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Monitoring for the Marine Strategy Framework Directive: Requirements and Options

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1. BACKGROUND

The Marine Strategy Framework Directive (MSFD: 2008/56/EC) requires that Member States take measures to achieve or maintain Good Environmental Status (GES) by 2020. According to Articles 5 and 11 of the MSFD, coordinated monitoring programmes should be established and implemented by **15 July 2014** in order to assess the environmental status of marine waters. Such programmes should include the indicative lists of characteristics, pressures and impacts of the Directive's Annex III, follow the specifications of Annex V and be able to assess the achievement of environmental targets that should be established in accordance with Article 10 by 15 July 2012.

According to Article 11 of the MSFD monitoring programmes shall be compatible within marine regions or sub regions and shall integrate and complement the monitoring requirements imposed by other EU legislation, such as the Habitats Directive (92/43/EEC) and Birds Directive (2009/147/EC) and international agreements, such as the Regional Seas Conventions (RSCs). Consistency, coherence and comparability within marine regions and subregions should be ensured by coordination of monitoring methods in the framework of RSCs taking also into account transboundary features and impacts.

The Commission Decision of 1 September 2010 (COM DEC; 2010/477/EU) lists criteria and indicators to assess GES for each descriptor of the MSFD Annex I, based, in particular, on the scientific and technical assessment prepared by the Task Groups set by the Joint Research Centre and the International Council on the Exploration of the Seas (Task Group Reports - please see Chapter 12 for detailed reference). Piha & Zampoukas (2011) compiled and reviewed the available methodological standards for monitoring (and also for target setting and assessment) under existing Community legislation, in particular the Water Framework Directive (2000/60/EC), the Environmental Quality Standards Directive (2008/105/EC), the Habitats Directive, the Birds Directive and other relevant Union legislation (including the Common Fisheries Policy, e.g. Council Regulation (EC) No 199/2008), taking also into account the approaches developed in the framework of RSCs.

2. MARINE MONITORING

For the scope of this report we defined monitoring under MSFD as **the systematic measurement of biotic and abiotic parameters of the marine environment**, with predefined spatial and temporal schedule, in order to produce datasets that can be used for application of assessment methods and derive credible conclusions (with defined confidence) on whether GES is achieved or not for the marine area concerned. In this context monitoring includes the choice of the parameters to measure, the sampling sites, the periodicity of sampling, the processing of the sample and the measurement of the parameter value. It does not include calculation of metrics and classification. In conclusion, monitoring should provide the data to allow assessment methods to classify a marine area as reaching or failing to reach GES.

According to Annex III Table 1 of the MSFD, several characteristics (physicochemical parameters, habitat types, biota and other) should be monitored. Data for these characteristics should allow for the calculation of the indicators related to the 11 Descriptors of Annex I to allow the evaluation of compliance with the targets set according to Article 10.

3. SCOPE OF THE REPORT

This report aims at identifying and highlighting the issues which need to be developed in order to prepare a coherent implementation of monitoring requirements under the MSFD.

While many marine monitoring programs at national, regional or global scale are underway since a long time, the Marine Strategy Framework Directive, adopted in 2008, is a new legislative instrument which requires data across all thematic areas relevant to the marine environment. Previous monitoring efforts, in particular those

coordinated by the Regional Sea Conventions, can provide a substantial amount of the needed data, while some aspects of monitoring still need to be further developed.

Despite existing relevant European legislation and other international agreements the coordination of monitoring programmes in the marine environment "is still in its infancy" (Heslenfeld & Enserink, 2008). According to OSPAR (2008a) many institutions are involved in monitoring and the need for better coordination to develop more efficient and cost-effective programmes is acknowledged.

In the Management Group Report and in the Task Group Reports the profits of using the same datasets for different indicators and descriptors are acknowledged. Additionally, the importance of infrastructures improvements and the introduction of less applied approaches (such as remote sensing, underwater video survey and Continuous Plankton Recorders) have been identified as overarching and critical issues that Member States are to consider while implementing the MSFD.

On the request of DG ENV and in order to assist Member States in planning their monitoring in the most effort efficient manner we screened the monitoring requirements imposed by the MSFD and other EU legislation and international agreements. We indicated where these overlap in order to show that existing monitoring prior to MSFD implementation should provide some of the data required for MSFD monitoring. We highlighted the MSFD monitoring requirements that do not overlap with those of other EU legislation and international agreements and also the cases where existing monitoring does not fully cover the required frequency and spatial extend. Some initial considerations on the challenges to extend monitoring from the coast to the open sea are also included.
The screening of monitoring requirements was restricted to:

a. Water Framework Directive (WFD: 2000/60/EC)
b. Environmental Quality Standards Directive (EQS: 2008/105/EC)
c. Habitats Directive (HD: 92/43/EEC)
d. Birds Directive (BD: 2009/147/EC)
e. Common Fisheries Policy (CFP: Council Regulation EC/ 199/2008[1]; Commission Decision 2010/93/EU[2])
f. Regional Sea Conventions covering European seas (OSPAR, HELCOM, Barcelona Convention – Mediterranean Action Plan, Bucharest Convention - Black Sea Commission).

Particularly for descriptor 9 (Contaminants in fish and other seafood) the Commission Regulation No 1881/2006 has been mentioned, as it sets maximum levels for certain contaminants in foodstuffs, including fish and other seafood[3] to which the MSFD refers specifically.

We also discussed the possibilities for integration of monitoring across different pieces of legislation and highlighted best practices already in place and publically available for some Member States. Pilot projects on common transnational monitoring and approaches for harmonized monitoring are also highlighted.

Moreover, we expressed some consideration for the usefulness of some approaches, such as those recommended in the Task Group Report, that are not commonly used by Member States for their marine monitoring. For these less applied monitoring approaches we considered their capacity to fulfil the MSFD requirements and particularly to provide data of higher quantity, with wider spatial coverage and for marine areas that were not easily covered by traditional monitoring technologies and tools.

[1] Council Regulation (EC) No 199/2008 of 25 February 2008 concerning the establishment of a Community framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the Common Fisheries Policy. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:060:0001:0012:EN:PDF

[2] Commission Decision of 18 December 2009 adopting a multiannual Community programme for the collection, management and use of data in the fisheries sector for the period 2011-2013
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:041:0008:0071:EN:PDF

[3] Commission Regulation No 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:364:0005:0024:EN:PDF

4. MONITORING PARAMETERS ACCORDING TO MSFD ANNEX III

Table 1 lists monitoring parameters of the MSFD and was based on an existing compilation of Craglia et al. (2010a). The aim of this analysis was to compile the monitoring requirements of the European environmental *acquis* concerning water protection and management (including the MSFD, the WFD and other legislation) and to contribute to the process of data specification and harmonization taking place for the implementation of the SEIS Communication[4] and the INSPIRE Directive[5]. For the MSFD this compilation was based on Annex III and has been adopted here in order to show how the identified monitoring parameters when the MSFD was published (2008) relate to the MSFD indicators as defined in the MSFD Com Dec 2010/477/EU.

The parameters were amended, where necessary, according to the purposes of the current report and are listed alphabetically from 1 to 38 for the biological ones and from 39 to 64 for the physicochemical ones. A reference number is attributed to each monitoring parameter and it is used in the evaluation of overlap with other legislation requirements presented in Tables 2-6. A column showing with which MSFD indicators of the COM DEC 2010/477/EU each parameter relates is also added. A parameter was considered relevant to an indicator in a *sensu lato* approach when it is required or useful for the calculation of the indicator.

A table with the relation between the MSFD Annex III characteristics and descriptors has already been shown in the Management Group Report (Cardoso et al. 2010). Here we show this relation for each indicator separately. A table linking MSFD Annex I and Annex III through the Decision criteria and indicators is included in the Annex 3 of the Commission Staff Working Paper SEC(2011) 1255[6] and has been consulted for the drafting of Table 1.

[4] Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee. Towards a Shared Environmental Information System (SEIS).
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2008:0046:FIN:EN:PDF

[5] Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE).
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:108:0001:0014:EN:PDF

[6] SEC(2011) 1255 final. Commission Staff Working Paper: Relationship between the initial assessment of marine waters and the criteria for good environmental status. http://ec.europa.eu/environment/marine/pdf/SEC_2011_1255_F_DTS.pdf

Table 1. Monitoring Parameters of the MSFD Annex III (adopted from Craglia et al., 2010a) and their relevant MSFD indicators of the COM DEC 2010/477/EU.

