WP 3 Deliverable 3.1

Existing biodiversity, non-indigenous species, food-web and seafloor integrity GEnS indicators

Deliverable 3.1

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Contents

1. Technical summary

Within the DEVOTES project, a catalogue of existing indicators of marine biodiversity and closely related topics such as non-indigenous species, food-webs, and seafloor integrity (EU Marine Strategy MSFD Descriptors 1, 2, 4, 6) has been established. Currently, the catalogue includes 557 entries with information on metadata ranging from indicator descriptions, data requirements, assignment to MSFD descriptors/criteria/indicators and developmental status to geographical coverage and applicable habitats, biodiversity components and related pressures. Both operational indicators and indicators in earlier stages of development are included. The aims of the catalogue are twofold: firstly, to identify the strengths and possible gaps of the European indicator set in order to be able to focus the development of new indicators where it is most urgently needed; and secondly, to foster transfer of know-how across countries and marine regions, so that indicators operational in one area could be potentially adapted to other areas. To enable efficient learning also from outside the European borders, the catalogue includes indicators not only from the EU but also from countries outside the EU.

The catalogue is available as a database with accompanying software, **DEVOTool**, which enables browsing the metadata as well as extracting lists of indicators using various criteria. Lists of indicators best fulfilling any set of criteria can be produced, enabling users to search, for example, for indicators that could be suitable to fill an identified gap in their marine area. Additionally, an analysis capability is included that can produce simple rankings of specific subsets of indicators based on different criteria and calculations. The tool and the indicator catalogue will be continuously updated.

In this deliverable, the collected set of indicators was analysed for coverage and gaps in general and for each regional sea separately. Ecosystem overviews for each regional sea have been written to highlight the specific features of those areas especially from the point of view of biodiversity. The aim of these overviews is to give context to the existing indicators and the observed gaps, i.e. to enable understanding of why certain indicators might be especially important or why other indicators are not needed.

An analysis of the contents of this catalogue revealed that, in the European regional seas, there are gaps mainly in indicators to address ecosystem structure, processes and functions, indicators for the genetic diversity, the effects of non-indigenous invasive species, and indicators related to the food-web structure and functioning (productivity and size distribution). Furthermore, the analysis of the indicator set revealed that there is considerable overlap between the MSFD indicators of biodiversity, food-webs, and seafloor integrity (D1, D4, D6). This may be due to different interpretation of the subordinate EU criteria by the EU Member States as well as double-counting of some indicators or biological processes.

The definitions of these descriptors should therefore be clarified and potential overlap reduced. Ultimately, this catalogue of indicators has the potential to be used outside the range of the EU regional seas and of the scope of the EU Marine Strategy.

Based on this work, we have the following recommendations that could be useful for the possible review of the Commission Decision on Criteria and Methodological Standards related to GES:

1. The relationship of D1, D4, D6 should be clarified and guidelines on whether the same ecosystem components should be covered by several or only one descriptor should be provided
2. D2 should be defined as a pure pressure descriptor and the related criteria and indicators should be adjusted accordingly
3. D6 should be redefined as a pressure descriptor instead of a combined pressure/state descriptor. The status of the benthic community should be assessed in D1 (including indicators for body length distribution of benthic species)

2. Introduction

2.1. Scope and content of the deliverable

Several marine biodiversity assessment and monitoring initiatives are in place worldwide. In such context, numerous indicators have been used and /or developed over the last few decades, driven either by environmental policies or in relation to research. To take advantage of the existing knowledge and past efforts to develop robust assessment tools and also to optimize current approaches in use by European Member States (**MS**) to fulfil their legal environmental responsibilities, a survey was undertaken to collate existing indicators for addressing marine biodiversity.

The purpose of this report is to review the current capabilities of the existing environmental indicators in the context of the EU Marine Strategy Framework Directive (**MSFD**, 2008/56/EC). Although this Directive focuses on different aspects of marine ecosystems, in the DEVOTES FP7 project the work focused on indicators related to biodiversity (DEVelopment Of innovative Tools for understanding marine biodiversity and assessing good Environmental Status, http://www.devotes-project.eu/). In the first stage of this Project, the objective was to compile currently existing indicators that could relate to four of the biodiversity related descriptors (D) for assessing the Good Environmental Status (**GEnS**) of marine waters, as laid out in the MSFD: biological diversity (D1), non-indigenous species (D2), food-web (D4), and seafloor integrity (D6) (**Figure 1**). Although in the proposal of DEVOTES project D2 was not included, during the preparation of this Deliverable it was decided to include also this descriptor in the analysis, because of its importance and relationships with the remainder biological descriptors.

Through a survey, the DEVOTES project catalogued metadata on potentially useful, which were then compared against the criteria and associated indicators as defined in the "Commission decision on the criteria for Good Environmental Status of marine waters" (Commission Decision 2010/477/EU). This report shows their potential for use in the scope of the MSFD and identifies gaps mainly regarding biodiversity components, habitats, geographical coverage, and the availability of the indicators for addressing specific relevant pressures in EU regional seas. Requirements for further developments, either by adapting current indices or developing new ones, are also briefly highlighted as a result of this survey.

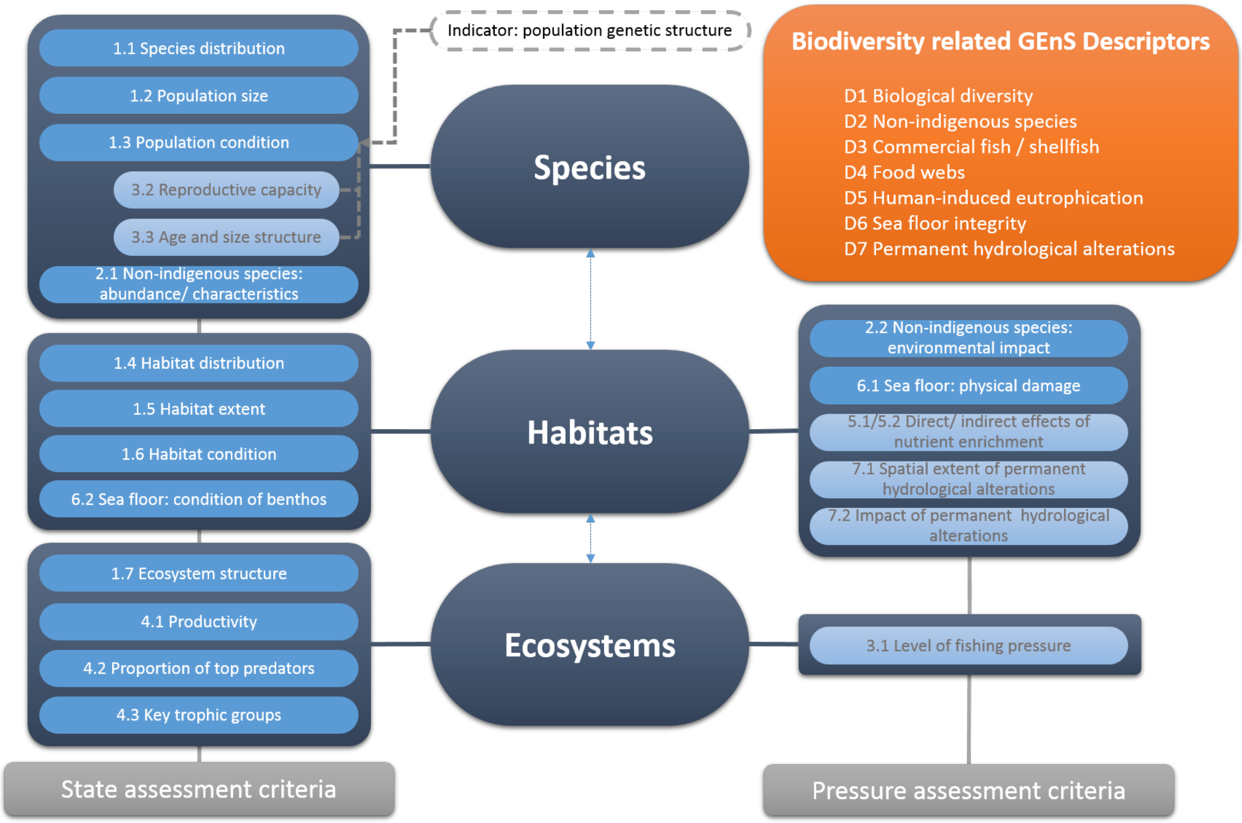


Figure 1. Conceptual model showing the biodiversity-related descriptors for assessing Good Environmental Status (GEnS), and the relevant pressure and state criteria, acting at different ecological scales, from species to ecosystems. Modified from a figure developed by S. Cochrane[1]. Criteria in light blue fall under descriptors 3, 5 and 7, not addressed by the DEVOTES project.

This reports also presents the **DEVOTool** (see Annex 1 and 2) – the software tool developed within the project to host the **DEVOTES Catalogue of Indicators**.

The information gathered in this catalogue is complementary to that gathered in the scope of the previous **DEVOTES Catalogue of Model-derived Indicators** (Deliverable 4.1, Piroddi *et al*. 2013, available at http://www.devotes-project.eu/deliverables-and-milestones/). The indicators and model-derived indicators compiled during both surveys will, in the near future, be stored in the same database.

2.1.1. Brief summary of the structure of this report

The following sections of this report include the main sources of information for the DEVOTES Catalogue of Indicators (section 2.2) and a brief introduction to the structure and type of information that can be found in the catalogue, as well as its potential uses and value for end-users (section 2.3).

[1] For a background document prepared for the Marine Strategy Coordination Group, within the framework of the Common Implementation Structure of the MSFD, in October 2011.

The information gathered was used to provide a comprehensive overview on the content of the catalogue and evaluate the capability of currently available indicators, namely their properties and features, potential application and data requirements (section 3.1). Special attention was given to the potential use of the indicators by member states (MS), Regional Sea Conventions (**RSC**) and stakeholders for addressing GEnS in the scope of the MSFD (section 3.2). Aditionally, it provides an analysis of weaknesses of the indicators currently in the catalogue with respect to their linkage to major pressures and impacts, biodiversity components, habitats and geographical coverage (section 3.3).

A comprehensive analysis by regional sea (i.e. Atlantic, Baltic, Mediterranean and Black Sea) is also presented (section 4), providing an ecosystem overview, while also reporting on the availability and capability of indicators for each specific area in terms of the major biodiversity values identified in each regional sea. In this sense, the ability of indicators to detect threats and impacts on biodiversity was also evaluated, together with identification of the major gaps in indicators availability in relation to major pressures acting in each area.

An overall gap analysis to the current existing indicators for marine biodiversity, based on the contents of the catalogue is presented, highlighting needs for further developments (section 5).

A brief review of emerging molecular based indicators is presented (section 6), since the current catalogue does not cover this type of indicators yet.

Additional functionalities of the **DEVOTool** software for exploring the DEVOTES Catalogue of Indicators are described (section 7).

The report ends by acknowledging the scope and the relevance of the current results for future DEVOTES outputs and tasks (section 8).

All supporting annexes of the results presented in this report are outlined at the end of the document.

DEVOTool software (Annex 1)

The **DEVOTool software** version released with the current report is **version 0.64**.

This software hosts the **DEVOTES Catalogue of Indicators** database (indicatorcatalogue.db).

Attention The results presented in this Deliverable 3.1 are based on the database **version 6**. Any future updates to the information contained in the current database version of the Catalogue of Indicators can result in differences with regard to the outcomes presently reported.

Note:

Box 1 below includes definitions of terms frequently used throughout the report. Although different meanings and definitions would be possible, these reflect the meaning they should be given in the present document.

BOX 1. DEFINITION OF TERMS

Indicator – *Quantitative measure that quantifies the amount of activity in the marine system causing a change (e.g. how many tonnes of seabed material are dredged in an area), the amount of change in the natural system (e.g. did the dredging result in the removal of important benthic species), or the effects of this on human uses of the system, whether for food production (fisheries) or general health (e.g. has a fishery declined as the result of the dredging) (Grey and Elliott 2009).*

Index - *A quantitative measure indicating a property of the environment, summarizing a complex issue in a single figure (e.g. Shannon's H biodiversity index).*

Status of development of an indicator – *Readiness of an indicator for being applied; three levels were considered*:

Operational indicator – *When the indicator is fully developed, tested and validated. Ideally with thresholds/classification associated and easily interpretable within a 'good' vs. 'bad' continuum, to be useful under regulatory contexts. It can be any of the following: used by the MS for national environmental monitoring; used in EU or International Conventions' monitoring programmes; developed, tested and validated indicator (from scientific literature), although not necessarily approved by any national /international law or convention;*

Under development indicator – *Existing indicator proposal, but not yet validated with field/real data*;

Conceptual indicator – *An indicator idea, supported by theoretical grounds but for which no practical measure or metric is yet available*.

Types of indicators – *These summarize the indicators in the catalogue into groups according to different properties and/or purposes. Within each main type, the indictors can be split into several categories*.

Promising indicator – *As used here, is an indicator that is well-suited from a given perspective, be it research and development, management, or some other specified use. It is an initial rating based on an end-user perspective, for those who need to test or apply indicators on various levels of readiness and need to restrict themselves to a small set of criteria*.

Good indicator – *A good indicator is an indicator that is not only promising, but also fulfils (quantitatively) a larger set of scientific criteria, such as (i) suitable description of ecological processes, (ii) good mathematical correlation with certain pressures yelding good confidence levels within, at least, specific ranges; and (iii) can be associated with a measure of uncertainty, i.e., successfully passes "quality check" procedures*.

2.2. Assessment of GEnS for the MSFD: building on existent know-how and initiatives

Assessment tools already adopted under several initiatives were collated that could be useful to address biodiversity-related descriptors as in the MSFD, particularly for biological diversity, non-indigenous species, food-web, and seafloor integrity. This is done primarily to assist EU Member States (MS) and Regional Sea Conventions (RSC) in efficiently searching, comparing and selecting available assessment tools to include in or update their monitoring.

According to the MSFD (Articles 6 and 11), Member States shall build their marine strategies upon relevant existing activities. They should also ensure that their monitoring programmes shall be compatible within marine regions or subregions and shall integrate and complement the monitoring requirements imposed by other EU legislation and international agreements, such as the RSC (Zampoukas *et al*. 2012).

Following the above recommendation, since the primary goal of building the DEVOTES Catalogue of Indicators (Annex 1) was to make its information available to support the implementation of the MSFD, the first sources of information were those programmes associated with existing EU Community legislation. In particular we screened proposals under:

- Water Framework Directive (**WFD**) (2000/60/EC)
- Habitats Directive (**HD**) (92/43/EEC)
- Birds Directive (**BD**) (2009/147/EC)
- other relevant Union legislation (including the Common Fisheries Policy (**CFP**): Council Regulation (EC) No 199/2008; Commission Decision 2010/93/EU)

These programmes are the most relevant to the scope of the DEVOTES work and are linked to the biodiversity related descriptors.

For the WFD indicators, the survey was primarily based on the WISER methods database (Birk *et al*. 2012) (available at http://www.wiser.eu/results/method-database/). Any updates detected on the information compiled in the WISER database were already included in the current catalogue; for example after subsequent WFD Intercalibration (IC) phase I results (e.g. Carleti and Heiskanen 2009; Commission Decision 2008/915/EC), or IC phase II preliminary results reported by the MS or even after changes in the methods by its authors. The recent Commission Decision 2013/480/EU (following Directive 2000/60/EC), establishing the values of the Member State monitoring system classifications as a result of the intercalibration exercise (Phase II) will be used to update the catalogue information in the near future.

The indicators used by the MS under HD, BD and CFP were also identified and included in the catalogue whenever information was available.

