction of the effects of small and large scale threats/disturbances.
(iii) Within a given reporting area, a monitoring program should include the highest possible number of relevant habitats in order to facilitate the detection of new small scale threat/disturbance and the upscaling of large scale threat/disturbance effects.

Resulting monitoring programs would clearly constitute huge tasks, which highlights the need, for each relevant habitat, to define/characterize environmental threats and current associated monitoring programs. In order to evaluate the feasibility of such an improved approach, we present below an example of a case study for the central part of the Bay of Biscay.

4.4. A case study for the central part of the Bay of Biscay

As a first step in the implementation of the MSFD, an "initial state" of the central part of the Bay of Biscay has been established, which includes a spatial characterisation of the distribution of the main environmental pressures. When cross-checked with the ecological interest of each area, this resulted in a cartography of the areas of special concern (DCSMM-MSFD, 2011), which can be compared with current monitoring programs and/or observations. The interest of such a case study relies in the fact that the information/know-how provided is potentially transferable to other areas subjected to the MSFD.

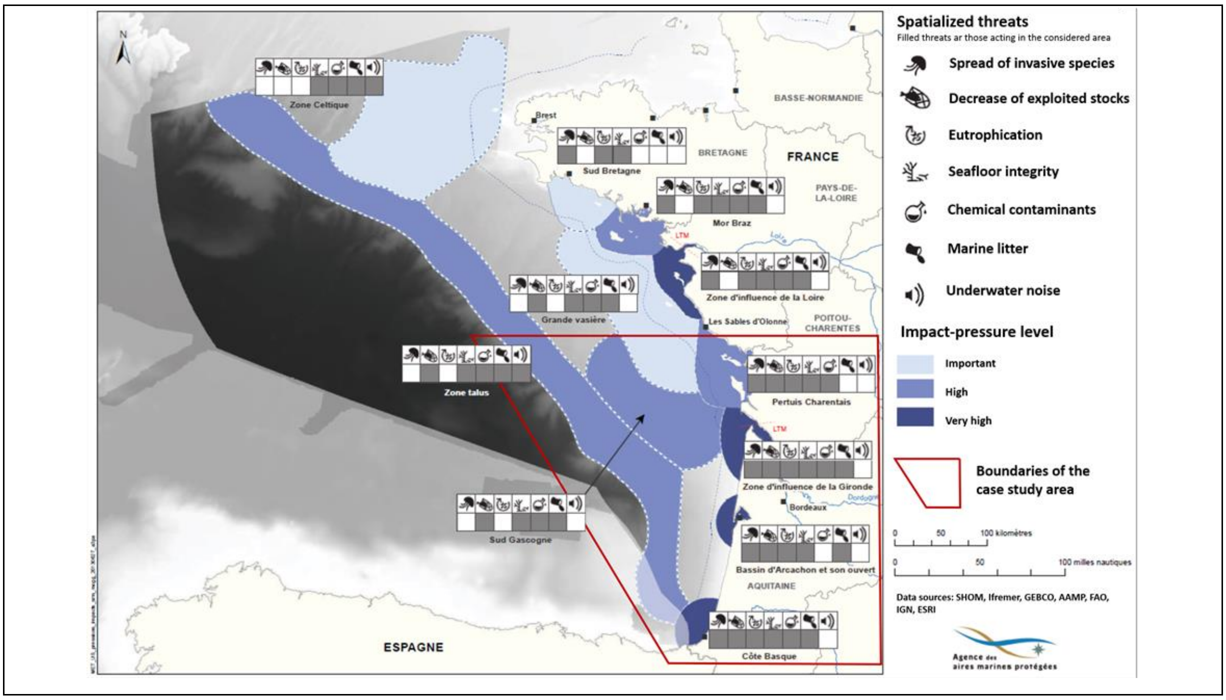


Figure 4-3: Areas of special concern and spatialization of the main environmental threats acting in the case study area (framed in red) as well as in the whole French part of the Bay of Biscay and Celtic Seas (Modified from AAMP, 2013).

As far as the central part of the Bay of Biscay is concerned, the mapping of the areas of special concerned has been established by the Marine Protected Areas Agency (Figure 4-3). Marine ecosystems are mainly threatened by:

- spread of invasive species
- decrease of exploited stocks
- eutrophication
- sea floor integrity
- chemical contamination
- marine litter
- underwater noise

The analysis of the spatial distribution of the areas of major concern shows that most of them are located inshore (i.e., at the immediate vicinity of most human activities and thus of man-induced disturbances). More specifically, one can identify four inshore areas: (1) the Marennes-Oléron Basin, (2) the Gironde Estuary, (3) the Arcachon Lagoon, and (4) the Adour Estuary and the connected area. Two offshore areas of special concern have also been identified: (1) the "Sud Gascogne" area, which includes the preferential deposition areas of the continental inputs originating from the Gironde River, and (2) the continental slope, which hosts benthic communities of special interest. All six areas are subjected to a large array of threats.