Ref. No	PARAMETER	MSFD indicator
1	Angiosperms biomass and its annual/seasonal variability	1.2.1, 1.6.1, 1.6.2, 1.7.1, 4.3.1, 5.3.1, 6.1.2
2	Angiosperms species composition and its annual/seasonal variability	1.6.2, 1.7.1, 2.1.1, 2.2.1, 4.3.1, 5.2.4, 6.2.1, 6.2.2
3	Fish abundance	1.2.1, 1.7.1, 2.1.1, 2.2.1, 3.1.1, 3.1.2, 3.2.1, 3.2.2, 3.3.1, 3.3.2, 3.3.3, 4.1.1, 4.2.1, 4.3.1
4	Fish age / size structure	1.3.1, 1.6.1, 3.1.1, 3.1.2, 3.2.1, 3.2.1, 3.3.1, 3.3.2, 3.3.2, 3.3.3, 3.3.4, 4.1.1, 4.2.1
5	Fish distribution	1.1.1, 2.1.1, 2.2.1
6	Genetically distinct forms of native species abundance	1.3.2, 2.2.1, 4.3.1
7	Genetically distinct forms of native species occurrence	1.3.2
8	Genetically distinct forms of native species spatial distribution	1.1.1, 1.1.2, 2.2.1
9	Habitats'(predominant, special, protected and endangered) characteristics	1.4.1, 1.4.2, 1.5.1, 1.5.2, 1.7.1, 6.1.1
10	Introduction of microbial pathogens	
11	Introduction of non-indigenous species	2.1.1, 2.2.1
12	Invertebrate bottom fauna biomass and its annual/seasonal variability	1.2.1, 1.6.1, 1.6.2, 1.7.1, 2.1.1, 2.2.1, 4.3.1, 6.1.2
13	Invertebrate bottom fauna species composition and its annual/seasonal variability	1.6.2, 1.7.1, 2.1.1, 2.2.1, 4.3.1, 6.1.1, 6.2.1, 6.2.2
14	Macro-algae biomass	1.2.1, 1.6.1, 1.6.2, 1.7.1, 2.1.1, 2.2.1, 4.3.1, 5.2.3, 5.3.1, 6.1.2
15	Macro-algae species composition	1.6.2, 1.7.1, 2.1.1, 2.2.1, 5.2.4, 6.2.1, 6.2.2
16	Marine mammals actual range	1.1.1
17	Marine mammals natural range	1.1.1
18	Marine mammals population dynamics	1.3.1, 4.1.1, 4.3.1
19	Marine mammals status	1.2.1, 1.3.1, 1.6.1
20	Non-indigenous or exotic species abundance	2.1.1, 2.2.1
21	Non-indigenous or exotic species occurrence	2.1.1, 2.2.1
22	Non-indigenous or exotic species spatial distribution	2.1.1, 2.2.1
23	Other protected species actual range	1.1.1
24	Other protected species natural range	1.1.1
25	Other protected species population dynamics	1.3.1
26	Other protected species status	1.2.1, 1.3.1, 1.6.1
27	Phytoplankton species compositions and its geographical and seasonal variability	1.7.1, 2.1.1, 2.2.1, 5.2.4
28	Reptiles actual range	1.1.1
29	Reptiles natural range	1.1.1
30	Reptiles population dynamics	1.3.1, 4.3.1
31	Reptiles status	1.2.1, 1.3.1, 1.6.1
32	Seabirds actual range	1.1.1
33	Seabirds natural range	1.1.1
34	Seabirds population dynamics	1.3.1, 4.1.1, 4.3.1
35	Seabirds species' status	1.2.1, 1.3.1, 1.6.1

36	Selective extraction of species	3.1.1
37	Translocations of non-indigenous species	2.1.1, 2.2.1
38	Zooplankton species compositions and its geographical and seasonal variability	1.6.2, 1.7.1, 2.1.1, 2.2.1
39	Acidification	1.6.3
40	Abrasion	1.6.3, 6.1.1, 6.1.2
41	Biological effects of contaminants	1.6.3, 8.2.1, 8.2.2
42	Concentration of contaminants	1.6.3, 8.1.1, 9.1.1, 9.1.2
43	Currents	1.6.3, 7.2.2
44	Depth	1.6.3, 7.2.2
45	Extraction	6.1.2
46	Ice cover	1.6.3
47	Marine litter	10.1.1, 10.1.2, 10.1.3, 10.2.1
48	Mixing characteristics	1.6.3
49	Nutrient concentrations	1.6.3, 5.1.1, 5.1.2
50	Oxygen	1.6.3, 5.3.2
51	Residence time	1.6.3
52	Salinity	1.6.3
53	Seabed Bathymetry	1.6.3
54	Seabed Structure	6.1.1, 6.1.2, 7.1.1, 7.2.1, 7.2.2
55	Seabed Substrata Composition	6.1.1, 6.1.2, 7.1.1, 7.2.1, 7.2.2
56	Seabed Topography	6.1.1, 6.1.2, 7.1.1, 7.2.1, 7.2.2
57	Sealing	6.1.2, 7.1.1, 7.1.2
58	Siltation (changes in)	1.6.3
59	Smothering	6.1.2, 7.1.1, 7.1.2
60	Temperature	1.6.3
61	Turbidity	1.6.3, 5.2.2
62	Underwater noise	11.1.1, 11.2.1
63	Upwelling	1.6.3
64	Wave exposure	1.6.3

From the above table it seems that introduction of microbial pathogens is not reflected in the COM DEC 2010/477/EU indicators although it appears in Annex III of the MSFD. A thorough detailed confirmation of monitoring parameters needed to support all Descriptors should still be made.

5. MONITORING PARAMETERS UNDER OTHER COMMUNITY LEGISLATION

The listing of the monitoring parameters required for the WFD, EQS, HD and BD was based on the existing analysis of monitoring requirements for the environmental *acquis* concerning water protection and management (Craglia et al., 2010a) and conservation of wild fauna and flora (Craglia et al., 2010b). The text of the Directives was used to extract the monitoring parameters. Modifications were made to the parameters according to the purposes of the current report. As such listing of monitoring parameters did not exist for the CFP its monitoring parameters were extracted in a similar way and are presented for the first time in this report. The listing of the WFD, EQS HD, BD and CFP monitoring parameters and their relation to MSFD monitoring parameters of Chapter 4 and COM DEC 2010/477/EU indicators are presented in Tables 2-6.

Table 2. Monitoring parameters of the WFD (adopted from Craglia et al., 2010a) their relative MSFD parameters (Annex III) and indicators (COM DEC 2010/477/EU).

Ref. num.	WFD PARAMETER	Relevant MSFD parameter of Annex III	Relevant MSFD indicator
1	Angiosperms Abundance	1	1.2.1, 1.6.1, 1.6.2, 1.7.1, 4.3.1, 5.3.1, 6.1.2
2	Angiosperms Composition	2	1.6.2, 1.7.1, 2.1.1, 2.2.1, 5.2.4, 6.2.1, 6.2.2
3	Angiosperms Cover	1	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, 1.2.1, 1.6.1, 1.7.1, 4.3.1
5	Angiosperms Presence of Sensitive Taxa	2	6.2.1
6	Benthic Invertebrate Fauna - Presence of Sensitive Taxa	15	6.2.1
7	Benthic Invertebrate Fauna Abundance	12	1.2.1, 1.6.1, 1.6.2, 1.7.1, 4.3.1, 6.1.2
8	Benthic Invertebrate Fauna Composition	13	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	13	1.7.1, 6.2.2
10	Macro-algae - Presence of Sensitive Taxa	15	6.2.1
11	Macro-algae Abundance	14	1.2.1, 1.6.1, 1.6.2, 1.7.1, 4.3.1, 5.2.3, 5.3.1, 6.1.2
12	Macro-algae Cover	14	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	14	1.1.1, 1.2.1, 1.6.2, 1.6.1, 1.7.1
14	Macro-algae Species Composition	15	1.6.2, 1.7.1, 2.1.1, 2.2.1, 6.2.1, 6.2.2
15	Phytoplankton Abundance	27	1.2.1, 1.6.1, 1.6.2, 1.7.1, 4.3.1, 5.2.1
16	Phytoplankton Biomass	27	1.6.2, 1.7.1, 4.3.1, 5.2.1
17	Phytoplankton Bloom Frequency / Intensity	27	4.3.1, 5.2.4
18	Phytoplankton Composition	27	1.7.1, 2.1.1, 2.2.1, 5.2.4
19	Phytoplankton Diversity	27	1.7.1, 5.2.4
20	Specific synthetic pollutants	41, 42	1.6.3, 8.1.1, 8.2.1, 8.2.2
21	Specific non-synthetic pollutants	41, 42	1.6.3, 8.1.1, 8.2.1, 8.2.2
22	Acidification	39	1.6.3
23	Ammonium	49	5.1.1, 5.1.2
24	Nitrates	49	5.1.1, 5.1.2
25	Nutrient Conditions	49	5.1.1, 5.1.2
26	Oxygenation	50	5.3.2, 1.6.3
27	Bed Quantity		6.1.1., 6.1.2, 7.1.1, 7.2.1, 7.2.2
28	Bed Structure	54	6.1.1., 6.1.2, 7.1.1, 7.2.1, 7.2.2
29	Bed Substrate	55	6.1.1., 6.1.2, 7.1.1, 7.2.1, 7.2.2
30	Conductivity		1.6.3
31	Depth Variation	53	1.6.3
32	Direction of Dominant Currents	43	1.6.3
33	Intertidal Zone Structure		
34	pH	39	1.6.3
35	Salinity	52	1.6.3
36	Temperature	60	1.6.3
37	Transparency	61	1.6.3, 5.2.2
38	Residence Time	51	1.6.3

Table 3. Monitoring parameters of the EQS Directive (adopted from Craglia et al., 2010a) their relative MSFD parameters (Annex III) and indicators (COM DEC 2010/477/EU).

Ref. num.	EQS PARAMETER	Relevant MSFD parameter of Annex III	Relevant MSFD indicator
1	Specific synthetic pollutants*	41, 42	1.6.3, 8.1.1, 8.2.1, 8.2.2
2	Specific non-synthetic pollutants*	41, 42	1.6.3, 8.1.1, 8.2.1, 8.2.2

*Biota is included in matrix to be monitored

Table 4. Monitoring parameters of the HD (adopted from Craglia et al., 2010b) their relative MSFD parameters (Annex III) and indicators (COM DEC 2010/477/EU).

Ref. num.	HD PARAMETER	Relevant MSFD parameter of Annex III	Relevant MSFD indicator
1	Natural range of natural habitat types of community interest	9	1.4.1, 6.1.1
2	Area covered by natural habitat types of community interest	9	1.4.1, 1.6.2, 1.7.1, 6.1.1
3	Specific structure of natural habitat types of community interest	9	6.1.1
4	Necessary functions of natural habitat types of community interest		
5	Status of conservation of species in natural habitat types of community interest	19, 26, 31, 35	1.6.1
6	Population dynamics of animal and plant species of community interest	18, 25, 30, 34	1.3.1, 1.6.1
7	Natural range of animal and plant species of community interest	17, 24, 29, 32	1.1.1
8	Presence of habitat for animal and plant species of community interest	9	1.5.1, 1.5.2
9	Population dynamics of animal and plant species of community interest in need of strict protection	18, 25, 30, 34	1.3.1, 1.6.1
10	Natural range of animal and plant species of community interest in need of strict protection	17, 24, 29, 32	1.1.1
11	Presence of (sufficiently large) habitat of animal and plant species of community interest in need of strict protection	9	1.5.1, 1.5.2
12	Incidental capture and killing of animals of community interest in need of strict protection		
13	Population dynamics of animal and plant species of community interest in need of strict protection	18, 25, 30, 34	1.3.1, 1.6.1
14	Natural range of animal and plant species of community interest in need of strict protection	17, 24, 29, 32	1.1.1
15	Presence of (sufficiently large) habitat of animal and plant species of community interest whose taking in the wild and exploitation may be subject to management measures	9	1.5.1, 1.5.2

Table 5. Monitoring parameters of the BD (adopted from Craglia et al., 2010b) their relative MSFD parameters (Annex III) and indicators (COM DEC 2010/477/EU).