Approaches developed in the framework of RSCs covering European seas were also taken into account, namely those by:

- HELCOM - Baltic Marine Environment Protection Commission - Helsinki Commission
- OSPAR Convention for the Protection of the marine Environment of the North-East Atlantic

The HELCOM Coreset indicators (from the preliminary report in 2013) and the OSPAR Common indicators, adopted to address also the MSFD requirements in these regional seas, were included in the DEVOTES catalogue of indicators. Both the already agreed indicators and the ones that are under developments and/or discussion in these RSCs were considered. The indicators adopted by the Barcelona Convention – Mediterranean Action Plan, or the Bucharest Convention - Black Sea Commission are still not adequately covered by the current version of the catalogue. The inclusion of their proposals is however planned for future updates as soon as they are made available.

An effort was also made to include the indicators and/or indices used by MSs in their MSFD reporting on Initial Assessments (Art. 8), Good Environmental Status (Art. 9), Environmental targets and associated indicators (Art. 10). Member States had, among other things, to make an initial assessment, determine a set of characteristics for GEnS and establish a comprehensive set of environmental targets and associated indicators for their marine waters to guide towards achieving GEnS in the marine.

The catalogue provides details of the main indicators used by eleven of the EU Member States in their Initial Assessments (**Figure 2**): Cyprus, Denmark, Finland, Germany, Greece, Lithuania, Portugal, Spain, Sweden, United Kingdom and Bulgaria* (*non-official sources*). Such original information can be found in detail in the Eionet Central Data Repository (http://cdr.eionet.europa.eu/recent_etc?RA_ID=608), except for those MS indicated otherwise (*). For the remaining EU MS with marine areas and obligations under the MSFD, there is still no information in the DEVOTES catalogue regarding the indicators used in their Initial Assessments (**Figure 2**): Belgium, Estonia, France, Ireland, Italy, Latvia, Malta, Netherlands, Poland, Romania and Slovenia. Future updates are envisaged at least for those MSs whose reports are publically available on the Eionet Central Data Repository.

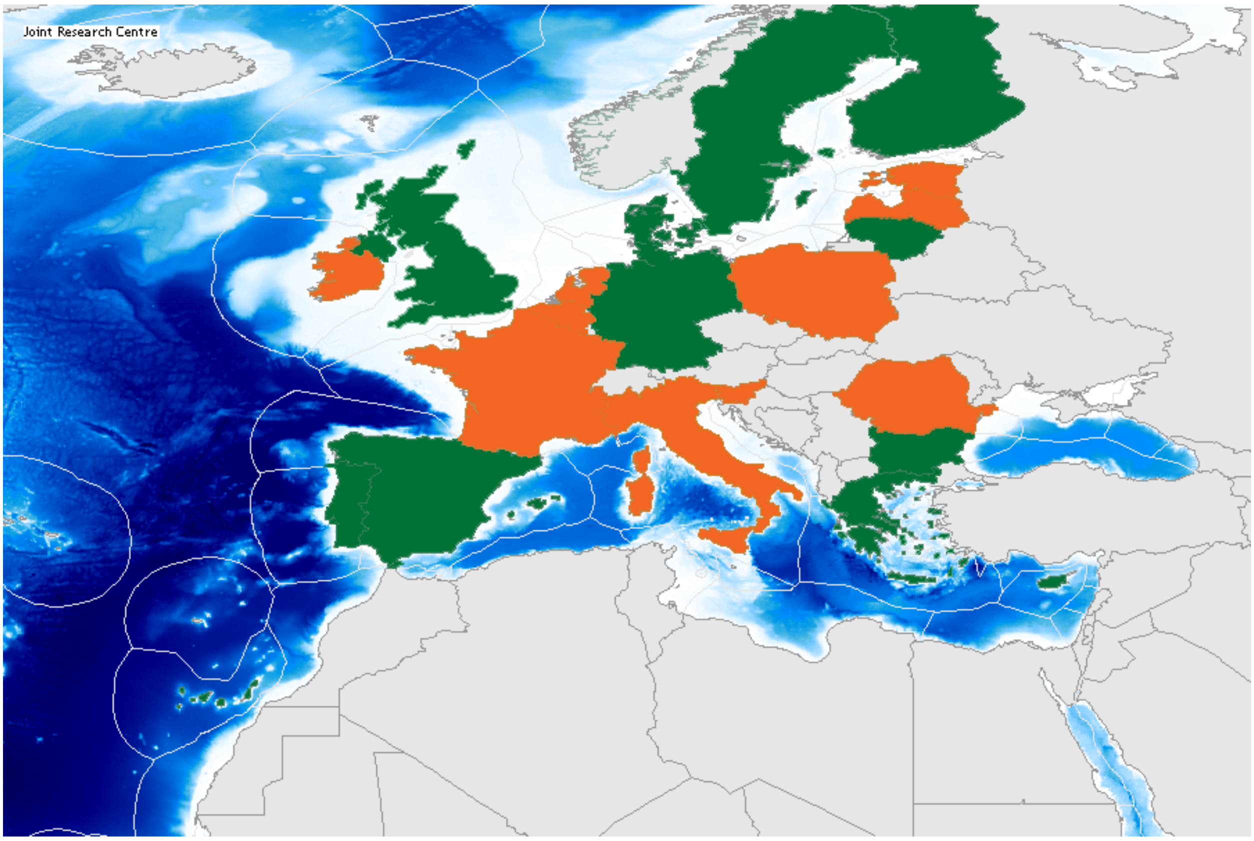


Figure 2. EU Member States whose indicators reported in the MSFD Initial Assessment Report are included in the DEVOTES Catalague of Indicators (green) and those whose information is not yet in the current version 6 of the catalogue (orange). (Figure taken and adapted from EMIS-JRC website: EMIS-EU-bathymetry-maritime boundaries-borders; http://emis.jrc.ec.europa.eu/).

Finally, and despite the fact that the criteria and associated indicators defined in the Commission Decision 2010/477/EU were built to some extent on existing obligations and developments in EU legislation, such criteria cover elements of the marine environment not yet addressed in existing policies (Zampoukas *et al*. 2012). Therefore, and although special attention was devoted to indicators developed and in use in the area of the four European regional seas, the DEVOTES survey was neither constrained nor to the EU marine area of influence nor to assessment tools used for EU legal requirements.

Hence, apart from the sources outlined above, the Catalogue of Indicators also contains indicators and indices developed and in use under diverse contexts, i.e. from research or monitoring programmes within Europe but also beyond Europe's geographical area (e.g. in the Red Sea area or in the USA) (**Table 1** and **Table 2**). Proposed indices published in the broad scientific literature were often reported during the survey and are also included in the catalogue.

Table 1. Countries with indicators in the catalogue, both EU Member States (MS) and non-EU.

European Union MS			Non-European Union countries	
Belgium	Germany	Portugal	Australia	Saudi Arabia
Bulgaria	Greece	Romania	Djibouti	Somalia
Cyprus	Ireland	Slovenia	Egypt	Sudan
Denmark	Latvia	Spain	Israel	Ukraine
Estonia	Lithuania	Sweden	Jordan	USA
Finland	Netherlands	United Kingdom	Norway	Yemen
France	Poland			

For all indicators reported there was information regarding at least one of the assessment and monitoring initiatives they were associated with, and in some cases, they were linked to more than one initiative. **Table 2** summarizes the number of indicators in the catalogue registered under each initiative. Efforts will be made to improve such information during the subsequent updates of the database. This will also include an attempt to link the information in this catalogue to that compiled for the **DEVOTES Catalogue of Monitoring Networks** (Deliverable 1.4, Patrício *et al*. 2014, available in http://www.devotes-project.eu/deliverables-and-milestones/), for which more than two hundred monitoring programmes were reported within the four European regional seas.

Table 2. Summary table of the main sources of information to the DEVOTES catalogue: initiatives under EU legislation and other international initiatives and programmes. The number of indicators with a link to any of the main type of initiatives is indicated.

International Convention	Regional Sea Convention	EU Directives	National monitoring	Research programmes
(24 indicators)	(64 indicators)	(188 indicators)	(105 indicators)	(170 indicators)
Convention on Biological Diversity (CBD)	HELCOM (Baltic Sea)	EC Birds Directive	German Marine Monitoring Programme (BLMP)	Data from different research programmes or projects (mainly Spanish Ministry of Agriculture, Food and Environment)
ICES	OSPAR (Northeast Atlantic)	EC Habitats Directive	Continuous Plankton Recorder (CPR) Survey (UK)	SOMLIT network (FR)
Trilateral Monitoring and Assessment Programme (TMAP) - Wadden Sea	Bucharest Convention (Black Sea)	EU Common Fisheries Policy	National Red List Assessments (KIS, SEBI) (DE)	Western Channel Observatory (UK)
	Jeddah Convention (Red Sea and Gulf of Aden)	EU WFD	National Strategy on Biological Diversity (NHS, KIS, LIKI, SEBI) (DE)	
		EU MSFD		

WHERE IN THE DEVOTOOL SOFTWARE (1) (ANNEX 1)

In the **DEVOTool software** that hosts the **DEVOTES Catalogue of Indicators** database, a list of any EU Directive, monitoring programmes or international initiatives that each indicator might be associated with is provided in the "**Metadata**" form. All the sources of information are also indicated in the "**Sources**" form.

Validation and quality check of the catalogue information

Although the metadata compiled were reviewed by partners before the analysis presented in this report, the catalogue still revealed some inconsistencies. Four major issues were identified and are outlined below together with the implications when submitting queries to the catalogue:

- **Heterogeneity in the amount and type of information reported by indicator**: A significant percentage of missing data (blank fields in the catalogue), especially if the missing data forms a pattern (e.g. little information on metric/index/method approach; deficient coverage of a given regional sea or failure to cover some scientific area due to no source contact or input rather than real lack of information available), will compromise the robustness of the analyses (identification of promising indicators and gap analysis), and influence final recommendations and conclusions drawn out of this catalogue.
- **Multiple reported indicators**: It includes the same indicator being reported repeatedly by more than one person/source and also different indicators reported as unique but actually being based on and conveying the same exact information. Some approaches may be under- or overrepresented in the catalogue compared to their actual availability (e.g. per geographical area or per biodiversity component). This may have implications for identifying priorities for the development of new indicators after the gap analysis or it could eventually lead to under-estimation of an indicator's potential when identifying the most promising ones.
- **Ambiguity while interpreting fields in the catalogue**: Due to the great number of contributors to this catalogue, ensuring a common understanding of the fields was not always fully achieved. Heterogeneous information under the same field could compromise the use of many of the entries in our catalogue, preventing an optimized usage of the effort devoted to this survey and more importantly, strongly reducing the amount of data available for meaningful analysis. We highlight that this ambiguity in interpreting fields in the catalogue was particularly evident for Pressures related fields and some of the Commission Decision criteria and indicators, leading us to foresee that any entity applying these MSFD requirements might face similar uncertainties towards them. Therefore one of the aims of this overview on the DEVOTES Catalogue of Indicators will be to identify those criteria and indicators most challenging and problematic for interpretation and contribute with suggestions to clarify their scope.
- **Survey gaps in the catalogue**: Apart from reporting gaps and weaknesses highlighted in previous points, survey gaps were also identified, i.e. certain types of indicator approaches (e.g. regarding new molecular-based tools) or for specific habitats (e.g. deep-sea habitats) were left out or are

poorly represented in the database for several reasons, such as for failing to contact experts for the survey. Survey gaps would have implications on identifying priorities for the development of new indicators after the gap analysis and would limit the indicators available for selection and use as the most promising ones under the implementation of the current Directive.

In order to overcome some of the highlighted weaknesses and improve the quality of the information in the catalogue, it will be subjected to continuous updating. In the near future and throughout the entire duration of the DEVOTES project we aim to:

- identify significant missing information in the catalogue originating from by a reporting gaps and attempt to complete those missing fields
- identify multiple entries for the same indicator, in order to merge and recode entries
- identify survey gaps in the catalogue, in an attempt to gradually fill these, surveys gaps ensuring at the same time that the Catalogue of Indicators will remain a live document

Notes

The indicators were collected as a joint effort of DEVOTES partners, who contributed with the information as accurately as possible from the sources available and cited. All institutions and partners that contributed are identified in the database ("Contributor code").

Since from this date, this will become a publicly available catalogue, any comment, correction or update to the content of the database is very much welcome and can be addressed to (Heliana Teixeira heliana.teixeira@jrc.ec.europa.eu or to Torsten Berg berg@marilim.de).

2.3. Catalogue of Indicators – potential uses and value to end-users

This section briefly describes the structure and type of information that can be found in the Catalogue of Indicators, as well as its functionalities and potential uses.

The catalogue includes metadata for each indicator allowing the evaluation of its relevance for the MSFD, attaining also to the major goals of the DEVOTES Project. The metadata is grouped into eight main topics, which are further divided into sections and fields in order to standardize the information and to provide relevant metadata for a subsequent analysis.

WHERE IN THE DEVOTOOL SOFTWARE (2) (ANNEX 1)

In the **DEVOTool software**, that hosts the **DEVOTES Catalogue of Indicators** database, all the information associated to an indicator is organized under three main forms: the "**Indicators**"; the "**Metadata**" and the "**Sources**".

The first main topic (Indicator properties) is in the "**Indicators**" form. The other 7 topics are located in the "**Metadata**" form. The references are all listed in the "**Sources**" form.

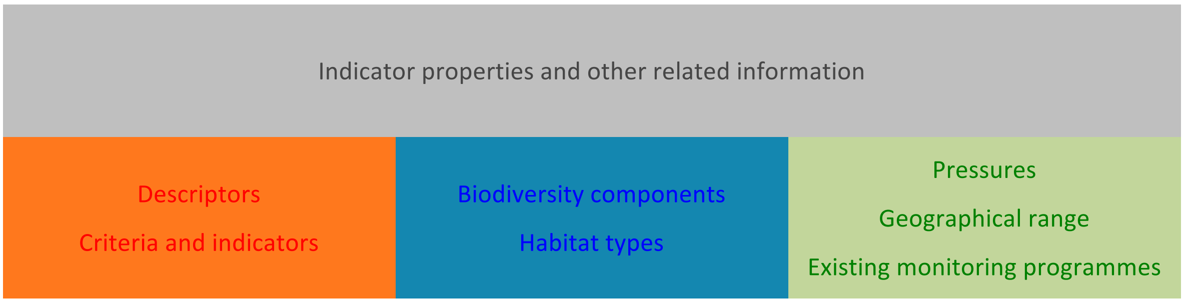


Figure 3. Thematic structure of the eight main topics in the indicator catalogue.

The main topics and a short description on the kind of sections and fields included are briefly summarized below. A detailed description of all sections, relevant for gap analysis, is given in chapters 3.2 and 3.3. All sections have a *"Source"* field where existing literature and other references can be included:

1. **Properties of the indicator and other related information**: *Twelve fields in six sections* were considered to standardize the intrinsic properties of the indicator with fields like *indicator descriprion* or *data requirements*. The complete list of sections and fields including field descriptions is given in **Table 3**.
2. **Descriptors**: *Fields* allowing to assign the relation to the 11 *MSFD descriptors.*
3. **Criteria and indicators**: *Fields* to relate indicators to the Commission Decision *criteria and indicators* (COM Dec 2010/477/EU) for the biodiversity related descriptors *D1*, *D2*, *D4* and *D6*.
4. **Biodiversity components**: *Fields* that allow recording which biodiversity components (*Phytoplankton*, *Macroalgae*, *Fish, etc.)* the indicator is targeting. For mobile components a set of predominant ecotypes (i.e. pelagic fish, demersal fish) was given for further division as well as

the possibility to insert taxonomical specifications the indicator relates to (field *Taxon name*: i.e. *Cyanobacteria, Caretta caretta*).