The four inshore areas are also those which are most monitored (Figure 4-4, Figure 4-5 and Figure 4-7). The monitoring taking place offshore is directly linked to the evaluation of fishing stocks (Figure 5.5.6). During the last years, it has been extended to other disturbances with the emergence of the MSFD. An inventory of the monitoring programs and observations currently available is provided below for the seven threats identified above.

4.4.1. Spread of invasive species

There is no specific monitoring program focusing specifically on invasive species within the considered area. However, several monitoring programs designed for the survey of biological communities (i.e. benthos, plankton and fishes) can be used to document the occurrence and/or the spread of invasive species. This is the case of the monitoring effort performed in the more coastal as part of WFD monitoring, which includes: (1) a yearly sampling of 17 intertidal and 16 subtidal sites for benthic invertebrates (since 2007), (2) the sampling, twice a year, of 4 sites for intertidal macro-algae and 4 other sites for subtidal algae (yearly since 2007), and (3) a monthly sampling of 14 sites for phytoplankton (since 1984). Offshore, the yearly campaigns EVOHE (since 1987) and PELGAS (since 1989) both involve sampling over the entire Bay of Biscay. They respectively focus on demersal and small pelagic fish stocks. Their results could therefore be used to assess the occurrence and/or the spread of invasive fish species. As stated above, the EVHOE yearly monitoring offshore campaigns have been modified since 2010 to also monitor benthic (mega)fauna and zooplankton. Their results could therefore also be used for monitoring species invasions in these two biological compartments.

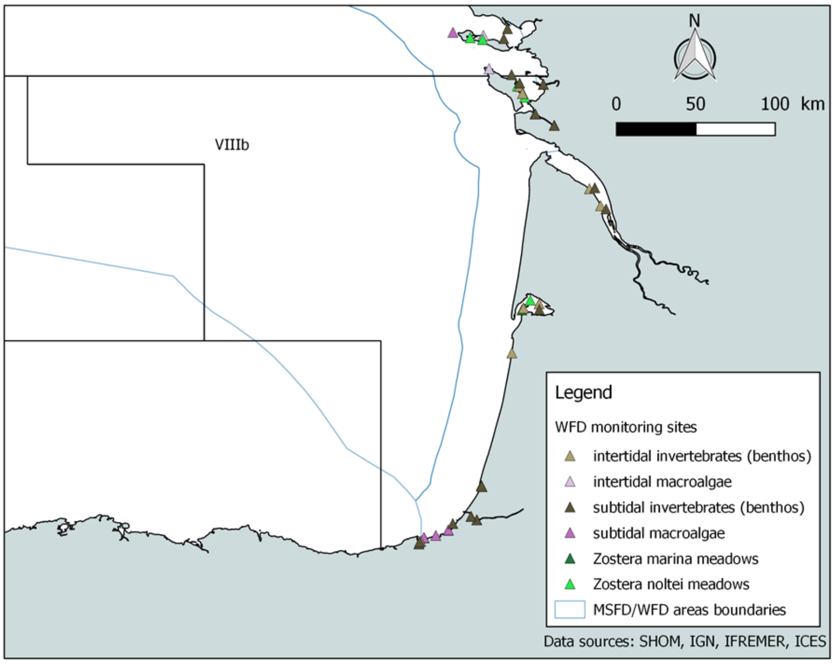


Figure 4-4: Geographical map showing the location of the monitoring sites sampled for biological benthic compartments in the case study area within the framework in the WFD (See text for details on the sampling frequencies).