Ref. num.	BD PARAMETER	Relevant MSFD parameter of Annex III	Relevant MSFD indicator
1	Trends and variations in population for the species birds in the Annex I	32, 33, 34, 35	1.1.1, 1.2.1, 1.3.1, 1.6.1, 4.1.1, 4.3.1
2	Trends and variations in population for species in danger of extinction	32, 33, 34, 35	1.1.1, 1.2.1, 1.3.1, 1.6.1, 4.1.1, 4.3.1
3	Trends and variations in population for vulnerable species	32, 33, 34, 35	1.1.1, 1.2.1, 1.3.1, 1.6.1, 4.1.1, 4.3.1
4	Trends and variations in population for species considered rare	32, 33, 34, 35	1.1.1, 1.2.1, 1.3.1, 1.6.1, 4.1.1, 4.3.1
5	Trends and variations in population for other species requiring particular attention	32, 33, 34, 35	1.1.1, 1.2.1, 1.3.1, 1.6.1, 4.1.1, 4.3.1
6	Trends and variations in population for migratory species not listed in the Annex I	32, 33, 34, 35	1.1.1, 1.2.1, 1.3.1, 1.6.1, 4.1.1, 4.3.1
7	National lists of species in danger of extinction		
8	Listing and ecological description of areas important to migratory species	9	1.5.1, 1.5.2, 1.6.3
9	Listing population levels of migratory species as shown by ringing	32, 33, 34, 35	1.1.1, 1.2.1, 1.3.1, 1.6.1, 4.1.1, 4.3.1
10	Role of certain species as indicators of pollution	41	8.2.1
11	Adverse effect of chemical pollution on population levels of bird species	41	8.2.1, 8.2.2

Table 6. Monitoring parameters of the CFP their relative MSFD parameters (Annex III) and indicators (COM DEC 2010/477/EU).

Ref. num.	CFP PARAMETER	Relevant MSFD parameter of Annex III	Relevant MSFD indicator
1	Share in unsorted landings for species and areas referred in COM DEC 2010/93/EC Chapter III B1	3, 5	1.1.1, 1.2.1, 1.7.1, 2.2.1, 3.1.1, 3.1.2, 3.2.1, 3.2.2, 3.3.1, 3.3.2, 3.3.3, 4.1.1, 4.2.1, 4.3.1
2	Length distribution of species listed in Appendix VII in the catches	3, 4	1.3.1, 1.6.1, 3.1.1, 3.1.2, 3.2.1, 3.2.2, 3.3.1, 3.3.2, 3.3.3, 3.3.4, 4.2.1
3	Average weight of discards of species listed in Appendix VII	3, 4	1.2.1, 1.6.1, 1.7.1, 2.2.1, 3.1.1, 3.1.2, 3.2.1, 3.2.2, 3.3.1, 3.3.2, 3.3.3, 4.1.1, 4.2.1, 4.3.1
4	Length distribution of discards of species listed in Appendix VII	3, 4	1.3.1, 1.6.1, 3.1.1, 3.1.2, 3.2.1, 3.2.2, 3.3.1, 3.3.2, 3.3.3, 3.3.4, 4.2.1
5	Age-reading of discards of species listed in Appendix VII	4	1.3.1, 3.1.1, 3.1.2, 3.2.1, 3.2.2
6	Weight of catches of recreational fisheries for the species and areas referred in Appendix IV (1 to 5)	3	1.2.1, 1.7.1, 2.2.1, 3.1.1, 3.1.2, 3.2.1, 3.2.2, 3.3.1, 3.3.2, 3.3.3, 4.1.1, 4.2.1, 4.3.1
7	Individual age of species listed in Appendix VII	4	1.3.1, 3.1.1, 3.1.2, 3.2.1, 3.2.2, 3.3.1
8	Individual length of species listed in Appendix VII	4	1.3.1, 1.6.1, 3.1.1, 3.1.2, 3.2.1, 3.2.2, 3.3.1, 3.3.2, 3.3.3, 3.3.4, 4.2.1
9	Individual weight of species listed in Appendix VII	4	1.6.1, 3.1.1, 3.1.2, 3.2.1, 3.2.2, 3.1.2, 3.2.1, 3.2.2, 4.2.1
10	Individual sex of species listed in Appendix VII		1.3.1
11	Individual maturity of species listed in Appendix VII		3.3.4
12	Individual fecundity of species listed in Appendix VII		1.3.1, 1.6.1
13	Wild salmon stocks in index rivers running to the Baltic Sea III b-d: Abundance of smolt, parr and ascending individuals	3, 5	1.2.1, 1.6.1, 1.6.2, 1.7.1, 2.2.1, 3.1.1, 3.1.2, 3.2.1, 3.2.2, 4.3.1
14	Species (data from fisheries-independent research surveys)	11	1.7.1, 2.1.1, 2.1.2
15	Species length (data from fisheries-independent research surveys)	4	1.3.1, 1.6.1, 3.1.1, 3.1.2, 3.2.1, 3.2.2, 3.3.1, 3.3.2, 3.3.3, 3.3.4, 4.2.1
16	Species abundance (data from fisheries-independent research surveys)	3	1.2.1, 1.6.1, 1.6.2, 1.7.1, 2.1.1, 2.2.1, 3.1.1, 3.1.2, 3.2.1, 3.2.2, 2.2.1, 4.3.1
17	Individual age (data from fisheries-independent research surveys)	4	1.3.1, 3.1.1, 3.1.2, 3.2.1, 3.2.2, 3.3.1
18	Individual length (data from fisheries-independent research surveys)	4	1.3.1, 1.6.1, 3.1.1, 3.1.2, 3.2.1, 3.2.2, 3.3.1, 3.3.2, 3.3.3, 3.3.4, 4.2.1

19	Individual sex (data from fisheries-independent research surveys)		1.3.1
20	Individual maturity (data from fisheries-independent research surveys)		3.3.4
21	Catches of species (based on logbooks)	3, 5	1.1.1, 1.2.1, 1.7.1, 2.2.1, 3.1.1, 3.1.2, 3.2.1, 3.2.2, 3.3.1, 3.3.2, 3.3.3, 4.1.1, 4.2.1, 4.3.1
22	Catches length (based on logbooks)	3, 4	1.3.1, 1.6.1, 3.1.1, 3.1.2, 3.2.1, 3.2.2, 3.3.1, 3.3.2, 3.3.3, 3.3.4, 4.2.1
23	Catches abundance (based on logbooks)	3	1.2.1, 1.6.1, 1.6.2, 1.7.1, 2.2.1, 3.1.1, 3.1.2, 3.2.1, 3.2.2, 4.3.1
24	Discards of species (based on observer trips)	3, 5	1.2.1, 1.6.1, 1.6.2, 1.7.1, 2.1.1, 2.2.1, 3.1.1, 3.1.2, 3.2.1, 3.2.2, 2.2.1, 4.3.1
25	Discards length (based on observer trips)	3, 4	1.3.1, 1.6.1, 3.1.1, 3.1.2, 3.2.1, 3.2.2, 3.3.1, 3.3.2, 3.3.3, 3.3.4, 4.2.1
26	Discards abundance (based on observer trips)	3	1.2.1, 1.6.1, 1.6.2, 1.7.1, 2.1.1, 2.2.1, 3.1.1, 3.1.2, 3.2.1, 3.2.2, 2.2.1, 4.1.1, 4.3.1

6. MONITORING UNDER THE REGIONAL SEAS CONVENTIONS

Article 6 of the MSFD recommends Member States to use existing regional institutional cooperation structures, such as those under Regional Sea Conventions, in order to achieve coherence and coordination of their marine strategies and build upon relevant existing programmes and activities.

The RSCs have developed monitoring guidance and environmental assessment schemes according to their current programs and recommend contracting parties to use them for their monitoring and assessment. A summary of the monitoring guidance developed by the RCSs, based on Piha & Zampoukas (2011), is given below:

6.1 OSPAR

OSPAR (1997a, b, c, d & e) has developed eutrophication monitoring guidelines for nutrients, Chl-a, benthos, phytoplankton species composition and oxygen. Monitoring data are used in the Common Procedure (OSPAR, 2005) for the identification of the eutrophication status and for the calculation of the relevant to nutrients, Chl-a and phytoplankton Ecological Quality Objectives (EcoQO) (OSPAR, 2009a).

In order to estimate EcoQO for healthy seal population and for sea bird breeding population size and breeding success in the North Sea (ICES, 2008) the productivity of these species should be monitored. Additionally, for the estimation of the EcoQO on large fish (OSPAR, 2008b), fish length should be monitored.

The OSPAR list of threatened and/or declining species and habitats (OSPAR, 2008c) list species that need to be protected but does not give recommendations/guidelines for monitoring.

OSPAR, through its Joint Assessment and Monitoring Programme (JAMP), has developed guidelines for monitoring contaminants in biota and sediments (OSPAR, 2002; 2009d) and for general and contaminant-specific biological effects monitoring (OSPAR, 1998; 2007a). OSPAR has also developed an EcoQO for assessing levels of oil pollutions for which a handbook (OSPAR, 2007b) exists with related monitoring guidelines.