5. **Habitat types**: *Fields* for indicating the coverage of specific *habitat types*. It is possible to select among *18 subtypes* within *Seabed* main type*, five subtypes* within *Water column* and *one final subtype* on *Ice-related habitats.*

6. **Pressures**: Fields to report the relation with specific pressures like physical loss, underwater noise, etc.

7. **Geographical range**: *Fields* to relate indicators to *Marine Regions* (mandatory EU regions as in MSFD). A further specification of the geographical scale is possible with *Marine subregions* (mandatory EU subregions as in MSFD) and *Marine subdivisions* or ecological assessments areas. Also fields for more specific assignments are present: *EU Member State official subdivisions*, *Non-EU SEAS*, *Non-EU SEAS subareas*, *Country*. In case that *GIS data* is available *three field*s are available to report information: *GIS-data availability*, *Link to GIS data (maps, samples, images)*, *Data contact*.

8. **Existing monitoring programmes**: *Fields* allow recording correspondence to *existing monitoring programmes*, where it is reported whether the indicators is associated to any monitoring programmes or initiatives as: *International Convention, Regional Sea Convention, EU Directives, National monitoring* or *Research programme*. It is also possible to report whether or not *time series* are available for an indicator. Finally extra information of relevance may be reported in the *Observations* field.

Table 3. Subfields included in the DEVOTES Catalogue of Indicators to collect metadata associated with the main topic "Properties of the indicator and other related information".

	Section	Fields	Brief description
1	–	Indicator name	The name of the indicator in the catalogue, which can differ from the original name (see below), in order to to unify and use equivalent terms, i.e. "Depth limit of …" and "Lower depth limit of …"
2	Identification	Original name Contributor Code RSC affiliation Last modification	Original name of the indicator Institutional and expert initials plus number code to identify the persons contributing the indicator properties and metadata Relation to the indicator sets of the Regional Sea Conventions Automatically filled with current date and time as soon as the properties dataset changes (does not apply when metadata from the other seven topics are changed)
3	Description	Indicator description Data requirements Collection method Costs	General description of how the indicator operates Kind of data, which are needed to apply and calculate the indicator Kind of collection method for the data needed (equipment/expertise required) Information relating to cost per sample or cost per unit area
4	Other	Overall indicator status Unit Confidence/Uncertainty	Automatically filled field. Can be: operational; under development; conceptual (see Box 1 – Definition of terms) and is the higest assigned status recordrd for the indicator) Indicator unit like Ind/m^2 or kg or EQR etc. Measure of uncertainty associated with the assessment
5	Source		List of all references relevant/used for the indicator
6	Observation		Textual remarks for any aspect of the indicator

Annex 2 provides full guidance on the information contained in the Catalogue of Indicators and how to explore it using the **DEVOTool** software (Annex 1).

Apart from listing existing marine biodiversity indicators as evidenced in the name, this Catalogue of Indicators offers other possibilities to end-users, due to the extra information associated with the indicators, as for example:

- describing the basic properties of the indicator or index and identifying the type of data required for its calculation, it can help users to easily recognise indicators for which they already might hold data or parameters collected through past or ongoing monitoring programmes, that would allow the use of specific indices

- the provision of broad information on the collection methods will show users the kind of devices and equipment used for data collection, which indirectly gives information on the requirements and potential costs associated with it;
- establishing a link to MSFD descriptors, it can help MS and RSC in the selection of indices to set up, complete or update their monitoring and assessment programmes
- reporting on the status of development of the indicator will enable distinction between the operational indicators, i.e. ready to use indices, and those where extra efforts on development and research should be placed
- identifying the scope of use of an indicator (e.g. to address Habitats Directive or within an international convention) and its geographical area of application, may enhance collaboration within marine regions; this is particularly valuable for neighbouring MS and RSC parties
- identification of the pressures to which the indicator is responsive will facilitate the selection of indicators in scenarios of pressures shift and speed up the update process of monitoring and assessment programmes
- identification of the habitats and biodiversity components the indicator is associated with will highlight the links between indicators and major features of interest of the ecosystem

Besides the catalogue content itself, the software contains functionalities that offer the possibility to perform queries using all sorts of combinations of the metadata in the catalogue. From simple to more advanced analyses, the end-user can explore the catalogue to extract reduced lists of indicators that fit specific needs. It is further possible to accompany those lists with some basic statistics and even to rank the indicators according to predefined criteria.

WHERE IN THE DEVOTOOL SOFTWARE (3) (ANNEX 1)

In the **DEVOTool software**, that hosts the **DEVOTES Catalogue of Indicators** database, you can explore its functionalities and perform queries according to various criteria, extract reduced lists of indicators and rank indicators in the "**Analyses**" form.

Section 7 of this report explores some of the functionalities of the Catalogue of Indicators in greater detail. The queries can work with pre-set but customizable criteria that allow for a flexible choice of indicators. This tailored selection of promising indicators is dictated by the end-users choice of criteria relevant to their final aims and uses. Ultimately, the DEVOTES Catalogue of Indicators has the potential to be used beyond the scope of the MSFD and the EU marine areas.

3. Overview of indicators to support biological diversity (D1), non-indigenous species (D2), food-web (D4), and seafloor integrity (D6)

3.1. DEVOTES Catalogue of Indicators: general overview of indicators' characteristics

Our survey resulted in currently 557 indicators that report on very diverse aspects related to the biota (from the subindividual level, through the species, community and ecosystem level) and their habitat features, but also to activities and pressures. All these indicators differ substantially in the type of information conveyed, in the type of data used and in their complexity. Therefore, to provide better information on the type of indicators that can be found in the catalogue, its content was summarized according to three different perspectives:

- **Indicator type** – In our context this mainly refers to what each indicator focuses on; 13 different types of indicators could be broadly distinguished. **Table 4** shows those categories providing some tentative definitons, where appropriate, and giving some examples extracted from the catalogue itself
- **Underlying variable type** - mainly this refers mainly to the data/information used for the indices calculation. 13 main types of variables or data were identified from the catalogue (**Table 5**)
- **Algorithm type** - mainly this refers to how data/information is integrated in the index; and six approaches were broadly identified (**Table 6**); although one of the categories - "*Indices reporting on trends*" - refers to a slighty different aspect and might be complementary to any of the other five categories. However, it was included since it increases the value and power of the index and it does imply the adoption of some mathematical approach to define how trends are captured by the proposed index in a standardized way

The categories proposed within each type are based on expert judgement, and are by no means mandatory classifications of the indicators compiled. However, they do provide complementary information that allows a quick overview and understanding of the content of the catalogue.

Categories outlined in **Table 4** for *Indicator type* were defined after interpretation of the indicators' properties and features reported in the catalogue. While the information used to propose those categories under *Underlying variable type* (**Table 5**) and *Algorithm type* (**Table 6**) was more easily extracted from the "Data requirements" and "Indicator description" fields of the catalogue. Some of the categories considered envisage already the inclusion of the indicators from **DEVOTES Catalogue of Model-derived Indicators** (Deliverable 4.1, Piroddi *et al*. 2013).

Within the same *type*, the indicators could often be related to more than one category. This is particularly valid when considering *Underlying variable type*; for example, a multmimetric index that uses several parameters such as abundance, biomass and taxonomic composition. But also in the *Indicator type*, broad approaches such as "Ecotoxicological indicators" might be considered both indicators of State (such as Physiological Condition indicators) or of Pressure (such as Pollution indicators), depending on specific features of the indicator itself. At this stage the categories are not yet implemented in the software and might still be subject to future adjustments.

In the catalogue there are both state and pressure indicators. Due to the scope of the DEVOTES project and of this survey, the main type of indicators are essentially ecological indicators (**Table 4**). However, there are also indicators that report on pressures and activities, and a few management indicators (check examples in **Table 4**).

Table 4. *Type of indicators* in the DEVOTES Catalogue; categories defined based on what the indicators focus on, with examples taken from the catalogue (Annex 1).

	Broad classification	Indicator Type	Definition and/or examples
1	ECOLOGICAL INDICATORS (state indicators)	Abundance Indicators	(e.g. individuals counts, densities, proportions, ratios…)
2	ECOLOGICAL INDICATORS (state indicators)	Spatial Distribution Indicators	Distribution (range and patterns) of **species** (areal coverage, depth limits/range, trends, latitudinal-longitudinal distribution) or **habitat** (areal coverage, depth limits/range, cartography, bathymetric distr., latitudinal-longitudinal distribution).
3	ECOLOGICAL INDICATORS (state indicators)	Indicator Species	Indices based on for e.g. early warning species, sensitive species, tolerant/pollution indicator species, non-indigenous species/indigenous species, keystone species, bioaccumulator species, toxic species and target species/groups (e.g. for conservation, or under some protection status, or of commercial interest, etc...).
4	ECOLOGICAL INDICATORS (state indicators)	Diversity Indicators	Indices using any community parameters to describe diversity, from species richness (species count and indices on richness, e.g. Margalef index or Menhinick index) to abundance patterns (e.g. dominance, evenness or equitability indices) and community structural composition (e.g. proportional abundance of different taxa/groups), to taxonomic distinctness, etc… These could take taxonomical, numerical, ecological, genetic and phylogenetic information into account.
5	ECOLOGICAL INDICATORS (state indicators)	Ecological Strategies Indicators	Indices based in for e.g. trophic guilds, r-K strategies, biological functional traits (feeding guilds, longevity, body size, mobility...), species life-history
6	ECOLOGICAL INDICATORS (state indicators)	Ecological Network Analysis (ENA) Indicators	Indicators based on foodwebs information - so to be linked to WP4 Catalogue of Model-derived Indicators (D4.1) (e.g. ENA indicators and flows, energies and efficiencies...)
7	ECOLOGICAL INDICATORS (state indicators)	Production Indicators	Biomass, Productivity rates, Primary and secondary production
8	ECOLOGICAL INDICATORS (state indicators)	Thermodinamically Oriented Indicators	Holistic ecological indicators intending to express emergent properties of ecosystems arising from self-organisation processes in the run of their development. Indices built upon concepts derived from the field of thermodynamics that can be seen as energy with a built-in measure of quality, as are for e.g. Ascendency and Exergy.
9	ECOLOGICAL INDICATORS (state indicators)	Demographic Characteristics Indicators	Demographic parameters (e.g. areas of reproduction; mortality rates; birth rates; fecundity rates; breeding success / # pups) and also population structure related such as for e.g. body size distribution (percentiles, mean, slope…) or age structure.
10	ECOLOGICAL INDICATORS (state indicators)	Habitat Integrity Indicators	Habitat features and properties, habitat-forming species, hydrological and physico-chemical indicators
11	PHYSIOLOGICAL INDICATORS (state indicators)	Physiological Condition Indicators	(e.g. Blubber thickness; Coral bleaching; Fatty-acid composition; Growth rate; Ecotoxicological indicators...)
12	PRESSURE INDICATORS	Pollution Indicators	Ecotoxicological indicators included; chemical pollutants indicators; bioaccumulator species; contaminants (in biota, water, sediment…)
13	PRESSURE INDICATORS	Pressure Indicators / Management Indicators	(e.g. Bag size of hunted species; Ballast water treatment indicator; Bycatch/nets/fishing gears…)

Table 5. Categories for grouping indicators in the DEVOTES Catalogue based on the *Underlying variable type*.

	Underlying variable type
1	Biomass
2	Abundance
3	Taxonomic composition
4	Functional classification into groups according to different ecological properties (e.g. trophic, tolerance, locomotion, niche…)
5	Spatial information type of data (also GIS)
6	Physico-chemical and environmental data
7	Isotopic data
8	Biochemical markers data
9	Population dynamics / demographic data
10	Physiological data
11	Data from molecular and genetic based approaches
12	Foodwebs
13	Remote sensing data

Table 6. Categories for grouping indicators in the DEVOTES Catalogue based on the *Algorithm type*.

	Algorithm type
1	Lists of categorical information (Presence/Absence, …)
2	Direct measurements (counts, area, concentrations, …)
3	Single or multimetric indices using basic arithmetics
4	Indices using multivariate and complex statistics
5	Indices derived from modelling approaches
6	Indices reporting on trends

Almost all indicators (96.5 %) in the catalogue have information on their development status (except for 4 %). Around half of these indicators (36 %) are still under development, i.e. the indicator proposal exists but was not yet validated with real data. Only 52 % are considered operational (**Figure 4**). Operational was considered to be any of the following: a) used by the MS for national environmental monitoring; b) used in EU or International Conventions' monitoring programmes; or c) developed, tested and validated indicator (Sci literature), although not necessarily approved by any national or international law or convention. In any case, some indicators reported as operational fail to report the targets or reference levels used or even the existence of those. Until further updates on the database, to get access to such details, the users should refer to the sources cited in the catalogue. A small percentage of conceptual indicators was also reported (8 % of all reported indicators). By conceptual it was understood an indicator idea supported by theoretical grounds, although no practical measure or metric is yet available.

The material is divided into the three different status possibilities: operational, under development, and conceptual. Indicators listed as "operational" are those that are operational in at least one region or for one habitat (if applicable). This does not mean they are operational in all areas where they are tested or their use is being investigated. Indicators listed, as "under development" are those that are not operational in any of the recorded settings. They can, however, be conceptual in some of them but need to be under development in at least one setting (region, habitat). Indicators listed as "conceptual" are those that are neither operational nor under development, but that are conceptual in any of the applied settings.

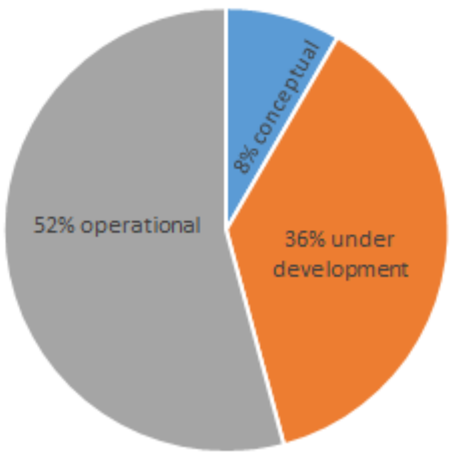


Figure 4. Development status of the indicators in the catalogue: operational, under development and conceptual, considering the 538 indicators for which such information was reported.

Finally, most of the indicators (approximately 80 %) did not report having any measure of confidence or uncertainty associated with their assessment results. Also, only few indicator entries reported information on costs associated with its use (9 %). Moreover, since "costs" was left as an open and undefined field for this survey, highly variable information was reported.

Both of the abovementioned features are extremely relevant during the process of selecting indicators for any monitoring and assessment programme. In this sense, efforts should be placed to increase coverage and standardization of this information in order to be able to provide better guidance both on indicators development and selection.

3.2. Indicators' potential to address MSFD GEnS assessment criteria and indicators for D1/D2/D4/D6

Indicators should be related to one or several descriptors and criteria defined for the MSFD. The following sections give an overview of the recorded indicators and their assignment to the descriptors and criteria.

3.2.1. Descriptors

Of the 557 indicators listed in the catalogue only 14 indicators lack an entry for descriptors. All of them are WFD related indicators, which should address at least one descriptor. Some experts might have misinterpreted, that indicators for WFD might not be valid for MSFD. Although the DEVOTES project is primarily targeting indicators for D1, D2, D4 and D6, the recorded indicators cover nearly all descriptors, since some of them are targeting more than one descriptor. The number of indicators per descriptor are listed in **Table 7** and illustrated in **Figure 5**.

Table 7. Number of indicators per descriptor, divided into indicators specifically addressing one descriptor and indicators addressing several (one or more) descriptors [sum (operational/under development/conceptual/no status)].