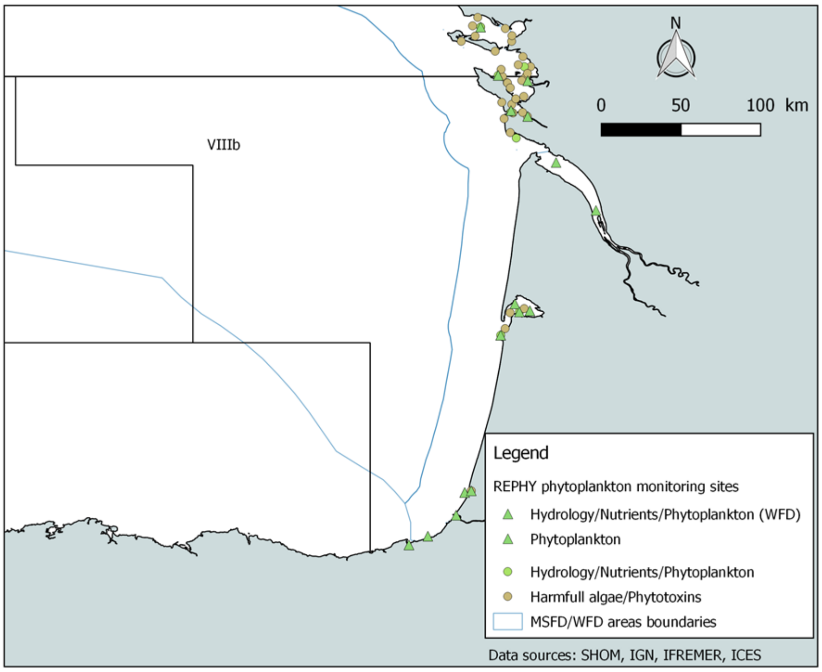


Figure 4-5: Geographical map showing the location of the monitoring sites sampled for phytoplankton and phytotoxins in the case study area within the REPHY program. Triangles indicate sites belonging to the WFD monitoring (See text for details on the sampling frequencies).

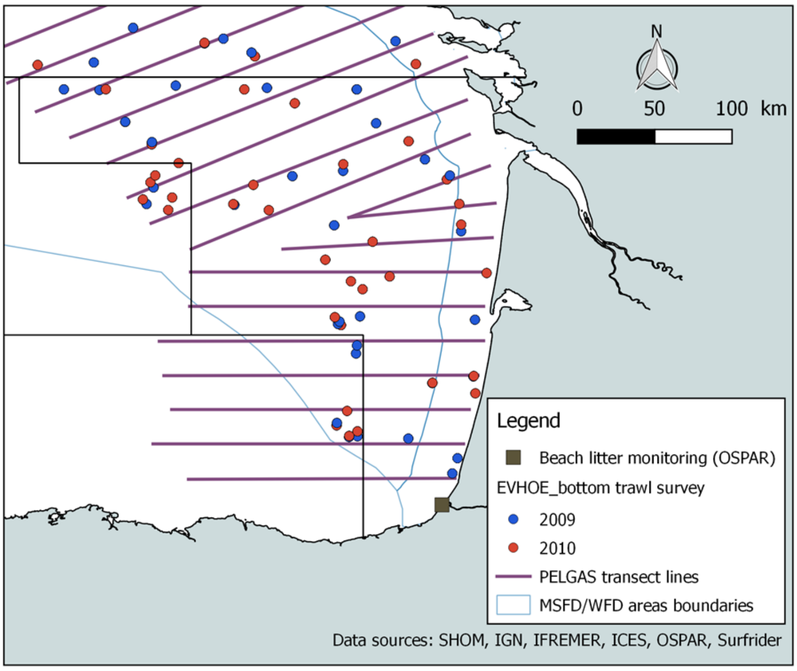


Figure 4-6: Geographical map showing the location of (1) the monitoring sites sampled for beach marine litter using the OSPAR protocol (rectangle) and bottom trawl survey (Fish/Litter/Benthic invertebrates) during the EVHOE program campaigns (in 2009 and 2010) and (2) of transect lines prospected during PELGAS monitoring campaigns (small pelagic fishes) (See text for details on the sampling frequencies).

4.4.2. Decrease of exploited stocks

Exploited fish stocks are specifically monitored on a yearly basis as part of the EVOHE (since 1987) and PELGAS (since 1989) programs (see above). The EVHOE sampling strategy allows for the coverage of the majority of the habitats trawled by fishing ships in the area and includes 140 bottom trawling transects spread over the whole Bay of Biscay and the French part of the Celtic Seas (Figure 4-6). The PELGAS campaign strategy consists of an acoustic prospection (to detect fish schools) and subsequent pelagic trawling samples along 27 transect lines (from the coast to the continental shelf break) spread over the whole Bay of Biscay. Sixteen of these transect lines are located within our considered study area.

4.4.3. Eutrophication

The concentration of nutrients in the water column, together with physical (temperature, salinity) and other parameters potentially associated with eutrophication events (dissolved oxygen, turbidity) are measured monthly at 15 sites (Figure 4-5) as part of WFD monitoring (hydrology). It should be underlined that: (1) sampling frequency is bimonthly at the three sites located in the Arcachon Bay (which are also monitored through the SOMLIT program), and (2) the monitoring of nutrient concentrations is only achieved between November and February in the Marennes-Oléron Bay and the Pertuis area versus year-round elsewhere. The sampling for phytoplankton (chlorophyll *a* and community composition) is also performed monthly at the same 15 monitoring sites as part of WFD monitoring. In aquaculture areas (i.e., Archachon and Marennes-Oléron Bays, Pertuis area), a more frequent sampling frequency (i.e., up to a weekly sampling) is achieved during risky periods. Monitoring then focusses on harmful algae including the quantification of phytotoxins in water and molluscs (Oysters, scallops) at both regular WFD and 36 additional sites (Figure 4-5).