OSPAR has developed monitoring guidelines for marine litter on beaches (2009b) and supporting photo guides (OSPAR, 2009c,e,f). An OSPAR Fulmar EcoQO has a fully developed methodology with related monitoring guidance (OSPAR, 2008d; van Franeker et al., 2011).

6.2 HELCOM

HELCOM addresses monitoring in the COMBINE program. The program manual provides guidelines for monitoring hydrographic and hydrochemical parameters, sediment traps, chlorophyll-a, phytoplankton, mesozooplankton, soft bottom macrozoobenthos, phytobenthos, coastal fish, bacterioplankton, as well as contaminants and their effects. More abiotic monitoring parameters, such as ice season and wave climate, are included in HELCOM's indicators fact sheets (Siegel & Gerth, 2010; Vainio et al., 2010; Pettersson et al., 2010; Feistel et al., 2010; Axe, 2010).

The biopollution index (Olenin et al., 2007) that was used by HELCOM (Olenina et al., 2009) for phytoplankton communities needs data on alien species abundance and impacts.

For the calculation of the indicators of the fact sheet on coastal fish communities (HELCOM, 2008) data on fish age, length and mortality are needed as well as data on species diversity and average trophic level of catches.

For the calculation of the reproductive success/health of white-tailed eagle (Helander et al., 2009), grey seal (Bäcklin et al., 2010) and ringed seal (Kunnasranta et al., 2010) the productivity of these species should be monitored.

The HELCOM Eutrophication assessment tool (HEAT) (Andersen et al., 2010) requires data on the biomass and abundance of benthic invertebrates as well as data on the presence of key and sensitive species. The HELCOM core indicator on the status of benthic invertebrate communities in the open Baltic Sea (Norkko & Villnäs, 2010) is based on diversity data.

For marine litter, HELCOM has developed Guidelines on sampling and reporting of marine litter found on beach (HELCOM Recommendation 29/2).

6.3 BUCHAREST CONVENTION

In the framework of the Bucharest Convention (Convention on the Protection of the Black Sea Against Pollution, Black Sea Commission) there is the regional monitoring program BSIMAP (Black Sea Integrated Monitoring and Assessment Program) based on national monitoring programs and financed by the Black Sea States. Compulsory parameters are related to nutrients, different contaminants and biology (phytoplankton, zooplankton, benthos, fish, mammals, invasive species). The status of implementation varies for different parameters. Manuals on sampling and analysis, including guidelines on equipment, site selection, abundance, biomass, blooms and taxonomic identification has been developed and used for soft-bottom macrozoobenthos (Todorova & Konsulova, 2005), zooplankton (Korshenko & Alexandrov, 2006) and phytoplankton (Moncheva, 2010; Moncheva & Parr, 2010).

6.4 BARCELONA CONVENTION

In the framework of the Barcelona Convention (UNEP – Mediterranean Action Plan) the TRIX (Vollenweider et al., 1998) is proposed for assessment and monitoring of eutrophication in the Mediterranean Sea (UNEP, 2007). It requires data on Chl-a, oxygen saturation, dissolved inorganic nitrogen and dissolved inorganic phosphorus.

For the detection of site-specific temporal trends of selected contaminants, trend monitoring is used for which a Protocol on Land-Based Sources[7] exists.

[7] http://195.97.36.231/dbases/webdocs/BCP/ProtocolLBS96_eng_P.pdf

7. MSFD INDICATORS AND THEIR RELATION WITH MONITORING PARAMETERS REQUIRED BY WFD, EQS, HD, BD, CFP, AND/OR RECOMMENDED BY THE RCSS

The MSFD Commission Decision 2010/477/EU on criteria and methodological standards on good environmental status of marine waters establishes a list of indicators for the evaluation of environmental status. As required by the MSFD Article 11, the linkage between MSFD requirements and requirements for monitoring under different specific European environmental legislation is shown in the following tables (7 – 17), where the MSFD indicators for the 11 descriptors of GES were listed together with relevant monitoring parameters in other EU legislation and in the RSCs. The cross means that there are monitoring parameters in EU legislation or monitoring recommendation and guidelines in the RCSs that can potentially be useful (if match with MSFD parameters and area of application) for the calculation/estimation of the MSFD indicator. Detailed tables relating indicators with specific monitoring parameters of the WFD, EQS, HD, BD and CFP are presented in the Annex.

DESCRIPTOR 1: BIOLOGICAL DIVERSITY

Table 7. Availability of monitoring parameters for the indicators (COM DEC 2010/477/EU) of biological diversity.

MSFD indicators	WFD[1]	HD[2]	BD[3]	CFP[4]	EQS	RSCs
1.1.1 Distributional range	X	X		X		
1.1.2 Distributional pattern within the latter, where appropriate						
1.1.3 Area covered by the species (for sessile/benthic species)	X					HELCOM Black Sea
1.2.1 Population abundance and/or biomass, as appropriate	X		X	X		HELCOM Black Sea
1.3.1 Population demographic characteristics (e.g. body size or age class structure, sex ratio, fecundity rates, survival/mortality rates)		X		X		HELCOM
1.3.2 Population genetic structure, where appropriate						
1.4.1 Distributional range		X				
1.4.2 Distributional pattern						
1.5.1 Habitat area		X	X			
1.5.2 Habitat volume, where relevant		X	X			
1.6.1 Condition of the typical species and communities[5]	X	X	X	X		HELCOM Black Sea
1.6.2 Relative abundance and/or biomass, as appropriate[6]	X	X	X	X		HELCOM Black Sea
1.6.3 Physical, hydrological and chemical conditions	X		X		X	OSPAR HELCOM Mediterranean
1.7.1 Composition and relative proportions of ecosystem components (habitats and species) [7]	X	X	X	X		HELCOM Black Sea

1: only for some species/groups and only in coastal waters
2: only for protected species and/or habitats
3: only for protected birds species
4: only for some fish and shellfish
5: There is no single definition of "condition" but abundance, biomass, length, weight and fecundity data can be used to estimate it
6: The cross indicates requirement for species abundance/biomass data and habitat cover
7: The cross indicates requirement for habitat extend and/or species abundance/biomass/ composition data

DESCRIPTOR 2: NON-INDIGENOUS SPECIES

Table 8. Availability of monitoring parameters for the indicators (COM DEC 2010/477/EU) of non-indigenous species.

MSFD indicators	WFD[1]	HD	BD	CFP[4]	EQS	RSCs
2.1.1 Trends in abundance, temporal occurrence and spatial distribution in the wild of non-indigenous species, particularly invasive non indigenous species, notably in risk areas, in relation to the main vectors and pathways of spreading of such species[8]	X			X		
2.2.1 Ratio between invasive non-indigenous species and native species in some well-studied taxonomic groups (e.g. fish, macroalgae, molluscs) that may provide a measure of change in species composition (e.g. further to the displacement of native species) [8]	X			X		HELCOM[9]
2.2.2 Impacts of non-indigenous invasive species at the level of species, habitats and ecosystem, where feasible						HELCOM[9]

1: only for some species/groups and only in coastal waters
4: only for some fish and shellfish
8: Although there is no obligation for particular alien species monitoring the existing monitoring for the CFP and WFD could possibly detect their presence and record their abundance. However, according to Vandekerkhove & Cardoso (2010) most existing monitoring programs fail to detect some indicative alien species.
9: Only a preliminary application of the biopollution index

DESCRIPTOR 3: COMMERCIAL FISH

Table 9. Availability of monitoring parameters for the indicators (COM DEC 2010/477/EU) of commercial fish.

MSFD indicators	WFD	HD	BD	CFP[10]	EQS	RSCs
3.1.1 Fishing mortality (F)[10]				X		HELCOM
3.1.2 Ratio between catch and biomass index (hereinafter catch/biomass ratio)[10]				X		HELCOM
3.2.1 Spawning Stock Biomass (SSB) [10]				X		HELCOM
3.2.2 Biomass indices[10]				X		HELCOM
3.3.1 Proportion of fish larger than the mean size of first sexual maturation[10]				X		HELCOM
3.3.2 Mean maximum length across all species found in research vessel surveys				X		HELCOM
3.3.3 95% percentile of the fish length distribution observed in research vessel surveys)				X		HELCOM
3.3.4 Size at first sexual maturation, which may reflect the extent of undesirable genetic effects of exploitation				X		

10: Cross indicates monitoring requirements for data on catch, discards, age, maturity, weight and/or length.

DESCRIPTOR 4: FOOD WEBS

Table 10. Availability of monitoring parameters for the indicators (COM DEC 2010/477/EU) of food webs.

MSFD indicators	WFD[1]	HD[2]	BD[3]	CFP[4]	EQS	RSCs
4.1.1 Performance of key predator species using their production per unit biomass (productivity)			X	X		OSPAR[11]
4.2.1 Large fish (by weight)[12]				X		OSPAR
4.3.1 Abundance trends of functionally important selected groups/species	X	X	X	X		HELCOM Black Sea

1: only for some species/groups and only in coastal waters
2: only for protected species and/or habitats
3: only for protected birds species
4: only for some fish and shellfish
11: Only for some species
12: Cross indicates monitoring requirements for length and weight data

DESCRIPTOR 5: EUTROPHICATION

Table 11. Availability of monitoring parameters for the indicators (COM DEC 2010/477/EU) of eutrophication.

MSFD indicators	WFD[1]	HD	BD	CFP	EQS	RSCs
5.1.1 Nutrients concentration in the water column	X					OSPAR, HELCOM, Mediterranean
5.1.2 Nutrient ratios (silica, nitrogen and phosphorus), where appropriate	X					OSPAR, HELCOM, Mediterranean
5.2.1 Chlorophyll concentration in the water column	X					OSPAR, HELCOM, Mediterranean
5.2.2 Water transparency related to increase in suspended algae, where relevant	X					OSPAR, HELCOM
5.2.3 Abundance of opportunistic macroalgae	X					OSPAR
5.2.4 Species shift in floristic composition such as diatom to flagellate ratio, benthic to pelagic shifts, as well as bloom events of nuisance/toxic algal blooms (e.g. cyanobacteria) caused by human activities	X					OSPAR, HELCOM
5.3.1 Abundance of perennial seaweeds and seagrasses (e.g. fucoids, eelgrass and Neptune grass) adversely impacted by decrease in water transparency	X					OSPAR, HELCOM
5.3.2 Dissolved oxygen, i.e. changes due to increased organic matter decomposition and size of the area concerned	X					OSPAR, HELCOM, Mediterranean

1: only for coastal waters

DESCRIPTOR 6: SEA-FLOOR INTEGRITY

Table 12. Availability of monitoring parameters for the indicators (COM DEC 2010/477/EU) of sea-floor integrity.