Descriptors	one descriptor	several descriptors
D1 Biological diversity	212 (138/61/11/2)	444 (240/177/23/4)
D2 Non-indigenous species	18 (5/8/5/0)	24 (7/12/5/0)
D3 Commercial fish/shellfish population	0	7 (2/4/1/0)
D4 Food-webs	33 (11/7/15/0)	167 (70/76/20/1)
D5 Eutrophication	0	86 (59/24/2/1)
D6 Seafloor integrity	43 (35/6/2/0)	183 (105/65/11/2)
D7 Hydrographical alteration	0	35 (32/2/0/1)
D8 Contaminants	0	7 (7/0/0/0)
D9 Contaminants in food	0	0
D10 Marine litter	0	0
D11 Energy/Noise	0	1 (0/1/0/0)

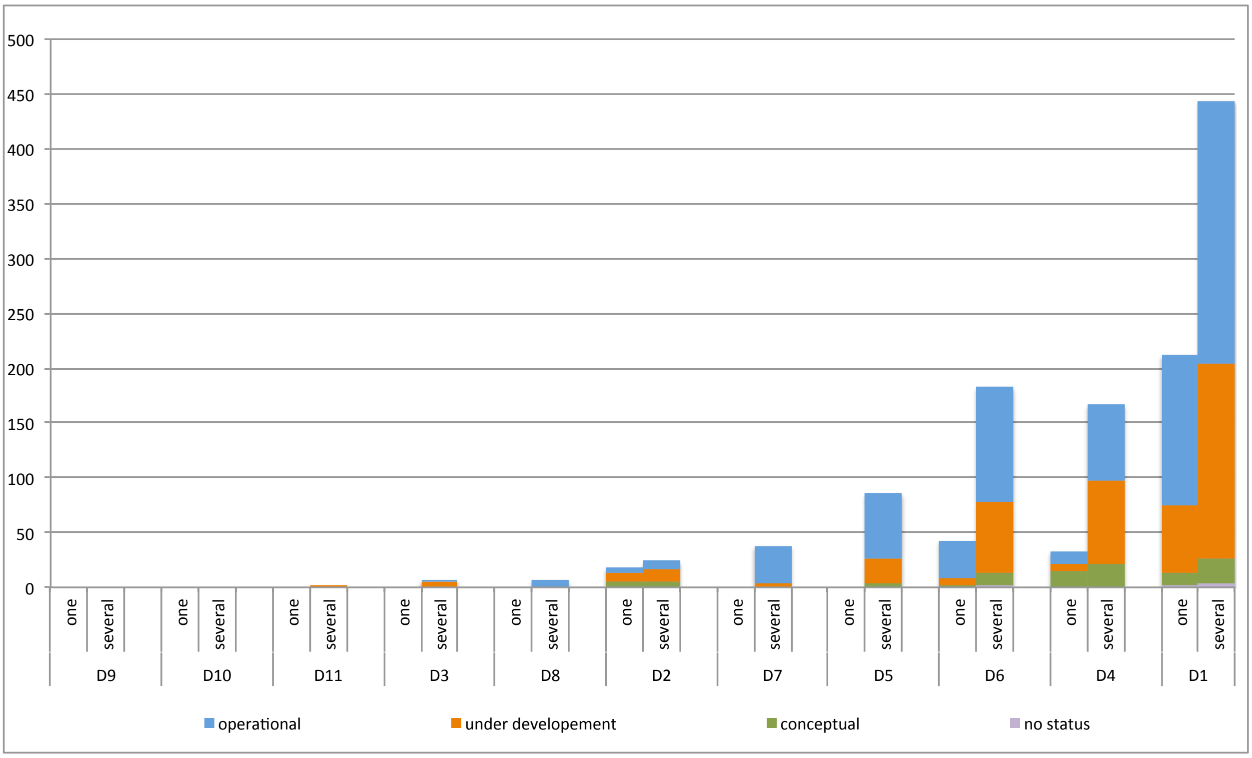


Figure 5. Number of indicators per descriptor in ascending order with indicator status and divided into indicators addressing one descriptor and several (one or more) descriptors.

In total, 444 indicators of the database are associated to D1 Biological diversity, while 24 are associated to D2 Non-indigenous species (NIS), 167 to D4 Food-webs and 183 to D6 Seafloor integrity. Analysing the remaining descriptors, not primarily targeted by DEVOTES, 86 indicators are related to D5 Eutrophication and 35 indicators are related to D7 Hydrological alteration. Although D3 Commercial fish/shellfish population is not targeted by DEVOTES the low number of indicators addressing D3 (7) may indicate a gap in the database, as it should be expected that there exists a higher proportion of indicators addressing both D4 and D3. Low numbers for D3 might indicate that the selected group "commercial fish/shellfish" might not be covered adequately enough for food-web indicators. Of the seven indicators addressing both D3 and D4 only two are operational ("Species richness of fish" and "LFI – Large Fish Indicator"). In contrast the low number of 7 indicators for D8 Contaminants, D11 Energy/noise (only one indicator) and the lack of indicators for D9 Contaminants in food and D10 Marine litter is due to the fact that they are pressure descriptors and not in the main focus of DEVOTES. Furthermore the pressure "marine litter" is a comparably new field in marine environmental studies and not targeted by most of the routine monitoring programmes.

Around half (55 %) of the indicators are associated to only one descriptor. 23 % are associated to two descriptors where most of them are both D1/D4 or both D1/D6 indicators. While this is the most widespread case in the database, the result can be regarded as being biased since the DEVOTES project focuses on these three descriptors and the collection of indicators subsequently was targeted towards these. 11 % of the indicators cover three descriptors and consequently most of these cases are covering D1/D4/D6. There are also a few (6 and 3 % respectively) indicators targeting four or five descriptors. These cases mostly include descriptors D5 or D7.

Most of the indicators targeting 4 or 5 descriptors are multi-metric methods (often used within the WFD). The metrics tend to have different targets and thus the aggregated index is reflecting different descriptors. The aggregation rules play an important role in these cases since they determine the relationship and potential interactions between the descriptors and subsequently the quality and informative value of the aggregated result with respect to the individual descriptors.

The high overlap rate of indicators between descriptors might create problems in the final assessment aggregation process, as double assessments should be avoided. This will be discussed further on criteria level.

Conclusions

No real gaps could be identified for descriptors D1, D2, D4 and D6. The low number of indicators addressing D3 Commercial fish/shellfish could indicate a gap for this selected group in the set of indicators for D4 Food-webs.

The strong overlap of indicators between descriptors (especially between D1 and D6) needs to be discussed on criteria level as a high redundancy could raise the risk of double assessments in the final aggregation process for GEnS and cause problems for users and stakeholder to understand the ecosystem approach of the MSFD and the differentiations between descriptors.

3.2.2. Criteria

D1 criteria

Table 8. MSFD criteria, indicators and specifications as listed in the indicator catalogue for D1 Biological diversity. Note that criterion 1.8 and the subsequent indicators are not part of the EU Commission Decision, but was added within the DEVOTES project.

EU Criteria	EU indicators	Specifications
1.1 Species distribution	1.1.1 Distributional range 1.1.2 Distributional pattern within range 1.1.3 Area covered by the species (for sessile benthic species)	– – –
1.2 Population size	1.2.1 Abundance and/or biomass	1.2.1.1 Abundance 1.2.1.2 Biomass
1.3 Population condition	1.3.1 Population demographic characteristics 1.3.2 Population genetic structure	1.3.1.1 Body size 1.3.1.2 Age class structure 1.3.1.3 Sex ratio 1.3.1.4 Fecundity rates 1.3.1.5 Survival/mortality rates 1.3.1.6 Other –
1.4 Habitat distribution	1.4.1 Distributional range 1.4.2 Distributional pattern	– –
1.5 Habitat extent	1.5.1 Area 1.5.2 Volume	– –
1.6 Habitat condition	1.6.1 Condition of the typical species and communities 1.6.2 Relative abundance and/or biomass 1.6.3 Physical, hydrological and chemical conditions	1.6.1.1 Species 1.6.1.2 Communities 1.6.2.1 Abundance 1.6.2.2 Biomass 1.6.3.1 Physical conditions 1.6.3.2 Hydrological conditions 1.6.3.3 Chemical conditions
1.7 Ecosystem structure	1.7.1 Composition of ecosystem components (habitats and species) 1.7.2 Relative proportions of ecosystem components (habitats and species)	1.7.1.1 Habitats 1.7.1.2 Species 1.7.2.1 Habitats 1.7.2.2 Species
1.8 Ecosystem processes & functions	1.8.1 Interactions between structural components 1.8.2 Services provided	– –

442 indicators are assigned to at least one of these criteria. Two indicators are related to D1 without the assignment to an EU criterion ("abundance or biomass of key species in the coastal waters" and "bag size of hunted species"). The number of indicators per D1 criterion is listed in **Table 9** and illustrated in **Figure 6**.

In general, these indicators cover mainly only one criterion (67 % of all indicators targeting D1). About 10 % of the indicators cover two or three criteria respectively. Higher counts are typically only covered by multi-metric indicators, often WFD indicators since they already are required to fulfil a number of normative definitions targeting different aspects of the biological components they were developed for.

Most indicators cover 1.6 Habitat condition (185) and within this criterion there are only a few that cover 1.6.3 Physical, hydrological and chemical conditions while 1.6.1 Condition of the typical species and communities, as well as 1.6.2 Relative abundance and/or biomass are covered by around 110 of the D1 indicators respectively.

Indicators addressing the criteria 1.1 “Species distribution” and 1.2 “Population size” exceed well the numbers for criteria 1.4 “Habitat distribution” and 1.5 “Habitat extent”. This reflects the fact that within the biodiversity components assessed on species level (marine mammals, reptiles, birds and fish) a large proportion of protected species occurs for which such indicators have a long tradition. In contrast, the conservation of habitats is a newer trend and the number of available indicators is thus limited. Especially for the criterion 1.5 “Habitat extent” a possible gap can be assumed.

Only few indicators are covering the ecosystem level (criterion 1.8) of the D1 criteria. The associated indicators 1.8.1 and 1.8.2 are not explicitely defined in the list of criteria for D1 as outlined in the Commission Decision (2010/477/EU). However such ecosystem properties are referred to in the text of the decision. Therefore, and because this aspect is important in terms of ecosystem health, under the scope of this DEVOTES survey they were considered in order to assess the availability of indicators that could address such aspects. In order to do a complete ecosystem health assessment, also the ecosystem services must be addressed, especially since they are part of the EU definition of GEnS.

125 indicators are addressing 1.7 “Ecosystem structure” of which 63 are operational. Only seven indicators are addressing 1.8 “Ecosystem processes and functions”, of which only one is operational. This is the BEQI (Benthic Ecosystem Quality Index) developed in the Netherlands (van Hoey *et al*. 2007) for the WFD, and it uses the relationship between macrobenthic biomass and ecosystem productivity. This indicator targets 1.8.1 “Interactions between structural components”. No operational indicator exists for 1.8.2 “Services provided” and in total only two existing indicators are present. An interesting approach for both EU indicators within the criterion is BTA (biological trait analysis), which is in a conceptual state. It uses functional groups instead of taxonomy in order to get information on the functional aspects of the ecosystem. Indicators addressing only the ecosystem criteria are few (15 for ecosystem structure and none for ecosystem processes). In contrast to the Habitats Directive (HD) that targets the conservation status, or the Water Framework Directive (WFD) that target the ecological status, the assessment within the MSFD should reflect the environmental status as a whole, thus also needs to incorporate the ecosystem level. Indicators addressing the ecosystem level are therefore of

special importance in the MSFD process. Despite the fact that ecosystem indicators in the catalogue are under-represented, the majority of the model-derived indicators included in the **DEVOTES Catalogue of Model-derived Indicators** revealed a high potential to inform on these complex, integrative ecosystem dimensions (Deliverable 4.1, Piroddi *et al*. 2013).

Apart from criterion 1.8 all other criteria are covered by at least 30 operational indicators and with 14 to 67 indicators under development. Thus, there is a good coverage of D1 on the species and population level and on the habitat level (beside habitat extent), while there is generally a potential gap on the ecosystem level.

The least covered EU indicator is 1.3.2 “Population genetic structure”. Only one indicator in the catalogue is covering this EU indicator. It is the operational indicator “Genetic population structure of selected biological components”. The DEVOTES catalogue does not yet cover these emerging assessment tools, however, section 6 of this report briefly addresses their status of development and potential for GEnS assessment in the scope of the EU Marine Strategy. Also EU indicator 1.5.2 Volume (EU criterion 1.5 “Habitat extent”) is poorly covered with only five operational indicators. One is very specifically investigating the volume of pelagic habitats and one is a valuation method integrating all available biological information into one indicator. The remaining three are WFD indicators for phytoplankton, where the volume of the habitat is only indirectly addressed. In fact, the WFD methods only look at biovolume of the individuals, not at habitat volume, and this might be an error during the survey reporting as explain in section 2.2, in this case due to misinterpretation of the MSFD criteria/indicator or of the reported indicators’ properties.

Table 9. Number of indicators per D1 criteria, divided into indicators specifically addressing one criterion and indicators addressing further criteria in addition [sum (operational/under development/conceptual/no status)].

D1 criteria	one criterion	several criteria
1.1 Species distribution	36 (23/10/1/2)	103 (66/32/2/3)
1.2 Population size	36 (23/13/0/0)	116 (69/45/2/0)
1.3 Population condition	46 (23/21/2/0)	70 (33/32/5/0)
1.4 Habitat distribution	19 (19/0/0/0)	71 (50/19/1/1)
1.5 Habitat extent	10 (9/0/1/0)	57 (39/14/3/1)
1.6 Habitat condition	44 (26/14/3/1)	185 (103/67/12/3)
1.7 Ecosystem structure	15 (8/5/2/0)	125 (63/51/10/1)
1.8 Ecosystem processes	0	7 (1/2/3/1)

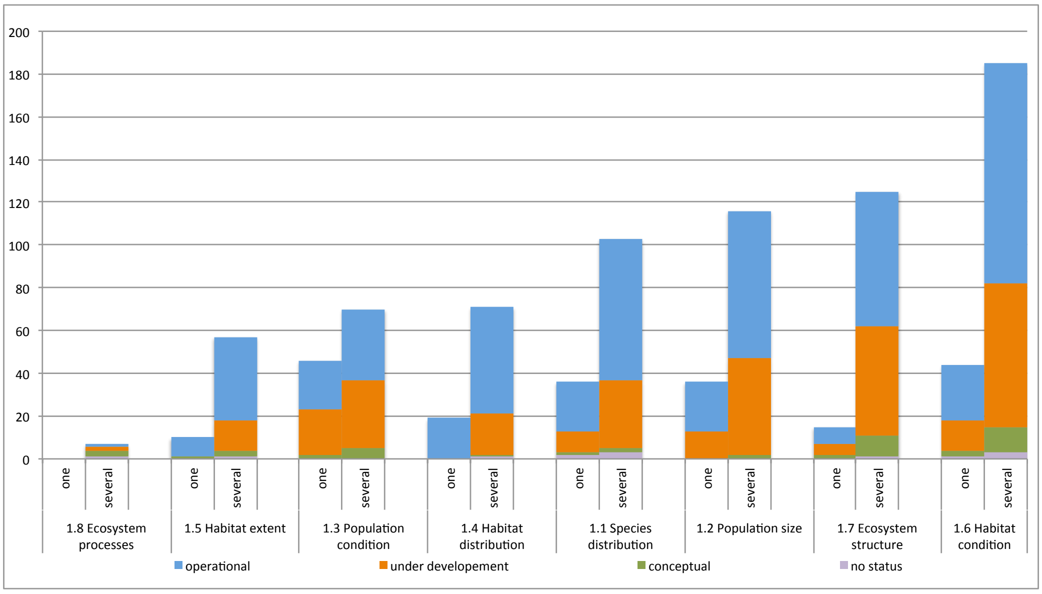


Figure 6. Number of indicators per D1 criteria in ascending order with indicator status and divided into indicators addressing one criterion and indicators addressing further criteria in addition.