The cover and composition of macroalgae, as a proxy for eutrophication is measured twice a year (during March and July) at 4 intertidal sites and 4 subtidal sites (Figure 4-4). Intertidal and subtidal benthic macrofauna compositions, which are potentially affected by eutrophication, are sampled at 17 and 16 sites, respectively as part of the WFD monitoring (Figure 4-3).

4.4.4. Seafloor integrity

There is no specific monitoring program assessing the physical integrity of the seafloor *per se* in the considered area. However punctual observations relative to the location and volumes of sediment during dredging and extraction operations are available (BRGM, CETMEF). Substrate abrasion resulting from bottom fishing can also be crudely assessed through the analysis of VMS data from fishing ships.

4.4.5. Chemical contamination

The concentration of contaminants has been monitored trough the ROCCH program since 2008 (indeed ROCCH is the continuation of the RNO program, which itself started in 1974). Within ROCCH, the concentrations of 41 contaminants (according to a list established for the WFD) are measured in the water monthly at 13 coastal sites as part of WFD monitoring (Figure 4.7). Within the same policy framework, the concentration of 34 hydrophobic contaminants (according to a list established by OSPAR) are measured yearly in: (1) the sediment at 13 sites (during summer), and (2) bivalve molluscs tissues at 15 monitoring sites (during November). 23 more sites are monitored annually for sediment contaminant concentrations (Figure 4-7) in order to more precisely assess these concentrations off the Gironde (up to 26 nm offshore) and Adour (up to 10 nm) rivers. Specific monitoring is also conducted in aquaculture areas (i.e., Arcachon and Marennes-Oléron Bays) through the sampling of 36 more sites where contaminant concentrations are measured yearly (during November) in mollusc tissues (Figure 4.7).

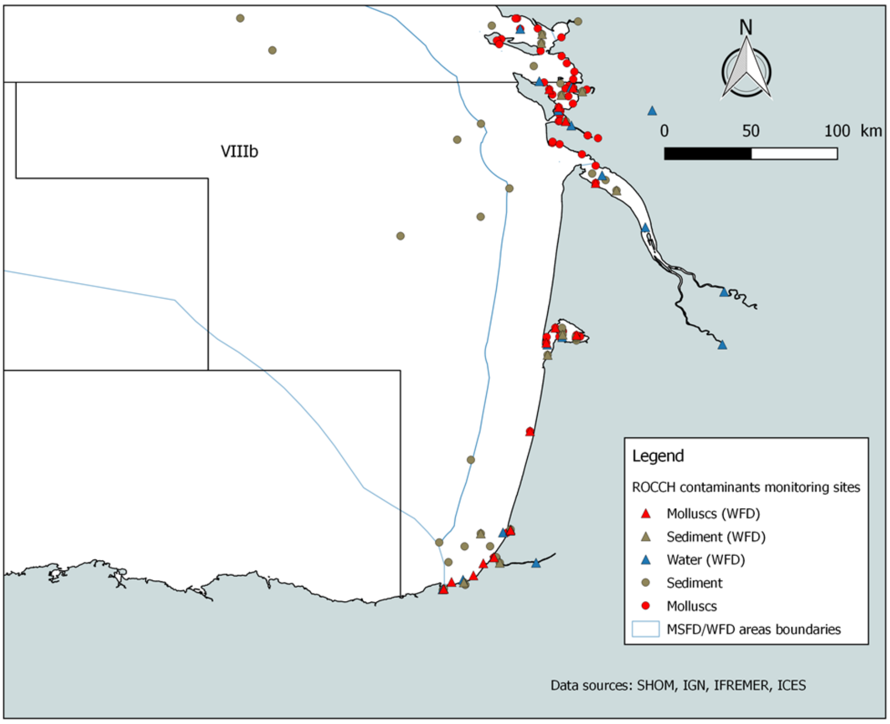


Figure 4-7: Geographical map showing the location of the monitoring sites sampled for chemical contaminants in the case study area within the ROCCH program. Triangles indicate sites belonging to the WFD monitoring (See text for details on the sampling frequencies).

4.4.6. Marine litter

Only one single beach (i.e. Anglet) within the whole considered area is specifically monitored for marine litter according to the OSPAR protocol (Figure 4-6). Offshore, marine litter deposited on the seafloor are monitored following the extension of the EVHOE program in 2008 (see above). During these campaigns, litter are trapped in nets during bottom trawling, identified and quantified (Figure 4-6). The occurrence of floating litter is also reported.