MSFD indicators	WFD[1]	HD[2]	BD	CFP	EQS	RSCs
6.1.1 Type, abundance, biomass and areal extent of relevant biogenic substrate	X	X				
6.1.2 Extent of the seabed significantly affected by human activities for the different substrate types[13]	X[13]					
6.2.1 Presence of particularly sensitive and/or tolerant species	X					HELCOM
6.2.2 Multi-metric indexes assessing benthic community condition and functionality, such as species diversity and richness, proportion of opportunistic to sensitive species	X					HELCOM Black Sea
6.2.3 Proportion of biomass or number of individuals in the macrobenthos above some specified length/size[14]						
6.2.4 Parameters describing the characteristics (shape, slope and intercept) of the size spectrum of the benthic community						

1: only for some species/groups and only in coastal waters
2: only for protected species and/or habitats
13: Affected sea-bed is not directly measured but abundance and cover of benthic species can be considered as an indication
14: Total macrobenthos biomass is measured for the WFD but not of separate size classes

DESCRIPTOR 7: HYDROGRAPHICAL CONDITIONS

Table 13. Availability of monitoring parameters for the indicators (COM DEC 2010/477/EU) of permanent alteration of hydrographical conditions

MSFD indicators	WFD[1]	HD	BD	CFP	EQS	RSCs
7.1.1 Extent of area affected by permanent alterations	X					
7.2.1 Spatial extent of habitats affected by the permanent alteration	X					
7.2.2 Changes in habitats, in particular the functions provided (e.g. spawning, breeding and feeding areas and migration routes of fish, birds and mammals), due to altered hydrographical conditions	X					

1: only for coastal waters

DESCRIPTOR 8: CONTAMINANTS AND POLLUTION EFFECTS

Table 14. Availability of monitoring parameters for the indicators (COM DEC 2010/477/EU) of contaminants and pollution effects

MSFD indicators	WFD[1]	HD	BD[3]	CFP	EQS[1]	RSCs
8.1.1 Concentration of the contaminants mentioned above, measured in the relevant matrix (such as biota, sediment and water) in a way that ensures comparability with the assessments under Directive 2000/60/EC	X				X	OSPAR, HELCOM, Mediterranean
8.2.1 Levels of pollution effects on the ecosystem components concerned, having regard to the selected biological processes and taxonomic groups where a cause/effect relationship has been established and needs to be monitored	X		X		X	OSPAR, HELCOM, Mediterranean
8.2.2 Occurrence, origin (where possible), extent of significant acute pollution events (e.g. slicks from oil and oil products) and their impact on biota physically affected by this pollution	X		X			OSPAR, HELCOM

1: only for coastal waters
3: only for protected birds species

DESCRIPTOR 9: CONTAMINANTS IN FISH AND OTHER SEAFOOD

Table 15. Availability of monitoring parameters for the indicators (COM DEC 2010/477/EU) of contaminants in fish and other seafood

MSFD indicators	WFD	HD	BD	CFP	EQS	RSCs
9.1.1 Actual levels of contaminants that have been detected and number of contaminants which have exceeded maximum regulatory levels[15]						
9.1.2 Frequency of regulatory levels being exceeded[15]						

15: Maximum levels for certain contaminants are set in Commission regulation No 1881/2006

DESCRIPTOR 10: MARINE LITTER

Table 16. Availability of monitoring parameters for the indicators (COM DEC 2010/477/EU) of marine litter.

MSFD indicators	WFD	HD	BD	CFP	EQS	RSCs
10.1.1 Trends in the amount of litter washed ashore and/or deposited on coastlines, including analysis of its composition, spatial distribution and, where possible, source						OSPAR, HELCOM
10.1.2 Trends in the amount of litter in the water column (including floating at the surface) and deposited on the seafloor, including analysis of its composition, spatial distribution and, where possible, source						
10.1.3 Trends in the amount, distribution and, where possible, composition of micro-particles (in particular micro-plastics)						
10.2.1 Trends in the amount and composition of litter ingested by marine animals (e.g. stomach analysis)						OSPAR[14]

14: Developed for one indicator species only which applies to most parts of the North East Atlantic.

DESCRIPTOR 11: UNDERWATER NOISE/ENERGY

Table 17. Availability of monitoring parameters for the indicators (COM DEC 2010/477/EU) of introduction of energy/underwater noise.

MSFD indicators	WFD	HD	BD	CFP	EQS	RSCs
11.1.1 Proportion of days and their distribution within a calendar year over areas of a determined surface, as well as their spatial distribution, in which anthropogenic sound sources exceed levels that are likely to entail significant impact on marine animals measured as Sound Exposure Level (in dB re 1µPa²·s) or as peak sound pressure level (in dB re 1µPa$_{peak}$) at one metre, measured over the frequency band 10 Hz to 10 kHz						
11.2.1 Trends in the ambient noise level within the 1/3 octave bands 63 and 125 Hz (centre frequency) (re 1µPa RMS; average noise level in these octave bands over a year) measured by observation stations and/or with the use of models if appropriate.						

Among the MSFD descriptors are indicators and thus monitoring parameters which so far had been less considered. The identification of these gaps goes along with the identification of gaps in monitoring certain geographical areas, such as e.g. the open sea, or gaps in the temporal coverage, i.e. the frequency of data acquisition for deriving representative data in timescales which are compatible with the MSFD cyclic process.

8.1 Gaps in coverage of indicators

Tables 7-17 show that only few indicators are not covered in any extend by any other existing requirement. These indicators are:

1.3.2 Population genetic structure, where appropriate

Information on the genetic structure of a population could be possibly derived by studying both phenotypes and genotypes. For the latter, many papers present applications of molecular techniques in population genetics and conservation issues (Avise & Hamrick, 1996; Avise, 1998 Haig 1998; Sweijd, 2000; Moran, 2002; Azam & Worden, 2004; Wayne & Morin, 2004). However, standards for monitoring genetic structure do not exist and this is a field where research is needed. At first it is important to evaluate for which species, populations and marine areas monitoring of genetic structure is appropriate and then search for the phenotypic characteristic and/or genetic loci that could be meaningful and feasible to monitor. Biological material for such studies could be derived from samples collected from existing monitoring or in case of protected species it can be their dead parts.

6.2.3 Proportion of biomass or number of individuals in the macrobenthos above some specified length/size

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

Requirement for measurement and recording of size should be added to the existing benthos monitoring and should be included to the ones that will be developed, particularly for off-shore areas. In particular for some benthic shellfish, data on size are collected according to the Data Collection Framework.

10.1.3 Trends in the amount, distribution and, where possible, composition of micro-particles (in particular micro-plastics) and all indicators related to Descriptor 11 (11.1.1, 11.2.1)

Descriptors 10 Marine Litter and Descriptor 11 Noise/Energy and related indicators are not mature Descriptors, as has been acknowledged also in the Commission Decision on criteria and methodological standards on good environmental status (GES) of marine waters (Commission Decision 2010/477/EU). As a consequence, gaps in monitoring are evident. As a follow up to the Commission Decision, technical subgroups for the further development of Descriptors 10 and 11 have been established in 2011. The recommendations developed for litter are published (MSFD GES Technical Subgroup on Marine Litter, 2011) while for noise they will be finalised in 2012.

For the rest of indicators relative monitoring exist but as demonstrated in Tables 7-15 it often only partially covers requirements and there are several limitations to its application for the requirements of the MSFD.

With regards to the EQS Directive, the Commission is obliged to continue to review the list of priority substances, prioritising substances for action on the basis of agreed criteria that demonstrate the risk to, or via, the aquatic environment, in accordance with the 4-year-cycle provided for in Article 16 of the WFD, and bring forward proposals as appropriate.

8.2 Gaps in spatial and temporal coverage

Spatial coverage of existing monitoring requirements and programs.

The MSFD is applied to marine waters under the sovereignty and jurisdiction of Member States that in case of Exclusive Economic Zones may extend up to 200 nm from the coast.

From the European legislation mentioned above HD, BD and CFP apply to all the marine areas where the habitats and species occur and/or where fish populations and fisheries activities occur. WFD & EQS explicitly apply to coastal (<1nm from the baseline) and for priority pollutants to territorial waters (< 12 nm).

Consequently, one of the biggest challenges is to extend monitoring off-shore. Further in this report some monitoring approaches capable of collecting data from wide marine areas are shortly presented and discussed in relation to the indicators that need to be considered in the open sea.

Frequency of monitoring:

In the MSFD there are no specifications for monitoring frequency. Since the cycle of assessment, determination of GES, target setting, monitoring and establishment of measures should be reviewed and updated every six years the provided data should allow representative assessments at that timescale. While for some indicators therefore the minimum monitoring frequency should not be less than every 6 years, others are based on trend assessments and monitoring of change, requiring therefore higher data acquisition frequencies.

The WFD provides some guidelines for the minimum operational (for water bodies at risk) monitoring frequency in coastal waters as shown below:

QUALITY ELEMENT	FREQUENCY
Phytoplankton	6 months
Other aquatic flora	3 years
Macro invertebrates	3 years
Morphology	6 years
Thermal conditions	3 months
Oxygenation	3 months
Nutrient status	3 months
Other pollutants	3 months
Priority substances	1 months

Surveillance monitoring (for water bodies not at risk) can be done once every six years or even once every 18 years in the cases of water bodies that reached good status in the previous surveillance monitoring exercise and when the relevant review provides no evidence of new pressures.