Conclusions

There exists a certain concentration on indicators for species/population distribution and size compared to indicators for habitat distribution and extent as a result of the protection and conservation focus set in the past. This needs to be balanced in the MSFD assessment either by reducing the number of superfluous indicators for species/population distribution and size or by finding new indicators for habitat distribution and extent.

Criteria on ecosystem level are not well represented in the catalogue. As the ecosystem approach is one of the central aspects of the MSFD, new indicators need to be developed to address those criteria, especially for criterion ecosystem processes that was added by the DEVOTES project.

Within the criterion population structure only one indicator covers the genetic structure. This highlights also a need for new indicator developments specifically addressing the genetic structure of populations.

D2 criteria

Table 10. MSFD criteria, indicators and specifications listed in the catalogue for D2 Non-indigenous species (NIS).

Criteria	EU indicator	Specification
2.1 Abundance and state characterization of non-indigenous species, in particular invasive species	2.1.1 Trends in abundance, temporal occurrences, spatial distribution	2.1.1.1 Abundance 2.1.1.2 Temporal occurrences 2.1.1.3 Spatial distribution
2.2 Environmental impact of invasive non-indigenous species	2.2.1 Ratio between invasive non-indigenous species and native species	
	2.2.2 Impacts of non-indigenous invasive species at the level of species, habitats and ecosystem	2.2.2.1 Species 2.2.2.2 Habitats 2.2.2.3 Ecosystem

19 indicators are assigned to at least one of these criteria. Two indicators are related to D2 without the assignment to an EU criterion ("abundance of coral colonies alive", "abundance of coral colonies", "species richness of coral colonies", "species richness of fish" and "WFD Quality index of subtidal macroalgae of French Channel and Atlantic coast"). The number of indicators per D2 criterion is listed in **Table 11** and illustrated in **Figure 7**.

Criterion 2.1 is targeted by a variety of indicators (15) of which six are already operational. Most of them directly address trends in the arrival or trends in the abundance of non-indigenous species (2.1.1). One indicator is restricted to the species *Mnemiopsis leidyi* and measuring wet biomass.

Criterion 2.2 is only covered by six indicators, one of them being conceptual and the others under development. At least four use a ratio of non-indigenous to indigenous species. Only one indicator (Biopollution level index) targets environmental impact (2.2.2) and uses the habitat level for this. This number is too low to cover this criterion appropriately in all marine regions, especially as only one indicator uses the ratio between *invasive* non-indigenous to indigenous species, which can be used as an impact indicator. Three of them are just using a ratio between non-indigenous to indigenous species, which has no significance in assessing the impact to the ecosystem (MSFD Task Group 2 Report).

The indicators targeting D2 are among the ones that are most restricted in their usage since they tend to cover only D2 criteria. There is little overlap to D1 (only two indicators also covering D1, criterion 1.2) and D4 (only two indicators). This is due to the specific nature of the non-indigenous species indicators and only in cases, when the non-indigenous taxa are also key trophic groups or species, the indicators also have an informative value according to D1 or D4.

Table 11. Number of indicators per D2 criteria, divided into indicators specifically addressing one criterion and indicators addressing further criteria in addition [sum (operational/under development/conceptual/no status)].

D2 criteria	one criterion	several criteria
2.1 Abundance and state	12 (5/4/3/0)	15 (6/5/4/0)
2.2 Environmental impact	5 (0/4/1/0)	6 (0/5/1/0)

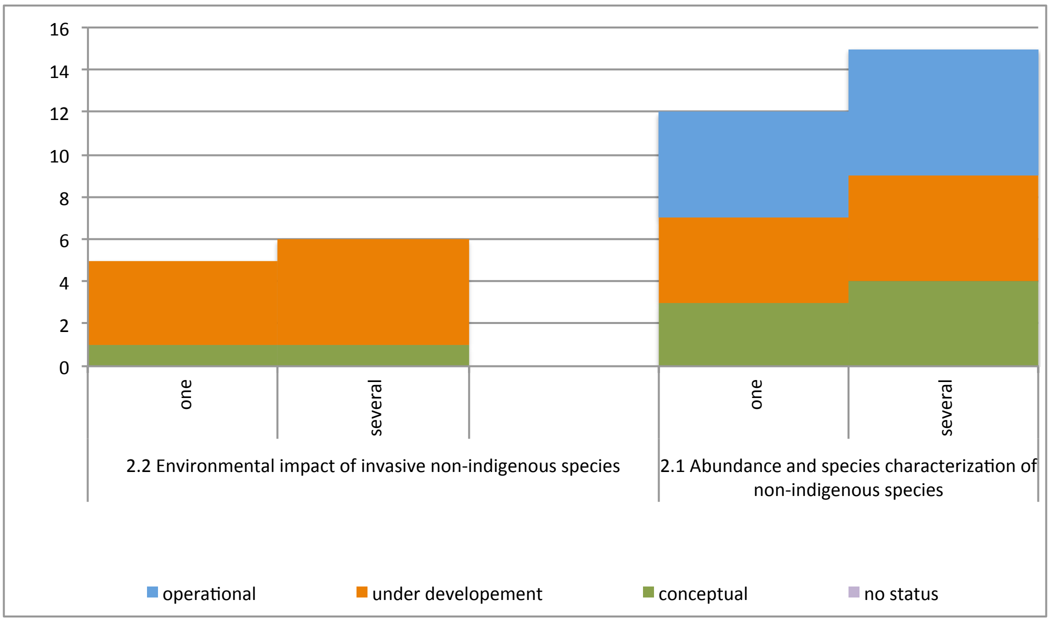


Figure 7. Number of indicators per D2 criteria in ascending order with indicator status and divided into indicators addressing one criterion and indicators addressing further criteria in addition.

The two D2 criteria are regarded as representing the pressure and state assessment respectively (see **Figure 1**, section 2.1), requiring the development of criteria-specific indicators. In this case the division is confusing. Non-indigenous species (NIS) are a pressure for D1 Biological biodiversity, D4 Food-webs or D6 Seafloor integrity. In consequence D2 could be treated as a pure pressure descriptor with subordinate MSFD criteria and indicators addressing the “magnitude of pressure” that NIS species might pose. The term “state” in context with NIS (as in EU criterion 2.1) is not helpful since a “state assessment” for a pressure is confusing. To avoid this situation the MSFD criteria and indicators of D2 could be restructured as illustrated below, following the guidance given in the interpretation manual for D2 (EUR 24342 EN, 2010).

Criteria	Indicators	Specification
2.1 Introduction	2.1.1 Number of pathways	–
	2.1.2 Trend in occurrence	2.1.2.1 Species number (richness) of NIS
		2.1.2.2 Ratio between *all* non-indigenous/native species
2.2 Establishment	2.2.1 Abundance	–
	2.2.2 Distribution range	–
2.3 Impact (alteration)	2.3.1 Species level	2.3.1.1 Ratio between *invasive* non-indigenous/native species
	2.3.2 Habitat level	–
	2.3.3 Ecosystem level	2.3.3.1 Proportion of trophic groups

The current division of criteria and indicators is not only confusing in terms of the use for pressure and state assessment, but also in connection with the classification of MSFD indicators into these criteria and the subsequent use by member states. Indicator 2.2.1 Ratio between *invasive* non-indigenous/native species is assigned to criterion 2.2 Environmental impact of *invasive* non-indigenous species. However very often only the ratio between all (also non-invasive) non-indigenous/native species is utilized, which has no significance for the impact itself. The draft for the new structure could minimize the risk of misinterpretation by users.

Conclusions

The criterion environmental impact of *invasive* non-indigenous species is not covered sufficiently by the available indicators. There is an urgent need for the development of indicators assessing the impact on species, habitat and ecosystem level.

It is recommended to define D2 as pressure descriptor and restructure the MSFD criteria and indicators accordingly to solve reoccurring confusions regarding the terms and definitions of this descriptor and its subordinate criteria.

D4 criteria

Table 12. MSFD criteria, indicators and specifications listed in the catalogue for D4 Food-webs. Note that criterion 4.4 is not part of the EU Commission Decision, but was added within the DEVOTES project.

Criteria	EU indicator	Specification
4.1 Productivity (production per unit biomass) of key species on trophic groups	4.1.1 Productivity of key predator groups or other trophic groups	4.1.1.1 Key predator species 4.1.1.2 Other trophic groups
4.2 Proportion of selected species at the top of food-webs	4.2.1 Large fish (by weight) 4.2.2 Other species	–
4.3 Abundance/distribution of key trophic groups/species	4.3.1 Abundance trends of functionally important selected groups/species	4.3.1.1 Groups with fast turnover rates 4.3.1.2 Groups/species that are targeted by human activities or that are indirectly affected by them 4.3.1.3 Habitat-defining groups/species 4.3.1.4 Groups/species at the top of the food-web 4.3.1.5 Long-distance anadromous and catadromous migrating species 4.3.1.6 Groups/species that are tightly linked to specific groups/species at another trophic level
4.4 Other (not part of EU COM Dec; added by the DEVOTES project)	–	–

168 indicators are assigned to at least one of these criteria. One indicator is not related directly to D4 but was reported as addressing a subordinate criterion; a mistake that needs correction. The number of indicators per D4 criterion is listed in **Table 13** and illustrated in **Figure 8**.

Most indicators are addressing the criterion 4.3 Abundance and distribution of key trophic groups/species (143) with 73 operational indicators. For this criterion a large overlap in the indicator set exists with D1 and especially D6 for indicators addressing habitat-defining species:

- D4 Food-webs: 4.3. Abundance and distribution of key trophic groups/species → 4.3.1 Abundance trends of functionally important selected groups/species → 4.3.1.3 Habitat-defining groups/species
- D6 Seabed integrity: 6.1. Substrate characteristics – physical damage → 6.1.1 Biogenic substrate → 6.1.1.1 Abundance & 6.1.1.4 Areal extent of biogenic substrate
- D1 Biodiversity: 1.4 Habitat distribution & 1.5 Habitat extent

For the food-web criteria it may not be very constructive for the assessment process to include this criterion. The proportion of indicators on habitat forming species exceeds the proportion of indicators, which are focusing on trophic groups, which should be primarily targeted in D4. This obscures possible gaps in the indicator set and it might create problems in the final aggregation during the assessment process, as double assessments can very likely occur.

Only 18 indicators address criterion 4.1 Productivity. Analysing indicators addressing 4.1 in detail show a strong focus of assessments for the top predators of the food-webs, whereas primary and secondary producers are clearly under-represented in the indicator set.

Eleven indicators address criterion 4.2 Proportion of selected species at the top of the food-web with eight operational indicators. Within criterion 4.2 two groups are distinguished. One group are large fish (by weight) – 4.2.1). EU indicator 4.2.2 Other species has been added by the DEVOTES project and is covered by four indicators. Two of them are looking at zooplankton and investigate abundance or body length distribution of zooplankton. In general zooplankton and/or abundance indicators may not be correctly assigned to criterion 4.2, which addresses the proportion of top predators. It needs to be clarified, if the indicators might be specific for jellyfish or not to decide about a re-classification.

The criterion 4.4 Other was introduced by the DEVOTES project since there where a few indicators that did not fit into the pre-defined categories of the EU COM Dec. 9 indicators are inside this group. They focus on breeding success, bottom-up and top-down effects in marine size spectra, trophic pyramids of richness and on competition avoidance through niche packing. Most of these indicators are not yet operational.

Table 13. Number of indicators per D4 criteria, divided into indicators specifically addressing one criterion and indicators addressing further criteria in addition [sum (operational/under development/conceptual/no status)].

D4 criteria	one criterion	several criteria
4.1 Productivity of key species or trophic groups	5 (1/2/2/0)	18 (11/3/4/0)
4.2 Proportion of selected species at the top of the food-web	4 (4/0/0/0)	11 (8/2/1/0)
4.3 Abundance/ distribution of key trophic groups/species	17 (5/4/8/0)	143 (71/58/12/2)
4.4 Other	3 (0/0/3/0)	9 (2/3/4/0)

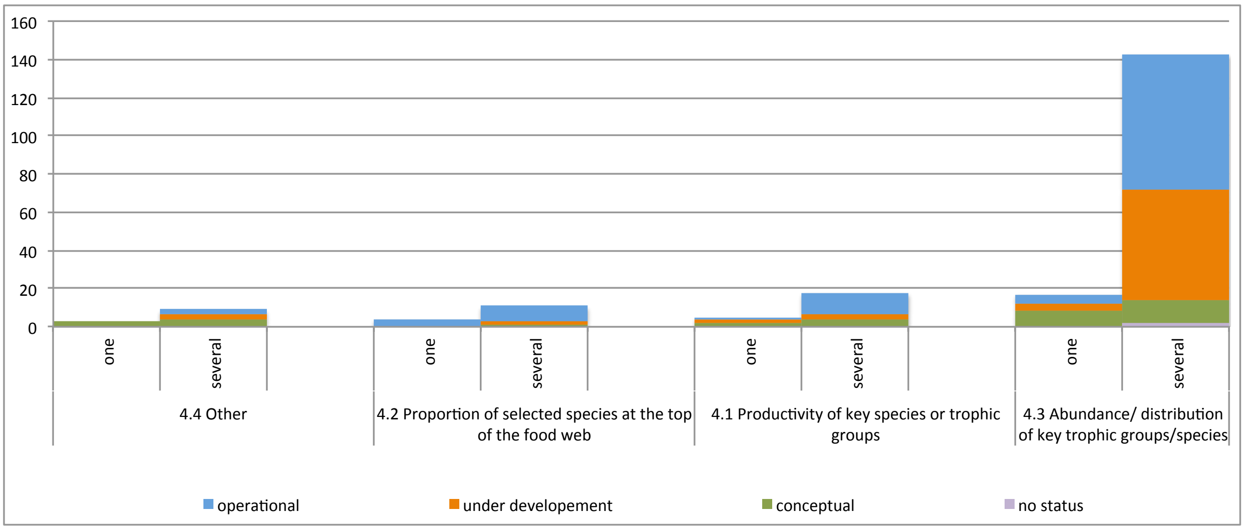


Figure 8. Number of indicators per D4 criteria in ascending order with indicator status and divided into indicators addressing one criterion and indicators addressing further criteria in addition.

Conclusions

The assessment of abundance, distribution and/or extent of habitat-defining species should be restricted to D1 or D6. Those ecosystem components should only contribute to 4.1 on trophic level (as primary, secondary producers) and preferably with biomass per trophic group to achieve a clear differentiation between D1, D4 and D6 descriptors and criteria avoiding the risk of double assessments.

Additional indicators related to the productivity of primary and secondary producers need to be developed to cover criterion 4.1 respectively as the focus of the available indicators is too much on the top predators. The bottom–up control of food-webs and ecosystems is not adequately covered.

The assignment of zooplankton abundance indicators to 4.2 proportion of selected species at the top of the food-web needs an evaluation as this assignment only makes sense if it relates to jellyfish and if the proportion of this group compared to others can really be calculated based on abundance data.

D6 criteria

Table 14. MSFD criteria, indicators and specifications listed in the catalogue for D6 Seafloor integrity.

Criteria	EU indicator	Specification
6.1 Substrate characteristics – physical damage	6.1.1 Biogenic substrate	6.1.1.1 Type of relevant biogenic substrate 6.1.1.2 Abundance of relevant biogenic substrate 6.1.1.3 Biomass of relevant biogenic substrate 6.1.1.3 Areal extent of relevant biogenic substrate
	6.1.2 Extent of seabed significantly affected by human activities for the different substrate types	–
6.2 Condition of benthic community	6.2.1 Presence of particularly sensitive and/or tolerant species	–
	6.2.2 Multi-metric indexes assessing benthic community condition and functionality	6.2.2.1 Species diversity 6.2.2.2 Richness 6.2.2.3 Proportion of opportunistic to sensitive species
	6.2.3 Proportion of biomass or number of individuals in the macrobenthos above some specified length/size	6.2.3.1 Biomass 6.2.3.2 Number of individuals
	6.2.4 Parameters describing the characteristics (shape, slope and intercept) of the size spectrum of the benthic community	–

163 indicators are assigned to at least one of these criteria. 20 indicators are related to D6 without the selection of a subordinate criterion. The number of indicators per D6 criterion is listed in **Table 15** and illustrated in **Figure 9**.