4.4.7. Underwater noise

There is no specific monitoring program focusing on underwater noise disturbance. A general assessment of this threat has nevertheless been possible for the initial state establishment for the implementation of the MSFD through the use of external data gathered from:

(1) marine traffic statistics established by the Lloyd's insurance company,
(2) activity reports from surveys by the CROSS Atlantique (Regional Operational Center for Survey and Rescue),
(3) fishing activity surveys (Ifremer SIH),
(4) ferry traffic statistics (from ferry companies),
(5) data of concessions approved for material extraction (from the French Minister of Environment, Energy and Sea),
(6) statistics on gas and petroleum prospection (BEPH).

4.4.8. Conclusions of the case study

The main conclusions of the case study carried out in the central Bay of Biscay are as follows:

(1) almost the entire area is subjected to a set of anthropogenic threats (without taking global change into account).
(2) the interface between the intensity of the threats and the ecological value of associated areas enables areas of concern that should preferentially be monitored to be defined.
(3) Most current monitoring programs are indeed taking place within such areas, which highlights the question of the spatial scale associated with reporting both in the WFD and the MSFD.
(4) There are many current monitoring programs but they are only little coordinated. One reason for this lies in the fact that these programs have been designed to monitor a single threat/disturbance
(5) There has been some recent effort in extending a monitoring program (e.g. EVHOE) to monitor several threats simultaneously. This is a good initiative but a better trade-off between the adequacy of sampling to adequately monitor those threats should be attempted,
(6) Some threats/disturbances (e.g. invasive species) are still assessed through (clearly non-optimal) sampling designs originally defined to monitor other threats/disturbances

Overall, the results of this case study illustrate the fact that the monitoring of the coastal environments primarily consist of a complex mosaic of habitats submitted to a large variety of (co-occurring) threats/disturbances acting at different spatial, temporal, functional, and other types of scales. A great deal of effort is currently put into the monitoring of coastal environments due to their economic, sociological and cultural importance. This effort should, however, clearly be optimized based on a holistic view of ecosystem functioning and better coordination between existing programs. A first step in this direction consists of overlaying existing threats and current monitoring actions. This results in a very complex body of information that requires specific skill to be later examined and transformed into propositions for an optimized monitoring program. Such an approach can only be achieved at a much smaller spatial scale than the ones associated with WFD and MSFD. It requires the knowledge of expert scientists for the considered areas, which also supports that such areas should be limited in size.

5. Conclusions

This study consolidates the main conclusions from the Dobris Assessment (EEA 1995) and more recent studies (EEA, 2008a, b and the EU-DEVOTES project), highlighting the need for improved monitoring of environmental threats in European coastal environment. Clear assessment and possible perspective on key challenges related to the observation of essential coastal variables is presented.

Participation in the JERICO-NEXT questionnaire was not exhaustive, but responses provided new insights into the gaps between the environmental pressures or threats and their impacts, and the monitoring of these impacts.

In summary, key findings of this report were that:

- Ongoing national monitoring programmes are focused on reporting to directives and international obligations, and not to contribute to better understanding of the possible impacts of the threats.
- The discrepancy between the small spatial scales at which threats are acting and the large spatial scale of reporting for WFD and MSFD purposes raises questions about the real significance of reporting the effects of threats/disturbances at large spatial scales.
- Monitoring programs are considered to be largely inadequate in terms of spatial or temporal resolution, and for the assessment of emerging threats.
- Monitoring of biological parameters is generally inadequate, with insufficient focus on coupling between biological and physical or chemical parameters.
- New technologies such as remote sensing, Ferryboxes, and gliders could help fill some spatial and temporal gaps in monitoring.
- Submission of monitoring data to central databases needs to be improved to ensure that monitoring data is available centrally.
- Issues of scale need to be addressed in fit-for-purpose monitoring programmes.
- More integrated cross-disciplinary approaches will require more co-ordinated monitoring across descriptors.
- Although some monitoring programmes address multiple pressures, there is scope for more harmonisation through improved monitoring design to create programmes which are fit for multiple purposes.

The JERICO-RI is not presently contributing to national monitoring programmes but has a high potential to fill in some of the observation gaps, especially related to physical and biogeochemical parameters, and the coupling between biology and physics across scales needed for integrative understanding. Through the JERICO-NEXT project, the JERICO-RI could become a major contributor towards future coastal monitoring programmes, through the elaboration of a science strategy which would pave the way to a better integration of physical, chemical and biological observations into an ecological process perspective. The particular challenge of simultaneously observing physical, chemical and biological parameters for assessments of complex coastal processes remains an open issue in relation to the temporal scale of sampling. This will be studied and thoroughly discussed in deliverable 1.2 of the JERICO-NEXT project.

6. References

AAMP (2013) Agence des Aires Marines Protégées.. Cartes d'enjeux concernant les parties françaises des sous-régions marines européennes. Juillet 2013

Anadón R, Danovaro R, Dippner JW, et al (2007) Impacts of Climate Change on the European Marine and Coastal Environment Ecosystems Approach. Eur Sci Found 84.