In the EQS Directive, the long-term trend analysis of concentrations of those priority substances that tend to accumulate in sediment and/or biota is advised to be based on data collected in monitoring occurring every three years, unless technical knowledge and expert judgment justify another interval.

According to the Habitats Directive Member States should report every six years the implementation of the conservation measures taken as well as an evaluation of the impact of those measures on the conservation

status of the natural habitat types and species and the main results of the surveillance of their conservation status. Consequently, the frequency of monitoring for the HD should be at least every six years.

According to the Birds Directive, Member States should report every three years on the implementation of protection measures, taking into account trends and variations in population levels. Consequently, the frequency of monitoring for the BD should be at least every three years.

Monitoring for the CFP should be done yearly or every three years depending on the species.

Conclusively, all the relevant *aquis* requires monitoring ranging from every 1 months to every 6 years and thus with intervals not longer than the 6 years cycle of MSFD implementation. The choice of MSFD monitoring frequency should be parameter and indicator specific e.g. more frequent for particularly dynamic biota such as phytoplankton and less for long lived species such as mammals and reptiles.

Guidance on the frequency of monitoring are also set as part of monitoring programmes related to the RSCs, such as the OSPAR Joint Assessment and Monitoring Programme, the Programme for the Assessment and Control of Marine Pollution in the Mediterranean region (MED POL), the Black Sea Integrated Monitoring and Assessment Programme (BSIMAP) and the HELCOM monitoring programme.

9. OPTIONS FOR INTEGRATED MONITORING

With the enormous amount of monitoring undertaken in the previous decades and the addition of further requirements through the MSFD, it is important to investigate the possibility for synergies between monitoring for different purposes. Also different MSFD Descriptors require the same or similar data, thus allowing a considerable reduction in effort through integration.

For the purpose of this report we considered integrated monitoring as the one providing data:

a) for the calculation of different indicators and the assessment of different descriptors
b) fulfilling the monitoring requirements of different pieces of legislation
c) covering the monitoring needs of more than one Member State
d) collected in comparable way between MSs

9.1 Integration across descriptors and indicators

The commonalities and possible synergies between indicators of different descriptors is obvious and also reflected in the fact that the MSFD Common Implementation Strategy Working Group on GES is currently discussing GES definition and target setting by grouping descriptors into themes and subthemes as below:

Ref. number	Themes	Subtheme	Descriptors
I	Nutrients enrichment and contaminants		5, 8 & 9
I A		Nutrients enrichment	5
I B		Contaminants	8 & 9
II	Disturbance		10 & 11
III	Biodiversity		1, 2, 3, 4, 6, 7
III A		Species	1(partly), 2, 3 & 4
III B		Habitats	1 (partly), 6 & 7

As shown before, different MSFD indicators need the same or similar basic data for their evaluation. E.g. while monitoring fish abundance and age/size structure provides data relevant for the biodiversity descriptors 1, 3 and 4 monitoring angiosperms and invertebrate bottom fauna species composition provides data relevant for biodiversity descriptors 1 and 6 and for nutrient enrichment descriptor 5. Monitoring surveys where many biotic and abiotic parameters of the water column and the sea bottom are measured are already a common practice in many Member States. The MSFD implementation groups encourage to further improve efficiency in that process. This should be discussed at EU level in order to allow an exchange of experiences.

9.2 Integration across legislative requirements and RCSs recommendation.

Tables 2- 6 of this report and the detailed tables in the Annex show that there is a significant overlap between the monitoring requirements of the MSFD and those of the rest of the nature and water protection aquis. Consequently, it is recommended that existing marine monitoring programmes could be amended in order to cover the MSFD parameters where there is no or only partial overlap.

The approach of United Kingdom that tends to planits monitoring in such an integrated manner is shortly presented:

The CEFAS Clean Seas Environmental Monitoring Programme (CSEMP) for England & Wales is presented in the following site:

http://www.cefas.co.uk/our-science/observing-and-modelling/monitoring-programmes/clean-seas-environment-monitoring-programme.aspx

There is both coastal and off shore monitoring for contaminants, benthos, litter, eutrophication and fish. Most samples are collected during an annual vessel cruise in summer supplemented by additional eutrophication sampling during winter, covering both the OSPAR and EU related monitoring requirements. SmartBuoys are also used to collect timeseries of surface (at 1 metre) salinity, temperature, turbidity, chlorophyll fluorescence and nitrate concentration in few sites.

Member States interested in knowing how marine monitoring is organized in other countries can also consult the JRC database of the Shared Environmental Information System (SEIS) Monitoring Capacity Baseline and Evolution Study at http://seis-basis.jrc.ec.europa.eu/preview/. The aim of this database is to record the current 'operational capacity' in terms of who is monitoring what in the European environment, how they are doing this, for which reporting obligations (and other policies) and where, including specific sites, certain countries or regions, as well as cross-border partnerships. Themes include, among others, Nature protection, Chemicals and Water. The database is not complete and it depends on the availability of publically available sources on national monitoring and inputs from stakeholders. Interested people need to register and use the search menu to find how environmental monitoring (including marine one) is organized in these Member States that provided relevant information.

Additionally, the German Federal Agency for Nature Conservation has a site with much information on their marine monitoring in relation to the European and Regional monitoring requirements. Some info is in English: http://www2.bfn.de/habitatmare/en/monitoring-anforderungen.php

9.3 Integration across Member States.

Member States, particularly ones sharing a marine area, could possibly arrange common monitoring surveys in order to share and minimize the costs and ensure that data acquisition is done in a similar and comparable manner thus allowing them to come to a comparable assessment and classification of their marine areas.

An example is the UK-Netherlands collaborative monitoring programme where Cefas (UK) and RIKZ (NL) are jointly operating a SmartBuoy to measure the rapidly changing environmental conditions in Dutch coastal waters. The main aim of this collaboration is to allow comparison of the measurements obtained from the

standard methods employed in a ship-based monitoring programme with the automated in situ SmartBuoy data (http://www.cefas.co.uk/our-science/observing-and-modelling/monitoring-programmes/uk-netherlands-collaborative-monitoring-programme.aspx).

Furthermore, European FP7 projects such as PERSEUS that will start in 2012 and others under later calls will develop innovative and integrated monitoring systems with the co-operation of several partners from different Member States and are expected to enhance and promote such integration.

9.4 Collection of data in a comparable way

Apart from joint sampling efforts, coordination and harmonization could profit from standardized approaches on what to sample and how to process it. ISO and CEN standards are available for few of the descriptors and indicators required by the MSFD and have been listed by Piha & Zampoukas (2011).

10. APPROACHES TO BE CONSIDERED FOR MSFD MONITORING

Data availability and its collection constitute a potential major obstacle to marine environment assessment, target setting and trends monitoring. At present, most of the methods in use necessitate gathering detailed information using direct observations or sampling methods. Such approaches often provide adequate information for coastal areas but off shore detailed information is usually sparse or absent. The costs and scales required to provide detailed information throughout our seas severely constrain approaches that require detailed evidence-based information. New broad-scale methods and methods that use surrogate information about the resource are needed.

Several approaches and techniques of measurement are available in marine environment monitoring. These consist of direct sampling, airborne and satellite imagery, hydrological measurements using CTD probes, remote sensing with the use of electromagnetic waves and acoustic methods. Marine monitoring involves the acquisition, processing, integration and visualisation of various kinds of data obtained through these techniques. The relative importance and integration of one or more of these depends of the goals and objectives established and the specific indicators to be monitored. The collection of data for monitoring of marine areas shall provide data allowing for the reliable spatial modelling of the study areas.

In this chapter some approaches that could be of value for an effective monitoring of the spatial scale relevant to the MSFD are listed and shortly described. These approaches, while not new, are not commonly included in marine monitoring programs. We addressed some first considerations on their usefulness according to the following criteria:

- Are they able to provide data from areas larger than just coastal waters?
- With which indicators would these approaches be related?
- Are these data of adequate resolution to calculate the MSFD indicators?

Conclusions are summarized in Table 18.

10.1 Moorings and buoys

Moored and free-floating buoys have a long history of use in oceanography and coastal sciences, measuring a large variety of important physical, chemical and biological variables such as salinity, temperature, turbidity, dissolved oxygen, trace metals, pCO2 and others, depending on the number of instruments they can handle. Data can be measured at high frequency at strategic sites and at different depths owing to sophisticated profiling equipment. Data are then transmitted in real-time to land-based observatories via communication satellites. The efficiency of buoys has been considerably increased owing to advanced technology including solar storage batteries, data logging controller, environment-friendly antifouling coatings. Autonomous devices like SmartBuoys operated by CEFAS in UK waters have already provided, over more than a decade, reliable data sets directly use for water quality management and monitoring changes in the ecosystem

functioning. The ARGOS buoy network provides data from buoys which are periodically sinking to depth and transmit the data when surfacing.

10.2 Ship of opportunity / FerryBox system

The use of volunteer merchant vessels to gather oceanographic data is an important cost-effective component of any monitoring programmes. As for the moorings, ships of opportunity can be fitted with various instrumentations to collect data related to physical, chemical and biological oceanography. As an alternative to often expensive and time-consuming research vessels, merchant fleet and specifically ferries offer a regular line sampling frequency across a wide range of water types. The so-called FerryBox system consists of an automatic flow-through system pumping sea water on the side of the ship and propelling it in a internal loop at constant velocity to conduct the various measurements. The FerryBox community is continuously increasing and represents ca. 20 different institutions in Europe. More details on the system and the operating companies can be found at http://www.ferrybox.org.

10.3 Continuous Plankton Recorder (CPR)

The CPR is a plankton sampling instrument designed to be towed from ships. The CPR is towed at a depth of approximately 10 metres. Water passes through the CPR and plankton is filtered onto a slow-moving band of silk. In the laboratory CPR samples are analyzed in two ways. The Phytoplankton Colour Index (PCI), a semi-quantitative estimate of phytoplankton biomass, is determined for each sample. Then, microscopic analysis is undertaken for each sample, and individual phytoplankton and zooplankton taxa are identified and counted. For more information on CPR see Warner & Hays (1994).