Indicators are evenly distributed across the two criteria with 103 indicators addressing 6.1 Substrate characteristics – physical damage and 102 indicators are related to criterion 6.2 Condition of the benthic community. The number of indicators addressing only one criterion is low as both criteria exhibit a high subject-specific overlap. The proportion of operational indicators is larger than 50 % for both criteria.

For criterion 6.1 Substrate characteristics – physical damage a large proportion (> 60 %) of related indicators are covering biogenic substrates (6.1.1), which can be regarded as a status indicator of D6. However, it is not clear why this status assessment should be restricted to biogenic substrates only. Accordingly some experts grouped also indicators in 6.1.1, which comprises other (geogenic) substrates.

A clarification is needed here. As mentioned before, there is a huge overlap with D1 Biological diversity (criteria 1.4 Habitat distribution, 1.5 Habitat extent) as well as with D4 Food-webs (Criterion 4.3 Abundance/ distribution of key trophic groups/species) for EU indicator 6.1.1.

The second aspect of criterion 6.1, the seabed affected by human activity (6.1.2) represents a pressure indicator, which is correctly subordinate to the pressure criteria. Indicators related to 6.1.2 are directly measuring the affected area or taking the ratio of affected/not affected area into account. Although the nature of 6.1.2 is relatively simple, none of these indicators are already operational. Some indicators assigned to 6.1.2 are misclassified like species diversity indicators or WFD indicators as those indicators are status indicators instead of pressure indicators. This needs to be re-evaluated.

Most of the indicators covering criterion 6.2 Condition of the benthic community are targeting 6.2.1 Presence of particularly sensitive and/or tolerant species (68 indicators). As habitat-defining species are very often regarded as particularly sensitive species, an overlap exists between EU indicators 6.1.1 and 6.2.1 causing a high risk of double assessments within one descriptor.

More than 50 % of the indicators are multi-metric indices that target 6.2.2 Multi-metric indexes assessing benthic community condition and functionality. These are largely WFD indices that utilize and combine the different assessment criteria outlined in the normative definitions of the WFD on various levels. The further division of 6.2.2 to species diversity, richness or proportion of opportunistic/sensitive species seems to be superfluous, as it is the nature of multi-metric indices to combine those metrics rather than assessing them individually. This has led to the fact that indicators assessing species richness, species diversity (Shannon-Wiener) and even only abundances of components were misclassified as being “multi-metric”.

Not many indicators are present for 6.2.3 Proportion of biomass or number of individuals in the macrobenthos […] and 6.2.4 Parameters describing the characteristics of the size spectrum, namely 9 and 5 respectively. The latter are mainly looking directly at the body length distribution.

Table 15. Number of indicators per D6 criteria, divided into indicators specifically addressing one criterion and indicators addressing further criteria in addition [sum (operational/under development/conceptual/no status)].

D6 criteria	one criterion	several criteria
6.1 Substrate characteristics – physical damage	25 (19/3/3/0)	103 (63/35/4/1)
6.2 Condition of the benthic community	16 (14/2/0/0)	102 (74/23/4/1)

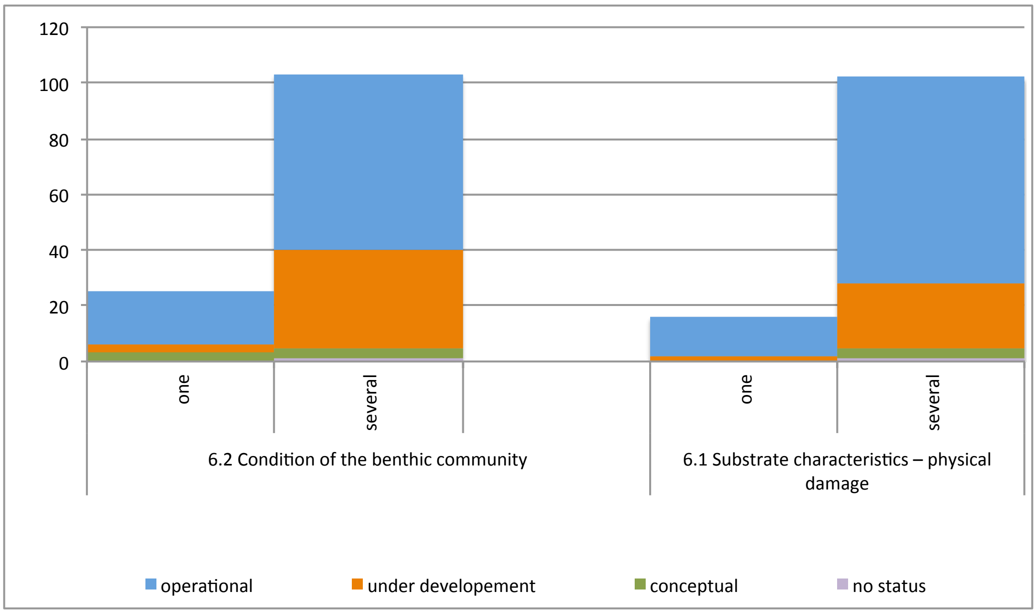


Figure 9. Number of indicators per D6 criteria in ascending order with indicator status and divided into indicators addressing only one criterion and indicators addressing further criteria in addition.

The Descriptor Seafloor integrity (D6) and its subordinate criteria and indicators are the source of several problems with negative effects for indicator classification, gap analysis and further indicator development. One problem is the unpleasant mixture between pressure criteria and subordinate status and pressure indicators as illustrated below. EU indicator 6.1.1 cannot be subordinate to a pressure criterion.

6.1 Substrate characteristics – physical damage	**pressure assessment criteria**
6.1.1 Biogenic substrates	status indicator
6.1.2 Extent of seabed significantly affected by human activities for the different substrate types	pressure indicator

Furthermore there is a strong overlap of identical ecological components, which are subordinate to different criteria and different types of criteria within D6:

6.1 Substrate characteristics – physical damage	**pressure assessment criteria**
6.1.1 Biogenic substrates	status indicator
6.2 Condition of the benthic community	**status assessment criteria**
6.1.2 Presence of particularly sensitive and/or tolerant species	status indicator

Finally the use of D6 as a combined pressure and status descriptor causes a strong overlap and repetition with D1. The status of benthic species, communities or habitats is also assessed in D1. The status assessment for D6, as it is defined presently, is only slightly different to the status assessment of D1. 85 % of indicators addressing 6.2 Condition of the benthic community are also addressing 1.4

Habitat condition. Only indicators addressing body size distribution of benthic species are not assigned to D1, those are at the moment only targeting EU indicators 6.2.3 and 6.2.4.

Conclusions

The risk of double assessments is highest for D6. It is recommended to re-evaluate D6 as a pressure indicator instead of a combined pressure/state indicator. The status of the benthic community should be assessed in D1 (including indicators for body length distribution of benthic species).

If D6 remains as a state descriptor, then pressure and status criteria must be divided clearly and subordinate indicators must refer to either only pressure or only status within one individual criterion.

By deleting 6.1.1 Biogenic substrates and specifying 6.2.1 Presence of particularly sensitive and/or tolerant species with subordinate specification 6.2.1.1 Habitat forming species, the risk of double assessment within D6 for habitat defining species can be avoided.

An adjustment and/or clear distinction between the terms habitat-defining (listed in D4 Food-web), biogenic substrate (listed in D6) and habitat forming as well as bioengineering (used by many member states and users) should be achieved.

3.3. Indicators' coverage of biodiversity components, habitats, pressures and spatial EU coverage

The ecosystem approach of the MSFD requires a set of indicators, which is not only able to cover the defined descriptors and criteria but also capable to take the various biodiversity components and habitat types into account. Analyses of existing indicators should enable an identification of gaps for biodiversity components and/or habitat types, which were out of the monitoring and assessment scope in the past but are of special interest for the marine ecosystem and its overall biodiversity.

The marine environment is exposed to a variety of different anthropogenic pressures. Some of those pressures are already part of the MSFD descriptors (D2 non-indigenous species, D5 eutrophication, D7 hydrological conditions, D8 contaminants, D9 contaminants in seafood, D10 litter, D11 energy like underwater noise or light). Descriptors D1, D4 and D6 are status descriptors and indicators addressing those descriptors should have a relation to anthropogenic pressures. However, a direct relationship to one or several pressures is often impossible to prove scientifically. The cross-linkages and dependencies between trophic levels and competitors for food and space are too numerous and variable within an ecosystem.

GEnS assessment is spatially based on EU Marine regional seas. A harmonized assessment approach within a regional sea is therefore essential for the MSFD implementation and also harmonization between regional seas would be advantageous. Indicators that are already operational and tested in one regional sea might be easier and less time consuming to apply and adapt to other areas compared to the development of new indicators.

3.3.1. Biodiversity components

Many existing indicators have been developed specifically for biodiversity components or subcomponents or specific taxa. To identify possible gaps for certain biodiversity components, indicators have been assigned to the relevant MSFD biodiversity components, where possible. **Table 16** gives an overview of the defined components and subcomponents. In particular cases, experts were also able to provide additional taxonomic specifications, if indicators address specific taxa or taxa groups.

Table 16. Classes of biodiversity components, subcomponents and examples of further taxonomical specifications, listed in the catalogue.

Biodiversity component	Subcomponent	Taxonomic specification (examples)
Microbes	–	
Phytoplankton	–	Incl. Cyanobacteria, *Phaeocystis* sp.
Zooplankton	–	Copepoda, *Mnemiopsis leidyi*
Angiosperms	–	Eelgrass, *Posidonia oceanica*, Seagrasses, *Zostera marina*, *Zostera noltii*
Macroalgae	–	*Cladophora* sp., *Cystoceira barbata*, *Furcellaria lumbricalis*
Benthic invertebrates	–	Annelida, *Chamelea gallina*, *Mytilus* spp., *Upogebia pusilla*
Pelagic invertebrates	–	
Fish	Diadromous fish, coastal fish, pelagic fish, pelagic elasmobranchs, demersal fish, demersal elasmobranchs, deep-sea fish, deep-sea elasmobranchs, ice-associated fish, other	*Coregonus lavaretus*, *Gadus morhua*, *Salmo salar*
Cephalopods	Coastal/shelf pelagic, deep-sea pelagic, other	
Marine mammals	Toothed whales, baleen whales, seals, ice associated mammals, other	*Balaenoptera acutorostrata*, *Halichoerus grypus*, *Phocoena phocoena*
Reptiles	Sea-turtles, other	*Caretta caretta*
Birds	Intertidal benthic feeding, inshore surface-feeding, inshore pelagic-feeding, inshore benthic-feeding, inshore herbivorous-feeding, offshore surface-feeding, offshore pelagic-feeding, ice associated birds, other	*Bucephala clangula*, *Clangula hyemalis*, *Gavia stellata*, *Polysticta stelleri*

Of the 557 indicators 457 have in minimum one entry for biodiversity components, and 100 lack an entry (**Figure 10**). Lack of entries regarding biodiversity components fields was identified for indicators that refer to:

- certain biotopes, habitats or areas without any relation to a biodiversity component, e.g.: “Areal extent of protected areas”, “Depth distribution of selected habitats” or “Ratio of area of protected area/total area”
- the chemical or physical status of the marine environment, e.g.: “Concentration of oxygen at the bottom”, “Depth of sediment redox potential discontinuity” or “Secchi depth”
- processes between certain levels of the ecosystem, e.g.: “Energy flows and transfer efficiencies among trophic levels or functional groups”
- defined groups independently of biodiversity components (functional groups, key-stone species, non-indigenous species), e.g.: “Abundance of functional groups“, “Number of biocenosis/facies” or “Rate of new introduction of non-indigenous species (per defined period)”

For the first three aspects the assignment of biodiversity components is needless or even misleading. For the last aspect the lack of an entry is partly caused by the conceptual status of those indicators. In such cases it might not be defined yet, if the indicator should be analysed independently of biodiversity components or will be developed and targeted for specific biodiversity components.

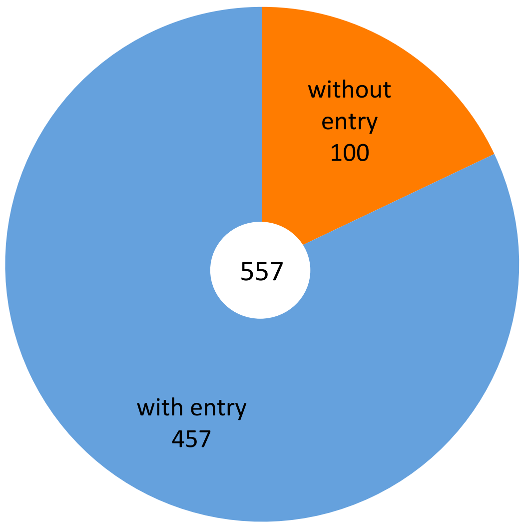


Figure 10. Number of indicators with or without an entry for biodiversity components.

The number of indicators differs conspicuously between biodiversity components (**Figure 11**). As single indicators can be related to more than one biodiversity component, the sum of indicators per biodiversity component is larger than the overall indicator number (651 ⇔ 557 indicators).

Benthic invertebrates and fish have the highest number of related indicators (>100); microbes and pelagic invertebrates (crustaceans) have the lowest number (1 indicator each). The number of indicators may reflect the species richness, the economic importance, the conservation status of the biodiversity component or the level of taxonomic knowledge and expertise available. The less species exist in a group the less is the number of indicators. Reptiles (15) and cephalopods (23) have a comparable low number of indicators. The high number of indicators for benthic invertebrates, fish and phytoplankton reflects the high species richness but for fish also the economic importance of this biodiversity component. In contrast, the comparably high number of marine mammal and bird indicators reflects the high conservation status of those components. Although angiosperms and macroalgae species are seldom protected as species per *se* they are often protected as structuring components of biotopes/habitats, which explains the comparably high number of indicators. Macroalgae have higher species richness than angiosperms and therefore more indicators exist already for macroalgae.

The biodiversity component zooplankton marks an exceptional case of the relations described above. Although zooplankton is high in species richness as well as abundance and forms an important link in many food-webs and nutrient cycles the number of indicators is comparably low (55 indicators). One of the reasons could be the absence of this component in the WFD, which results in a lack of methods developed to assess its status.

The low number of indicators for microbes and pelagic invertebrates may also indicate a possible gap of existing indicators. Both components may be covered by other biodiversity groups:

- Cyanobacteria are often a part of phytoplankton indicators and might have been not selected separately by the experts. For other microbial groups regular monitoring programmes are not conducted and also research projects are rare
- Pelagic invertebrates (crustaceans – cephalopods are regarded separately) on the other hand are often part of fish indicators thus might have been not selected separately by the experts

It needs to be clearly defined, if it is necessary to treat those groups separately from fish or phytoplankton. If so, the experts need to re-evaluate their phytoplankton and fish indicators accordingly to identify real gaps in the indicator set for those groups.

Table 17. Number of indicators per biodiversity component, divided into indicators specifically addressing one component and indicators addressing several (one or more) components [sum (operational/under development/conceptual/no status)].