Andersen, J.H., K. Dahl, C. Göke, M. Hartvig, et al. (2014) Integrated assessment of marine biodiversity status using a prototype indicator-based assessment tool. Front. Mar. Sci. 1:55. Doi:10.3389/fmars.2014.00055.

Auber A, Travers-Trolet M, Villanueva MC, Ernande B (2015) Regime Shift in an Exploited Fish Community Related to Natural Climate Oscillations. PLoS ONE 10(7): e0129883. doi:10.1371/journal.pone.0129883

Bax N, Williamson A, Aguero M, et al (2003) Marine invasive alien species: A threat to global biodiversity. Mar Policy 27:313–323. doi: 10.1016/S0308-597X(03)00041-1

Beauchard O, Berg T, Bizsel KC, et al (2014) Ecosystem Overview of the European Regional Seas. Report on SWOT analysis of monitoring. Annex 3. WP1. Deliverable 1.4. DEVOTES.

Birdlife sea level rise threat. http://datazone.birdlife.org/sowb.

Collingridge K, Forster R, Petersen W (2013) Report on the current status of fixed platforms in Europe. D3.3.1. FP7-JERICO project. http://www.jerico-ri.eu/previous-project/deliverables/d3-3-1-report-on-the-current-status-of-fixed-platforms-in-europe .

Conversi A, Umani SF, Peluso T, Molinero JC, Santojanni A, Edwards M (2010) The Mediterranean Sea regime shift at the end of the 1980s, and intriguing parallelisms with other european basins. PLoS ONE 5, e10633.

Crain CM, Halpern BS, Beck MW, Kappel CV (2009) Understanding and Managing Human Threats to the Coastal Marine Environment. The Year in Ecology and Conservation Biology, 2009: Ann. N.Y. Acad. Sci. 1162: 39-62

Danovaro R, Fonda S, Pusceddu A (2009) Climate change and the spreading of marine mucilage and pathogenic microbes in the Mediterranean Sea. PLoS ONE 4(9), e7006.

DEVOTES (2014) Catalogue of Monitoring Networks. v3. http://www.devotes-project.eu/devotes-release-new-version-catalogue-monitoring-networks/.

Dippner JW, Kröncke I (2003) Forecast of climate-induced change in macrozoobenthos in the southern North Sea in spring. Climate Research, 25:179-182

DCSMM-MSFD (2011) Directive Cadre Stratégie pour le Milieu Marin Rapport de l'atelier de synthèse de l'évaluation initiale. *Ministère de l'Ecologie, du développement durable des transports et du logement*. Paris, 13-15 Septembre 2011.

EC (1991a) Directive of 21 May 1991 concerning urban waste water treatment (91/271/EEC). Off J Eur Communities L 135:40–52.

EC (1991b) Council Directive of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (91/676/EEC). Off J Eur Communities L 375:1–8.

EEA (1995) Europe's Environment - The Dobris Assessment. State of the environment report No 1/1995. http://www.eea.europa.eu/publications/92-826-5409-5.

EEA (1999) State and pressures of the marine and coastal Mediterranean environment. doi: http://europa.eu.int

EEA (2008a) Europe's Environment. The Fourth Assessment. Chapter 5 Marine and coastal environment. http://www.eea.europa.eu/publications/92-826-5409-5. 44 pp.

EEA (2008b) Europe's Environment - The Dobris Assessment. Chapter 35 Coastal Zone Threats and Management. State of the environment report. 6 pp.

EEA (2011) Europe's environment. An Assessment of Assessments. http://www.eea.europa.eu/themes/regions/pan-european/sub-regional-assessment-of-assessment-reports/eastern-europe-assessment.

EU (1992) Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. Off J Eur Communities 206:7–50.

EU (2000) Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for community action in the field of water policy. Off J Eur Communities 327:1–72.

EU (2008) Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). Off J Eur Union 164:19–40.

European Marine Board (2013) Linking Oceans Human Health: A Strategic Research Priority for Europe. Position paper 19 of the European Marine Board, Ostend, Belgium. 116 pp.

Giani M, Djakovac T, Deggobis D, Cozzi S, Solidoro C, Umani SF (2012) Recent changes in the marine ecosystems of the northern Adriatic Sea. Estuarine, Coastal and Shelf Science 115:1-13.

Grémare A, Amouroux JM, Vétion G (1998) Long-term comparison of macrobenthos within the soft bottoms of the Bay of Banyuls-sur-mer (northern Mediterranean Sea). Journal of Sea Research, 40(3): 281-302

Halpern BS, Walbridge S, Slkoe KA, *et al (*2008) A global map of human impact on marine ecosystems. Science 319: 948-952

HELCOM (2007) HELCOM Baltic Sea Action Plan. 101 pp.