CPR can sample larger areas than other phytoplankton and zooplankton devices such as bottles and nets. Data on biomass that are needed for many indicators can easily be taken while taxonomic identification needed for other indicators needs the same skills and human power as with any other sampling method.

CPR has also been used to monitor microlitter in the water column (see Thompson et al., 2004). However the CPR samples at approximately 10m depth and so will not sample floating debris.

10.4 Underwater video & Imagery

Video can be used to take images of both the sea-bed and the water column. Video cameras can be tethered to oceanographic vessels as well as other non-research vessels (ferries, fishing vessels, ships of opportunity). Depending on the quality of the images recorded they can provide information on the structure of the sea-bed, the composition and abundance of macroscopic benthic biota and the composition and abundance of macroscopic pelagic biota. Non-living items, such as litter, can also be recorded. The technique performs well in terms of resolution and information content but not so good in relation to workload and areal coverage.

An example is the counting of *Nephrops* burrows in Ireland where an underwater video camera is towed over the sea bed for around 200m and 0.8 knots on a purpose built sledge as presented in the following site: http://www.marine.ie/home/services/surveys/fisheries/Nephrops+Under+Water+TV+Surveys.htm

Another application of video has been developed to monitor the impacts of offshore wind farms. According to Sheehan et al. (2010) it seems possible to extract macrobenthos quantitative data (including some level of taxonomic identification and size measurements) by using a high-definition video camera, plus LED lights and laser scale markers, mounted on a "flying array". Care should be taken to minimize or eliminate any possible damage to the sea bed by avoiding contact of the equipment with the bottom.

10.5 Underwater acoustics

Hydroacoustics (echo sounding or sonar), is commonly used for detection, assessment, and monitoring of underwater physical and biological characteristics. The very efficient transmission of sound in water makes this remote-sensing technique highly effective in most aquatic ecosystems and under many environmental conditions providing a valuable complement to capture-based sampling techniques.

Sonars can be used for the detection of animal and plant populations and provide some information on their abundance, size, behavior and distribution. They are already widely in use in the marine environment both by fishermen and by fisheries scientists for the investigation of fish populations. Hydroacoustic surveys provide for non-intrusive methods for quantifying the abundance and distribution of fish. Advances in acoustic technology, and especially data analysis software, have made this survey method even more powerful in recent years. While there are limitations in terms of species identification, acoustic surveys used in conjunction with other methods or as a relative measure, provide a quantifiable metric over the years. Validation should occur simultaneously through the use of high resolution sonar imaging, underwater cameras, and other methods.

Sonars are also used for habitat mapping (mainly depth, bottom roughness and hardness reflecting differences in sub-stratum types). More recently, the combination of different hydroacoustic methods (i.e. single beam echosounder, multi-beam sonar and side scan sonar) enables the spatial classification of the seafloor and its vegetation. The resulting 3 D images are of the same quality and precision as those found in the field of biomedicine.

Recording of sounds produced by marine animals (mainly mammals) could possibly provide info on their population abundance, their movements and location of their habitats. A related project is running in Catalonia: http://listentothedeep.com/

10.6 Remote sensing

Earth Observation (EO) from satellite provides information at unprecedented time scales over large and distant areas of the world ocean in a real cost-effective way, where only few observations can be conducted by traditional methods using oceanographic vessels. Satellite remote sensing techniques also grant consistent methodologies while capturing the regional and local variability at a frequency nearly compatible with the dynamics of marine processes. Such kind of synoptic observations have made important contributions to monitor the state of the marine environment in terms of its physical and biological properties and is increasingly used to foster sustainable management of the marine and coastal resources, including fisheries.

Optical sensors on-board satellite (e.g. MERIS on ENVISAT; http://envisat.esa.int/instruments/meris) relates to the 'colour' of the sea surface that varies with the concentration and composition of a large variety of living and non-living material is suspension. An important quantity is the concentration of chlorophyll, an omnipresent pigment in all phytoplankton species commonly used as an index of phytoplankton biomass. Other products of interest include total suspended matter, pigmented fraction of dissolved organic matter, as well as some indication of phytoplankton functional groups. Data can be accessed freely through space agencies or via specific web sites such as the Environmental Marine Information System from the Joint Research Centre (http://emis.jrc.ec.europa.eu).

10.7 Autonomous Underwater Vehicles (AUVs) and Gliders

The development of AUV technology for marine and coastal studies has increased considerably over the last decade as an alternative to costly and heavy logistic demand of research vessels. AUVs are free-swimming torpedo-shaped devices remotely operated from the surface within the range of the telemetry system on-board. Owing to a number of propulsion techniques most often powered by rechargeable batteries, AUVs can cover large distance (ca. 10 miles) at various depths to provide a 3D view of the water column. Gliders are specific AUVs propelling themselves using buoyancy-based techniques, increasing the underwater autonomy of the vehicle for observations of longer time-scale features. The scientific payload of AUVs and gliders can be

set with physical and bio-optical instruments measuring water quality variables (such as nutrients and contaminants), phytoplankton biomass, in addition to physical and geochemical properties such as temperature, oxygen, conductivity. They can also transport video-cameras to get pictures of organisms (mostly pelagic) and/or debris and also detectors of passive acoustic signals. The European Gliding Observatories (EGO; http://www.ego-network.org/) has been set up to promote the use of glider technology in marine and coastal studies, to share data, and to provide technical advices and training.

Table 18. Monitoring methods, their applicability in off-shore areas and their capability to collect data relevant for MSFD indicators

METHOD/DEVICE	RELATIVE MSFD INDICATORS	OFF-SHORE SPATIAL COVERAGE	CONSIDERATIONS
Moorings and Buoys *	1.6.3, 5.1.1, 5.1.2, 5.2.1, 5.2.2, 5.2.3, 5.2.4, 5.3.2, 8.1.1, 8.2.2, 9.1.1, 9.1.2, 11.1.1, 11.2.1	X	Require periodic visits for maintenance and cleaning of the instruments. Point measurements over the water column.
Ships of opportunity *	5.1.1, 5.1.2, 5.2.1, 5.2.2, 5.2.3, 5.2.4, 7.1.1, 8.1.1, 8.2.2, 9.1.1, 9.1.2	X	Transect measurements at one depth level (surface or sub-surface), use of fishery vessels for sampling
Underwater video & Imagery	1.1.1, 1.1.2, 1.1.3, 1.2.1, 1.3.1, 1.4.1, 1.4.2, 1.5.1, 1.5.2, 1.6.2, 1.7.1, 2.2.1, 2.2.2, 3.2.2, 4.3.1, 5.2.3, 5.3.1, 6.1.1, 6.1.2, 6.2.1, 6.2.2, 6.2.3, 6.2.4, 7.1.1, 7.2.1, 7.2.2,	X	Better applied to benthic habitats and biota. Taxonomic resolution not always comparable to the one achieved by traditional tools (e.g. grabs, corers) , surveys for marine litter including image acquisition and recognition technology
Acoustics	1.1.1, 1.1.2, 1.1.3, 1.2.1, 1.4.1, 1.5.1, 1.6.3, 1.7.1, 3.2.2, 4.3.1	X	Taxonomic identification not always at species level
CPR	1.1.1, 1.1.2, 1.2.1, 1.6.1, 1.6.2, 1.7.1, 2.1.1, 2.2.2, 4.3.1, 5.2.1, 5.2.4, 10.1.3	X	Needs to be towed from special vessel with specific speed
Remote sensing	1.5.1.,1.6.3, 5.2.1, 5.2.2, 5.2.4, 7.2.1, 7.2.2, 8.2.2	X	Passive optical and thermal sensors of limited use under cloud cover and low sun angle Taxonomic resolution restricted to phytoplankton functional groups
AUVs and Gliders**	1.1.1, 1.1.2, 1.1.3, 1.2.1, 1.3.1, 1.4.1, 1.4.2, 1.5.1, 1.5.2, 1.6.2, 1.6.3, 1.7.1, 2.2.1, 2.2.2, 4.3.1, 5.1.1, 5.1.2, 5.2.1, 5.2.2, 5.2.4, 5.3.2, 7.1.1, 7.2.1, 7.2.2, 8.1.1, 8.2.1, 8.2.2, 11.1.1, 11.2.1	X	Cost depends on the onboard instrumentation. Require considerable technical expertise.

* refers to automated and unattended systems

** depending on the scientific payload

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12. MSFD MANEGEMENT GROUP REPORT &TASK GROUP REPORTS

Further details on the assessment methods can be found in the MSFD Task Group reports relating to the descriptors of GES listed in Annex I of the Directive:

A. C. Cardoso, S. Cochrane, H. Doerner, J. G. Ferreira, F. Galgani, C. Hagebro, G. Hanke, N. Hoepffner, P. D. Keizer, R. Law, S. Olenin, G. J. Piet, J. Rice, S. I. Rogers, F. Swartenbroux, M. L. Tasker & W. van de Bund 2010. Scientific support to the European Commission on the Marine Strategy Framework Directive. Management Group Report. EUR 24336 EN - 2010
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The following tables are the detailed version of Tables 7-14 of the report and present the relation of MSFD indictors of the COM DEC 2010/477/EU with specific monitoring parameters of the Water Framework Directive (WFD), Habitats Directive (HD), Birds Directive (BD), Environmental Quality Standards Directive (EQS), and the Common Fisheries Policy (CFP) that are listed in Tables 2-6 of the report. For Descriptors 9, 10 and 11 no correlation tables are presented as their indicators are not reflected in the beforementioned pieces of legislation.

Table 1. MSFD indicators (COM DEC 2010/477/EU) for Descriptor 1 and the relation with required parameters from other legislation. The numbering of the parameters refers to the reference number presented in Tables 2-6 of this report.