Biodiversity component	one component	several components
Microbes	1 (0/1/0/0)	1 (0/1/0/0)
Phytoplankton	57 (20/18/4/15)	87 (33/27/12/15)
Zooplankton	26 (12/11/3/0)	55 (24/20/11/0)
Angiosperms	31 (24/5/0/2)	59 (41/13/3/2)
Macroalgae	45 (31/14/0/0)	81 (50/24/7/0)
Benthic invertebrates	80 (31/41/7/1)	114 (46/50/17/1)
Pelagic invertebrates	0	2 (1/1/0/0)
Fish	68 (40/23/5/0)	105 (52/41/12/0)
Cephalopods	4 (4/0/0/0)	23 (10/9/4/0)
Marine mammals	34 (10/22/2/0)	56 (16/33/6/1)
Reptiles	6 (6/0/0/0)	15 (8/2/4/1)
Birds	33 (20/12/1/0)	52 (25/22/5/0)

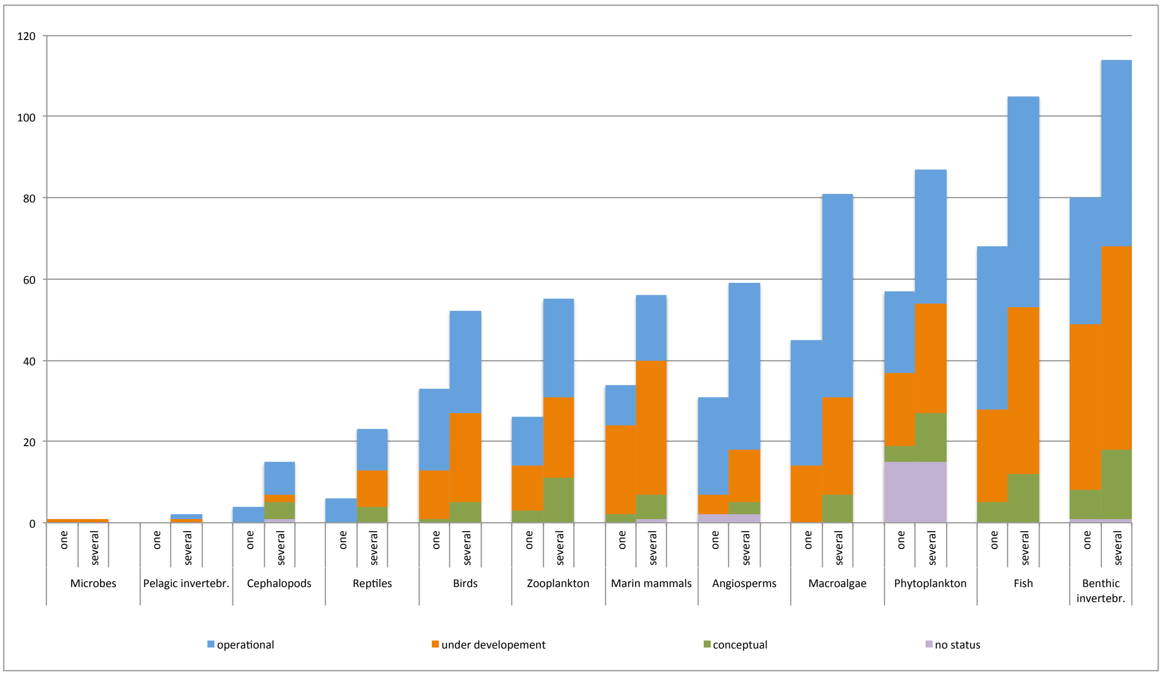


Figure 11. Number of indicators per biodiversity component in ascending order with indicator status and divided into indicators addressing one component and several (one or more) components.

Of the 475 indicators with a biodiversity component entry, 73 indicators address more than one biodiversity component and 385 indicators are specifically developed for only one biodiversity component. The indicators which address only one biodiversity component, follow more or less the pattern described above. However, the number of specific bird and marine mammals indicators exceeds the number of specific angiosperm and zooplankton indicators. The lower number of indicators specifically addressing angiosperms can be explained by the fact that there are numerous indicators related to assess "Areal extent …", "Distributional range …" or "Depth distribution… "of selected habitats or habitat-structuring species addressing not only specifically angiosperms but also macroalgae or benthic invertebrates. The low number of zooplankton specific indicators further highlight a possible gap for zooplankton indicators. Only 26 zooplankton indicators exist for this specific component and only a small proportion is operational (12).

No indicators address pelagic invertebrates only.

Although the microbe indicator is specific for this group the number is too low to cover this biodiversity component adequately and the indicator is still under development.

The number of specific reptile (6) and cephalopod (4) indicators is also very low. However, all of the indicators are already operational. Analysing the D1 criteria that those indicators address, it becomes evident that for cephalopods, which are mainly addressed in terms of fisheries, only criteria for species distribution and population size are covered, but no indicators cover the criterion "population condition", whereas for reptiles, which are mainly addressed as protected speces *per se*, all relevant D1 criteria (species distribution, population size and population condition) can be met.

Although the number of specific marine mammal indicators is high (34) the number of operational (10) indicators is low compared to other components. Still all three relevant D1 criteria can be met with operational indicators. A comparably low number of operational indicators exist also for phytoplankton indicators, but in this case a high number of indicators occur without any status, most of them WFD phytoplankton assessments which were expected to be operational already. Those status entries need to be corrected by the responsible experts.

One task of the DEVOTES project is the identification of key stone species (Task 6.1.3 Identification of keystone species and processes). In this context taxon specific indicators might be of importance. **Figure 12** illustrates the number of taxon specific indicators (genus and species level) per biodiversity component. Microbes, cephalopods and phytoplankton have no taxon-specific indicators. For zooplankton one indicator relates to an invasive comb jellyfish species ("Biomass of *Mnemiopsis leidyi*"), which has influenced the food-web structure and fish egg and larvae abundance of the Black Sea negatively, and might therefore be identified as a key stone predatory species. For reptiles there is one indicator specifically addressing the endangered loggerhead sea turtle ("Abundance of sea turtle spawning population"). Highest taxon-specific indicator numbers exist for easily recognizable, large growing mobile or habitat-forming species with conservation status. For example there are several indicators for the seagrass *Posidonia oceanica* (assessing areal extent, depth distribution, structural descriptors, survival rate or multi-metric analyses) and the toothed whale *Phocoena phocoena* (assessing "abundance, nutritional status or pregnancy rates"). Both species will, most probably, belong to the key stone species of specific regional seas.

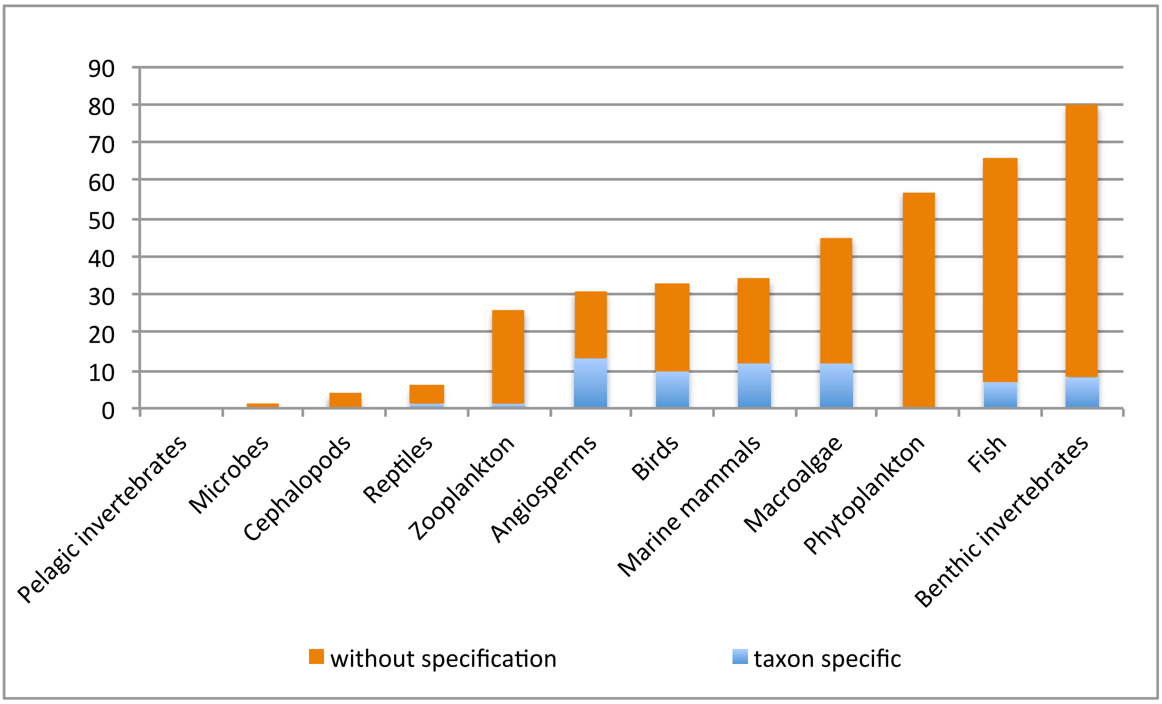


Figure 12. Numbers of indicators addressing only one biodiversity component, divided into taxon specific and non-specific indicators.

Further analyses on subcomponents basis give no hints on gaps as most indicators are apparently independent from subcomponents and are applicable for all subcomponents. However, some experts did select all possible subcomponent entries for such indicators but others left the entries blank. On the other hand, indicators with a preliminary development status (under development or conceptual) may not be defined yet on subcomponent level.

In other cases it might not have been clear for experts that multiple selections are necessary and important in terms of gap analysis. Ice-associated communities/species, which are selectable for fish, marine mammals and birds, have not been assigned to any indicators. However, there are species like the grey seal (*Halichoerus gryphus*) using drifting ice for pupping in the Northern Baltic Sea, which fulfils the definitions given in the interpretation manual for D1 Biological diversity (MSFD Task Group 1 Report): "ice-associated – species which depend upon ice and ice-driven biological processes for habitat, shelter, reproduction or feeding for at least some parts of the year, or for parts of their life-cycle." In such cases the subcomponent "seal" and "ice-associated mammals" should have been selected. But even if those entries are corrected a gap for ice-associated ecotypes of fish, mammals and birds can be assumed.

Conclusions

For microbes and pelagic invertebrates it needs to be clarified, if a separation from phytoplankton or fish is essential for MSFD purpose. If so, cephalopods and pelagic invertebrates should be grouped as biodiversity component "pelagic invertebrates" with cephalopods and crustaceans as subcomponent. For microbes, subcomponents like cyanobacteria, bacteria and viruses could be included. Subsequently, experts need to re-evaluate their indicators accordingly for these groups.

Gaps in the indicator set can be assumed for zooplankton and probably also for microbes and pelagic invertebrates. For cephalopods no existing indicators are covering the criterion condition.

Entries of subcomponents need to be checked to clearly define gaps in the indicator set. A distinction is required between indicators addressing all subcomponents and those indicators not yet developed as to provide such detail on subcomponents or even components. Gaps can already be assumed for ice-associated ecotypes of fish, mammals and birds.

3.3.2. Habitat types

Phytoplankton, zooplankton, angiosperms, macroalgae and benthic invertebrates should be treated together with their associated habitat types (MSFD Task Group 1 Report). At least those biodiversity components should therefore be assigned to certain habitat types in the catalogue. Additionally this also refers to all indicators, which are related to a specific habitat or biotope instead of a biodiversity component like "Areal extent of rocky habitats". Mobile components like marine mammals, reptiles, birds and fish should be treated on species or community/ecotype (e.g. pelagic feeding birds) state level (MSFD Task Group 1 Report). An assignment to habitat types for those components is not necessary and partly misleading or contradictory in context of a gap analysis. **Table 18** gives an overview of the available habitat types and subtypes of the catalogue.

Table 18. Habitat types and subtypes listed in the catalogue.

Habitat type	Subtype
Seabed	Littoral rock and biogenic reef, littoral sediment
	Shallow sublittoral rock and biogenic reef, shallow sublittoral coarse sediment, shallow sublittoral sand, shallow sublittoral mud, shallow sublittoral mixed sediment
	Shelf sublittoral rock and biogenic reef, shelf sublittoral coarse sediment, shelf sublittoral sand, shelf sublittoral mud, shelf sublittoral mixed sediment
	Upper bathyal rock and biogenic reef, upper bathyal sediment
	Lower bathyal rock and biogenic reef, lower bathyal sediment
	Abyssal rock and biogenic reef, abyssal sediment
Water column	Reduced salinity water
	Variable salinity (estuarine) water
	Marine water: coastal
	Marine water: shelf
	Marine water: oceanic
Ice habitats	Ice associated habitats

Of the 557 indicators of the catalogue 423 have at least one entry in habitat type and/or subtype and 134 lack an entry (**Figure 13**). No entries were mainly given for indicators that refer to:

- the mobile biodiversity components: marine mammals, reptiles, birds and fish (if they cannot be clearly categorized to either pelagic or demersal fish); e.g.: “By-catch of marine mammals and water birds in fishing gears”, “Distributional pattern within the distributional range of sea-turtles” or “Sex ratio of fish”;
- the chemical or physical status of the marine environment, if indicators cannot be clearly categorized to either seabed or water column environment status; e.g.: “Chemical and physical variables from existing monitoring programmes” or “Ratio of area potentially affected by discharge of materials”;
- processes, which are independent of the habitat type; e.g.: “Competition avoidance among species” or “Energy flows and transfer efficiencies among trophic levels or functional groups”;
- defined groups or habitats independently of the type (functional groups, selected habitats, non-indigenous species); e.g.: “Depth distribution of selected habitats” or “Ratio of surface water bodies in good ecological status”.

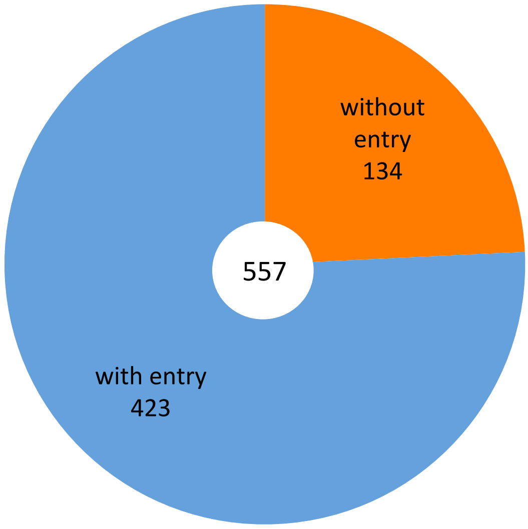


Figure 13. Number of indicators with or without an entry for habitat type.

In total 281 indicators are related to seabed habitats, 171 to water column habitats and none to ice habitats (**Figure 14**). As single indicators can be related both to seabed and water column, the sum of indicators *per* type is higher than the overall indicator number with entry (453 ⇔ 423 indicators). Of the 423 indicators with entries, 29 indicators address more than one habitat type, 252 indicators address only seabed and 142 only water column habitats.

Table 19. Number of indicators per habitat type, divided into indicators specifically addressing one habitat type and indicators addressing further habitat types in addition [sum (operational/under development/conceptual/no status)].