JNCC. Threats to coastal habitats. http://jncc.defra.gov.uk/page-5377.

Labrune C, Grémare A, Guizien K, Amouroux JM (2007) Long-term comparison of soft bottom macrobenthos in the Bay of Banyuls-sur-Mer (north-western Mediterranean Sea): A reappraisal. Journal of Sea Research, 58: 125–143

Oesterwind D, Rau A, Zaiko A (2016) Drivers and pressures - Untangling the terms commonly used in marine science and policy. J Environ Manage 181:8–15. doi: 10.1016/j.jenvman.2016.05.058

OSPAR (2010) The North-East Atlantic Environment Strategy: Strategy of the OSPAR Commission for the Protection of the Marine Environment of the North-East Atlantic 2010-2020. 2020:27 pp.

Patrício J., H. Teixeira, K. Mazik, et al. (2013) Report cataloging the monitoring Networks used within EU member states. Deliverable 1.3 – EC-DEVOTES project. www.devotes-project.eu.

Patrício J, Little S, Mazik K, et al (2014) Report on SWOT analysis of monitoring. WP1. Deliverable 1.4. DEVOTES. 104 pp.

Patrício J, Little S, Mazik K, et al (2016) European Marine Biodiversity Monitoring Networks: Strengths, Weaknesses, Opportunities and Threats. Front Mar Sci 3:1–18. doi: 10.3389/fmars.2016.00161

Petersen JK, Malm T (2006) Offshore Windmill Farms: Threats to or Possibilities for the Marine Environment. Ambio 35:75–80. doi: 10.1579/0044-7447(2006)35[75:OWFTTO]2.0.CO;2

Rosenberg R, Blomqvist M, Nilsson HC, Cederwall H, Dimming A (2004) Marine quality assessment by use of benthic species-abundance distributions: a proposed new protocol within the European Union Water Framework Directive. Marine Pollution Bulletin, 49: 728-739

Russo A, Rabitti S, Bastianini M (2002) Decadal Climatic Anomalies in the Northern Adriatic Sea inferred from a New Oceanographic Data Set. Marine Ecology 23:340-351.

Seitz RD, Wennhage H, Bergstrom U, et al (2013) Ecological value of coastal habitats for commercially and ecologically important species. ICES J Mar Sci 71:18 pp. doi: 10.1093/icesjms/fst152

She J, Al E (2014) Assessing biogeochemical monitoring networks in regional seas. Fact Sheet 2. Operational Ecology (OPEC) Marine Ecosystem Forecasting. 2 pp.

Tett P, Gowen RJ, Painting SJ, Elliott M, Forster R, Mills DK, Bresnan E, Capuzzo E, Fernandes TF, Foden J, Geider RJ, Gilpin LC, Huxham M, McQuatters-Gollop AL, Malcolm SJ, Saux-Picart S, Platt T, Racault MF, Sathyendranath S, van der Molen J, Wilkinson M (2013) Framework for understanding marine ecosystem health. Marine Ecology Progress Series, 494:1-27

UNEP/UNECE (2016) GEO-6 assessment for the Pan-European region. United Nations Environment Programme, Nairobi, Kenya. 376 pp.

Warwick RM, Emblow C, Féral JP, Hummel H, van Avesaath P, Heip C (2003). European Marine Biodiversity Research Sites. Report of the European Concerted Action: BIOMARE (Implementation and Networking of large scale, long term Marine Biodiversity Research in Europe). *NIOO-CEME, Yerseke, the Netherlands, ISBN 90-74638-15-5*

Zampoukas N, Piha H, Bigagli E, Hoepffner N, Hanke G, Cardoso AC (2012). Monitoring for the Marine Strategy Framework Directive: Requirements and options. JRC Scientific and Technical Reports. http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/23169/1/lbna25187enn.pdf

7. Annex 1

Table A1.1: Monitoring requirements of HELCOM, OSPAR, Barcelona and Bucharest Conventions that are related to indicators within the Marine Strategy Framework Directive (MSFD) Descriptors 1, 2, 4 and 6.