MSFD indicators	WFD	HD	BD	CFP	EQS
1.1.1 Distributional range	4, 13	7, 10, 14			
1.1.2 Distributional pattern within the latter, where appropriate					
1.1.3 Area covered by the species (for sessile/benthic species)	3, 12				
1.2.1 Population abundance and/or biomass, as appropriate	1, 3, 4, 7, 11, 12, 13, 15		1, 2, 3, 4, 5, 6, 9	1, 3, 6, 13, 16, 21, 23, 24, 26	
1.3.1 Population demographic characteristics (e.g. body size or age class structure, sex ratio, fecundity rates, survival/mortality rates)		6, 9, 13		2, 4, 5, 7, 8, 10, 12, 15, 17, 18, 19, 22, 25	
1.3.2 Population genetic structure, where appropriate					
1.4.1 Distributional range		1, 2			
1.4.2 Distributional pattern					
1.5.1 Habitat area		8,11, 15	8		
1.5.2 Habitat volume, where relevant		8,11, 15	8		
1.6.1 Condition of the typical species and communities	1, 3, 4, 7, 11, 12, 13, 15	5, 6, 9, 13	1, 2, 3, 4, 5, 6, 9	2, 3, 4, 8, 9, 12, 13, 15, 16, 18, 22, 23, 24. 25, 26	
1.6.2 Relative abundance and/or biomass, as appropriate	1, 2, 3, 7, 8, 11, 12, 13, 14, 15, 16, 17, 18	2	1, 2, 3, 4, 5, 6, 9	13, 16, 23, 24, 26	
1.6.3 Physical, hydrological and chemical conditions	20, 21, 22, 26, 30, 31, 32, 34, 35, 36, 37, 38		8		1, 2
1.7.1 Composition and relative proportions of ecosystem components (habitats and species)	1, 2, 3, 4, 7, 8, 9, 11, 12, 13, 14, 15, 16, 18, 19, 20, 21	2	1, 2, 3, 4, 5, 6, 9	1, 3, 6, 13, 14, 16, 21, 22, 24, 26	

Table 2. MSFD indicators (COM DEC 2010/477/EU) for Descriptor 2 and the relation with required parameters from other legislation. The numbering of the parameters refers to the reference number presented in Tables 2-6 of this report.

MSFD indicators	WFD	HD	BD	CFP	EQS
2.1.1 Trends in abundance, temporal occurrence and spatial distribution in the wild of non-indigenous species, particularly invasive non indigenous species, notably in risk areas, in relation to the main vectors and pathways of spreading of such species	2, 8, 14, 18			14, 16, 24, 26	
2.2.1 Ratio between invasive non-indigenous species and native species in some well studied taxonomic groups (e.g. fish, macroalgae, molluscs) that may provide a measure of change in species composition (e.g. further to the displacement of native species)	2, 8, 14, 18			1, 3, 6, 13, 14, 16, 21, 23, 24, 26	
2.2.2 Impacts of non-indigenous invasive species at the level of species, habitats and ecosystem, where feasible					

Table 3. MSFD indicators (COM DEC 2010/477/EU) for Descriptor 3 and the relation with required parameters from other legislation. The numbering of the parameters refers to the reference number presented in Tables 2-6 of this report.

MSFD indicators	WFD	HD	BD	CFP	EQS
3.1.1 Fishing mortality (F)				1, 2, 3, 4, 5, 6, 7, 8, 9, 13, 15, 16, 17, 18, 21, 22, 23, 24, 25, 26	
3.1.2 Ratio between catch and biomass index (hereinafter catch/biomass ratio)				1, 2, 3, 4, 5, 6, 7, 8, 9, 13, 15, 16, 17, 18, 21, 22, 23, 24, 25, 26	
3.2.1 Spawning Stock Biomass (SSB)				1, 2, 3, 4, 5, 6, 7, 8, 9, 13, 15, 16, 17, 18, 21, 22, 23, 24, 25, 26	
3.2.2 Biomass indices				1, 2, 3, 4, 5, 6, 7, 8, 9, 13, 15, 16, 17, 18, 21, 22, 23, 24, 25, 26	
3.3.1 Proportion of fish larger than the mean size of first sexual maturation				1, 2, 3, 4, 6, 7, 8, 15, 17, 18, 21, 22, 25	
3.3.2 Mean maximum length across all species found in research vessel surveys (3.3.2)				1, 2, 3, 4, 6, 8, 15, 18, 21, 22, 25	
3.3.3 95% percentile of the fish length distribution observed in research vessel surveys (3.3.3)				1, 2, 3, 4, 6, 8, 15, 18, 21, 22, 25	
3.3.4 Size at first sexual maturation, which may reflect the extent of undesirable genetic effects of exploitation				2, 4, 8, 11, 15, 18, 20, 22, 25	

Table 4. MSFD indicators (COM DEC 2010/477/EU) for Descriptor 4 and the relation with required parameters from other legislation. The numbering of the parameters refers to the reference number presented in Tables 2-6 of this report.

MSFD indicators	WFD	HD	BD	CFP	EQS
4.1.1 Performance of key predator species using their production per unit biomass (productivity)			1, 2, 3, 4, 5, 6, 9	1, 3, 6, 21, 26	
4.2.1 Large fish (by weight)				3, 4, 6, 8, 9, 15 18, 21 22, 25	
4.3.1 Abundance trends of functionally important selected groups/species	1, 3, 4, 7, 11, 12, 15, 16, 17		1, 2, 3, 4, 5, 6, 9	1, 3, 6, 13, 16, 21, 23, 24, 26	

Table 5. MSFD indicators (COM DEC 2010/477/EU) for Descriptor 5 and the relation with required parameters from other legislation. The numbering of the parameters refers to the reference number presented in Tables 2-6 of this report.

MSFD indicators	WFD	HD	BD	CFP	EQS
5.1.1 Nutrients concentration in the water column	23, 24, 25				
5.1.2 Nutrient ratios (silica, nitrogen and phosphorus), where appropriate	23, 24, 25				
5.2.1 Chlorophyll concentration in the water column	15, 16				
5.2.2 Water transparency related to increase in suspended algae, where relevant	37				
5.2.3 Abundance of opportunistic macroalgae	11				
5.2.4 Species shift in floristic composition such as diatom to flagellate ratio, benthic to pelagic shifts, as well as bloom events of nuisance/toxic algal blooms (e.g. cyanobacteria) caused by human activities	17, 18, 19				
5.3.1 Abundance of perennial seaweeds and seagrasses (e.g. fucoids, eelgrass and Neptune grass) adversely impacted by decrease in water transparency	1, 11				
5.3.2 Dissolved oxygen, i.e. changes due to increased organic matter decomposition and size of the area concerned	26				

Table 6. MSFD indicators (COM DEC 2010/477/EU) for Descriptor 6 and the relation with required parameters from other legislation. The numbering of the parameters refers to the reference number presented in Tables 2-6 of this report.

MSFD indicators	WFD	HD	BD	CFP	EQS
6.1.1 Type, abundance, biomass and areal extent of relevant biogenic substrate	8, 27, 28, 29	1, 2, 3			
6.1.2 Extent of the seabed significantly affected by human activities for the different substrate types	1, 3, 7, 11, 12				
6.2.1 Presence of particularly sensitive and/or tolerant species	2, 5, 6, 8, 10, 14				
6.2.2 Multi-metric indexes assessing benthic community condition and functionality, such as species diversity and richness, proportion of opportunistic to sensitive species	2, 8, 9, 14				
6.2.3 Proportion of biomass or number of individuals in the macrobenthos above some specified length/size					
6.2.4 Parameters describing the characteristics (shape, slope and intercept) of the size spectrum of the benthic community					

Table 7. MSFD indicators (COM DEC 2010/477/EU) for Descriptor 7 and the relation with required parameters from other legislation. The numbering of the parameters refers to the reference number presented in Tables 2-6 of this report.

MSFD indicators	WFD	HD	BD	CFP	EQS
7.1.1 Extent of area affected by permanent alterations	27, 28, 29				
7.2.1 Spatial extent of habitats affected by the permanent alteration	27, 28, 29				
7.2.2 Changes in habitats, in particular the functions provided (e.g. spawning, breeding and feeding areas and migration routes of fish, birds and mammals), due to altered hydrographical conditions	27, 28, 29				

Table 8. MSFD indicators (COM DEC 2010/477/EU) for Descriptor 8 and the relation with required parameters from other legislation. The numbering of the parameters refers to the reference number presented in Tables 2-6 of this report.

MSFD indicators	WFD	HD	BD	CFP	EQS
8.1.1 Concentration of the contaminants mentioned above, measured in the relevant matrix (such as biota, sediment and water) in a way that ensures comparability with the assessments under Directive 2000/60/EC	20, 21				1, 2
8.2.1 Levels of pollution effects on the ecosystem components concerned, having regard to the selected biological processes and taxonomic groups where a cause/effect relationship has been established and needs to be monitored	20, 21		10, 11		1, 2
8.2.2 Occurrence, origin (where possible), extent of significant acute pollution events (e.g. slicks from oil and oil products) and their impact on biota physically affected by this pollution	20, 21		11		1, 2

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Abstract
According to the Marine Strategy Framework Directive (MSFD: 2008/56/EC) coordinated monitoring programmes should be established and implemented by Member States in order to assess the environmental status of marine waters and the achievement of environmental targets. These programmes shall be compatible within marine regions or sub regions and shall integrate and complement the monitoring requirements imposed by other EU legislation and international agreements. In this report, monitoring requirements are reviewed and overlaps and gaps (including considerations on spatial scale and temporal frequency) are highlighted. The screening of monitoring requirements is restricted to the WFD (2000/60/EC), EQS Directive (2008/105/EC), Habitats Directive (92/43/EEC), Birds Directive (2009/147/EC), Common Fisheries Policy and Regional Sea Conventions covering European seas (OSPAR, HELCOM, UNEP MAP, Black Sea Commission). Additionally, concepts of integrated monitoring and the benefits of less applied monitoring approaches are discussed.

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