HELCOM *	OSPAR**	Barcelona Convention***	Bucharest Convention****	Related MSFD indicators
Chl-a	Chl-a	Chl-a	Chl-a	1.6.2, 1.7.1, 4.3.1
Phytoplankton	Phytoplankton indicator species		Phytoplankton (total density, total biomass)	1.1.3, 1.2.1, 1.6.1, 1.6.2, 1.7.1, 4.3.1, 6.1.2
Phytobenthos			Macrophytobenthos	1.1.3, 1.2.1, 1.6.1, 1.6.2, 1.7.1, 4.3.1, 6.1.2
Zooplankton			Mesozooplankton, Biomass of *Noctilluca*	1.1.3, 1.2.1, 1.6.1, 1.6.2, 1.7.1, 4.3.1, 6.1.2
Zoobenthos	Benthic communities		Macrozoobenthos	1.1.3, 1.2.1, 1.6.1, 1.6.2, 1.7.1, 4.3.1, 6.1.2
Birds				1.1.1, 1.2.1, 1.3.1, 1.6.1, 4.1.1, 4.3.1
Mammals				1.1.1, 1.2.1, 1.3.1, 1.6.1, 4.1.1, 4.3.1
Fish			Fish landings	1.1.1, 1.2.1, 1.3.1, 1.6.1, 4.1.1, 4.3.1
Non-indigenous species				2.1.1, 2.2.1, 2.2.2
Hydrography	Salinity, Temperature, Oxygen	Temperature, Salinity, Dissolved oxygen	Oxygen, pH, Salinity, Secchi depth, Temperature	1.6.3
Nutrients	NH_4-N_2, NO_2-N_2, NO_3-N_2, PO_4-P_3, SiO_4-Si_4	NO_3-N, NO_2-N, NH_4-N, PO_4-P, SiO_4	N (NH_4, NO_2, NO_3, N-total), P (PO_4 & P-total), SiO_4	1.6.3
	TOC, POC		Total Suspended Solids	1.6.3

Table A1.2: Monitoring requirements of the Water Framework Directive (WFD) and their relevant Marine Strategy Framework Directive (MSFD) indicators (COM DEC 2010/477/EU) (Zampoukas et al.*, 2012).*

	Water Framework Directive Parameter	Relevant MSFD Indicators
1	Angiosperms Abundance	1.2.1, 1.6.1, 1.6.2, 1.7.1, 4.3.1, 6.1.2
2	Angiosperms Composition	1.6.2, 1.7.1, 2.1.1, 2.2.1, 6.2.1, 6.2.2
3	Angiosperms Cover	1.1.3, 1.2.1, 1.6.1, 1.6.2, 1.7.1, 4.3.1, 6.1.2
4	Angiosperms Depth Distribution	1.1.1, 1.2.1, 1.6.1, 1.7.1, 4.3.1
5	Angiosperms Presence of Sensitive Taxa	6.2.1
6	Benthic Invertebrate Fauna - Presence of Sensitive Taxa	6.2.1
7	Benthic Invertebrate Fauna Abundance	1.2.1, 1.6.1, 1.6.2, 1.7.1, 4.3.1, 6.1.2
8	Benthic Invertebrate Fauna Composition	1.6.2, 1.7.1, 2.1.1, 2.2.1, 6.1.1, 6.2.1, 6.2.2
9	Benthic Invertebrate Fauna Diversity	1.7.1, 6.2.2
10	Macro-algae - Presence of Sensitive Taxa	6.2.1
11	Macro-algae Abundance	1.2.1, 1.6.1, 1.6.2, 1.7.1, 4.3.1, 6.1.2
12	Macro-algae Cover	1.1.3, 1.2.1, 1.6.1, 1.6.2, 1.7.1, 4.3.1, 6.1.2
13	Macro-algae Depth Distribution	1.1.1, 1.2.1, 1.6.2, 1.6.1, 1.7.1
14	Macro-algae Species Composition	1.6.2, 1.7.1, 2.1.1, 2.2.1, 6.2.1, 6.2.2
15	Phytoplankton Abundance	1.2.1, 1.6.1, 1.6.2, 1.7.1, 4.3.1
16	Phytoplankton Biomass	1.6.2, 1.7.1, 4.3.1
17	Phytoplankton Bloom Frequency / Intensity	4.3.1
18	Phytoplankton Composition	1.7.1, 2.1.1, 2.2.1
19	Phytoplankton Diversity	1.7.1
20	Acidification	1.6.3
21	Ammonium	1.6.3
22	Nitrates	1.6.3
23	Nutrient Conditions	1.6.3
24	Oxygenation	1.6.3
25, 26, 27	Bed Quantity, structure and substrate	1.6.3, 6.1.1, 6.1.2
28	Conductivity	1.6.3
29	Depth Variation	1.6.3
30	Direction of Dominant Currents	1.6.3
31	pH	1.6.3
32	Salinity	1.6.3
33	Temperature	1.6.3
34	Transparency	1.6.3
35	Residence Time	1.6.3

8. Annex 2

Regions and Sub-Regions given in the questionnaire are shown here.

Figure A2.1. Map showing all Regions of relevance to this project. For the North-East Atlantic (purple shading), the map shows ICES Regions I to XII and their sub-regions. For the Baltic Sea and Mediterranean Sea (blue shading), sub-regions are shown in Figures A2.2 and A2.3.

Figure A2.2. HELCOM Baltic Sea Sub-Regions

Figure A2.3. FAO Mediterranean Sub-Regions