Habitat type	one habitat type	several habitat types
Seabed	252 (154/84/12/2)	281 (166/92/20/3)
Water column	142 (49/66/12/15)	171 (61/74/20/16)
Ice habitat	0	0

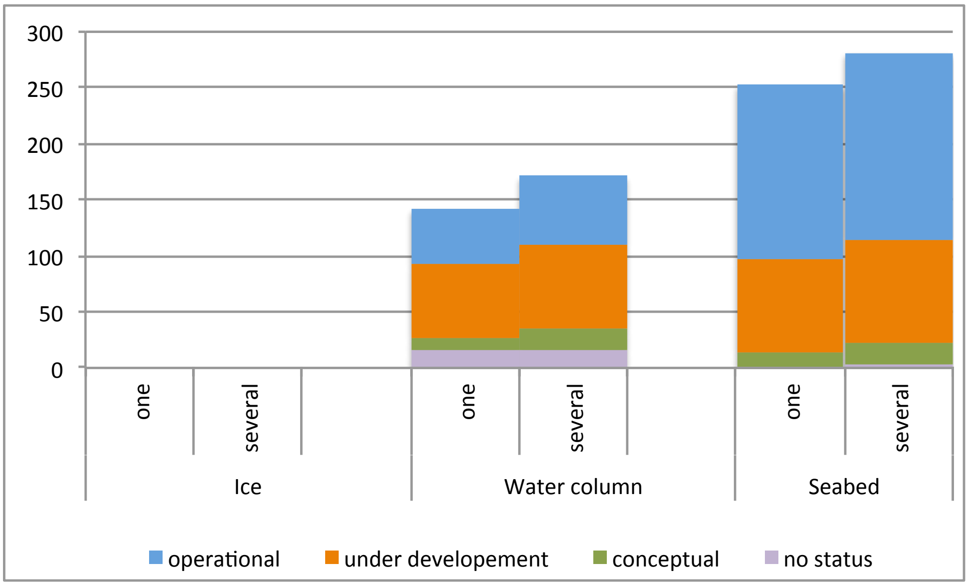


Figure 14. Number of indicators per habitat type in ascending order with indicator status and divided into indicators addressing one habitat type and further habitat types in addition.

As there are more biodiversity components relevant for benthic communities (angiosperms, macroalgae, benthic invertebrates, demersal fish) with higher indicator numbers compared to pelagic habitats (phyto-, zooplankton, pelagic fish) the higher numbers of seabed indicators meet the expectations. Additionally, there is a variety of indicators connected directly (without an entry in biodiversity component) to benthic habitats ("Areal extent of rocky habitats" or "Distributional range of circalittoral and bathyal soft bottom habitats") but only very few indicators connected directly to pelagic habitats (for example "Secchi depth" or "Chl *a* concentration").

The proportion of operational indicators is much higher for seabed habitats than water column habitats. Status assessments for benthic communities have a longer tradition and are easier to conduct compared to the spatially strongly variable water column communities.

The lack of ice habitat indicators may be caused by an unclear or misleading definition and classification for those habitats and their related communities. Biodiversity components with ice-associated communities/species are selectable for fish, marine mammals and birds only. As those three components are mobile components, the classification to a habitat type is not strictly required if an indicator evaluates the species state. Ice habitats should be of importance for the Central and Northern Baltic Sea as well as for the Northern subdivisions of the North-East Atlantic Sea. Two indicators exist that refer to grey seal pupping: "Number of pups of grey seals", "Abundance of seals (at haul-out sites and within breeding colonies)" in the Baltic. As both are indicators for a specific species and not for the "ecotype ice associated mammals" no habitat type was selected. It need to be discussed and clarified with the EU MSFD experts if in such cases "seal" and "ice-associated mammals" should have been assigned to biodiversity ecotypes and if the selection of ice habitat is strictly mandatory in such cases although it is an indicator on species basis.

Habitat types could be divided further into subtypes (see **Table 18**). For water column indicators a further division to subtypes was applied to only few indicators. It was observed that the experts of different countries have used the subtypes in such different ways that further analysis for subtypes is not reasonable. For example some Baltic experts have chosen “reduced salinity water” as subtype but others “marine waters: coastal” as subtype, which is misleading for the Baltic Sea. Therefore no further analysis of indicators concerning water column subtypes could be done. A gap for Baltic Sea water column indicators can be excluded as a variety of indicators exist for this habitat type in the Baltic Sea (see section 4.1.2).

For seabed indicators a further classification to subtypes was done for a larger proportion of indicators and with less misleading entries, making a further analysis reasonable. For the analysis the seabed subtypes are grouped according to:

- bottom type: hard bottom (rock and biogenic reef), soft bottom (sand, mud and sediment), mixed bottom (mixed and coarse sediment)
- depth zone: littoral, shallow sublittoral, shelf, bathyal (upper and lower) and abyssal

Bottom type

In total 43 seabed indicators address mixed bottom, 84 hard bottom and 100 soft bottom (**Figure 14**). The number of indicators addressing only one specific subtype is low for all types (**Table 20**), and especially for mixed bottoms. However, mixed bottoms are seldom defined and assessed separately in monitoring programmes, and may only be relevant for specific marine regions, which naturally lack “rock bottoms”, like the Southern and Western Baltic Sea. However, mixed bottoms are important in terms of biodiversity as they combine hard and soft bottom communities resulting in a very high overall biodiversity per unit area.

The overall number of indicators assigned to hard bottom is lower than for soft bottom, but the number of indicators specifically addressing hard bottom is higher. This reflects the fact that there are more indicators for macroalgae, which need hard bottom for attachment, compared to angiosperms, which need soft bottom for anchoring. Furthermore, sampling of hard bottom requires specific monitoring methods differing from standard methods like grab sampling, and thus require specific indicators in terms of their spatial and methodological applications and data requirements.

The proportion of operational indicators is highest for soft bottom, which is also related to monitoring methods and equipment. Hard bottom assessments methods are often utilizing diving work or video techniques, which can be time consuming and costly, difficult to harmonize between working groups. Also, they do not have such a long sampling tradition as soft bottom standardized methods like grab or corer sampling do.

Table 20. Number of indicators per bottom type, divided into indicators specifically addressing one bottom type and indicators addressing further bottom types in addition [sum (operational/under development/conceptual/no status)].

Bottom type	one bottom type	several bottom types
Mixed bottom	5 (1/4/0/0)	43 (22/14/6/1)
Hard bottom	47 (24/23/0/0)	84 (44/36/3/1)
Soft bottom	37 (22/15/0/0)	100 (62/28/8/2)

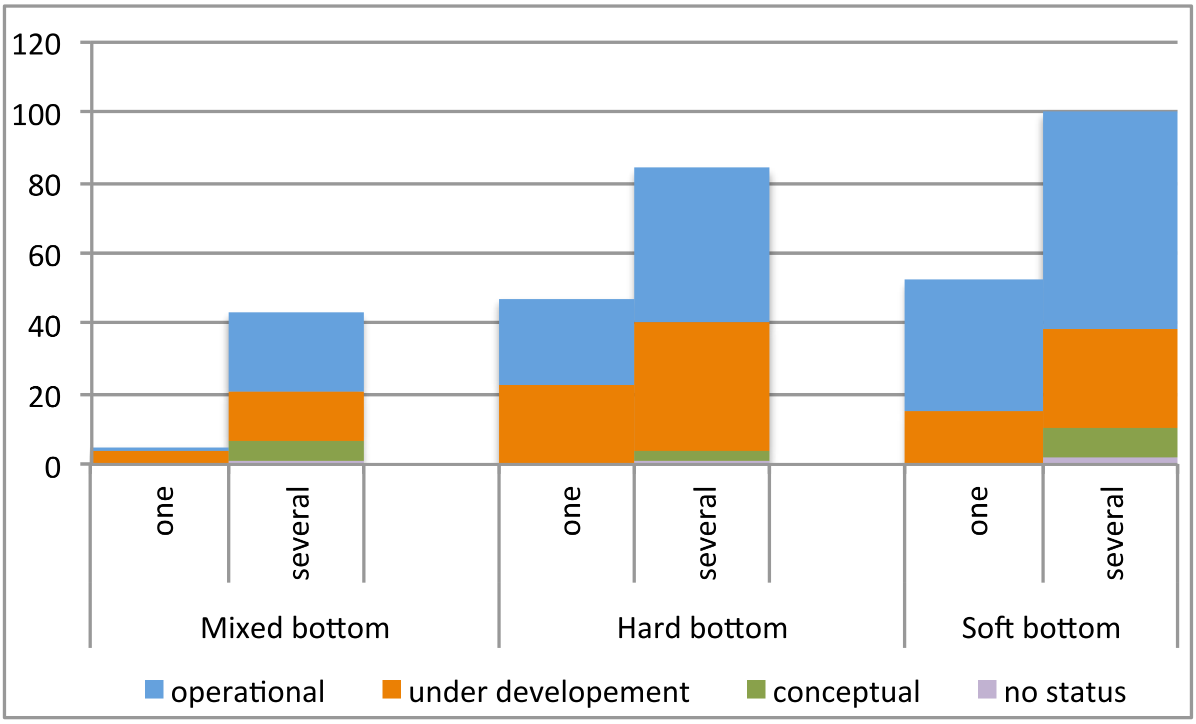


Figure 15. Number of seabed indicators per bottom type in ascending order with indicator status and divided into indicators addressing one bottom type and further bottom types in addition.

Depth zone

Seven seabed indicators address the abyssal, 16 the bathyal, 52 the shelf, 65 the littoral and 131 the shallow sublittoral zone (**Figure 16**). There are no existing indicators exclusively addressing the abyssal or bathyal zone and only four indicators are specific for the shelf zone. Most indicators address the shallow sublittoral zone (58). Most of the benthic WFD assessment systems are assigned to this depth zone. 22 indicators are specifically related to the littoral zone (**Table 21**), such as WFD assessment systems for intertidal communities.

Table 21. Number of seabed indicators per depth zone, divided into indicators specifically addressing one depth zone and indicators addressing several depth zones [sum (operational/under development/conceptual/no status)].

Subtype	one depth zone	several depth zones
Littoral	21 (12/9/0/0)	65 (37/20/7/1)
Shallow sublittoral	64 (35/28/0/1)	131 (74/47/8/2)
Shelf sublittoral	5 (0/5/0/0)	52 (27/19/5/1)
Bathyal	0	16 (11/5/0/0)
Abyssal	0	7 (7/0/0/0)

The decreasing number of indicators with depth is mainly related to the degree of access, as shallow depth zones are easy to reach and in consequence have a longer tradition in science. Abyssal and bathyal zones are not present in any of the EU regional seas and subdivisions. They are rarely occurring within the territorial waters of the coastal countries. Sampling and assessment are complex and require larger ships and technically complex, expensive sampling equipment. The littoral zone is the easiest accessible zone for scientists and it could be expected that most indicators are related to this depth zone or have at least the highest number of operational indicators. However, the areal extent of the littoral zone is low compared to the shallow littoral and the definition of littoral might be not sufficiently explicit enough. In many countries other classifications are more in use like hydrolittoral ⬄ sublittoral or intertidal ⬄ subtidal to divide the upper most depth zones. Therefore the division of indicators into those two zones may not have been handled in a comparable way among all indicators. Vegetation growth occurs mainly in the shallow sublittoral zones giving another explanation for the high number of indicators for this depth zone.

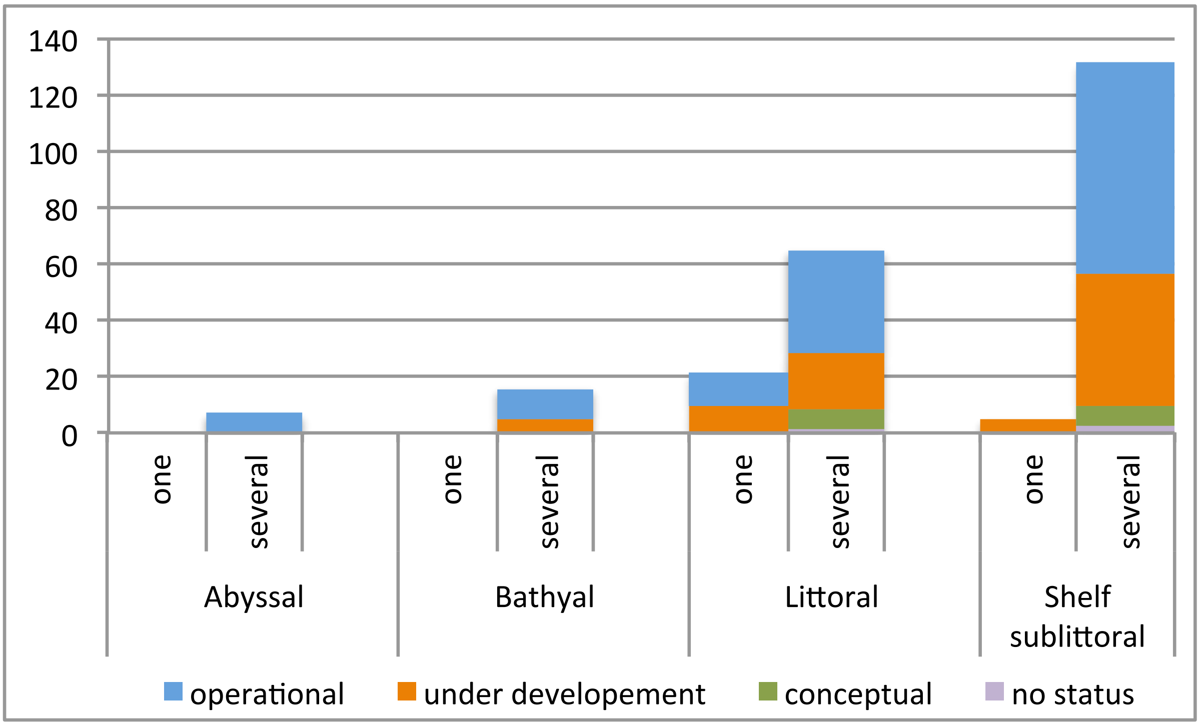


Figure 16. Number of seabed indicators per depth zone in ascending order with indicator status and divided into indicators addressing one depth zone and further depth zones in addition.

The lack of indicators which specifically address the bathyal and abyssal zone can be regarded as a gap in the indicator set. Those zones host such specific communities and species and require specific sampling and assessment conditions, which should be assessed by at least some specific indicators.

Conclusions

It needs to be clarified, if the selection of ice habitats is mandatory, in the case ice associated fish, birds, mammals ecotypes are selected, even if the specific indicator operates on species and not on community/ecotype level. The gap for those ecotypes thus relates to a gap in ice habitat indicators.

The entries for water column subtypes need to be corrected for the respective Baltic Sea indicators and checked also accordingly for other regional seas. But no gap for the “reduced salinity” subtype can be expected as the number of indicators available for the Baltic Sea water column is high.

A gap for mixed bottom indicators cannot be assumed as the low indicator number rather relates to the unclear definition of such types and the regional restriction of this bottom type.

The low number of abyssal and bathyal indicators, specifically addressing those depth zones, highlights a gap in the indicator set. Many species and communities of those zones are too ecologically exceptional to assess them with higher-level indicators only.

3.3.3. Pressures

Ideally, indicators are directly related to pressures and preferably respond to only one pressure or at least a manageable number of pressures. However, “state indicators” cannot be treated the same as “pressure indicators”. Scientifically proven relations between D1, D4 and D6 indicators and certain pressures are rare and often impossible to deduce as the indicators are typically indirectly related to pressures and respond to a large variety of pressures at the same time. Another problem is that the pressures used in the catalogue (taken from the MSFD Annex II) are inconsistently defined (on different levels of detail) and divided into heterogeneous groups. “Extraction of species” for instance is divided to six different categories, “contamination with compounds” into three categories whereas “Physical damage to habitats” or “acute pollution events” are only represented by one category (see **Table 22**).

As consequence of the vague division between pressure and state descriptors as well as criteria and indicators in MSFD, experts have assigned pressures to indicators in a very inconsistent way. For example some experts have related indicators like “Abundance of …”, Biomass of …” to nearly all pressures given in the catalogue but other experts have assigned those indicators to none of the pressures at all. Those different approaches made reasonable analyses difficult and resulted in a considerable high number of indicators (235) lacking a pressure entry (**Figure 17**). Nearly 80 % of indicators lacking an entry are related to abundance, areal extent, distribution range and pattern. Several WFD assessment systems lack a pressure entry, although the verification of a pressure-imapct relationship is mandatory for WFD assessment systems. Those entries need to be re-evaluated.

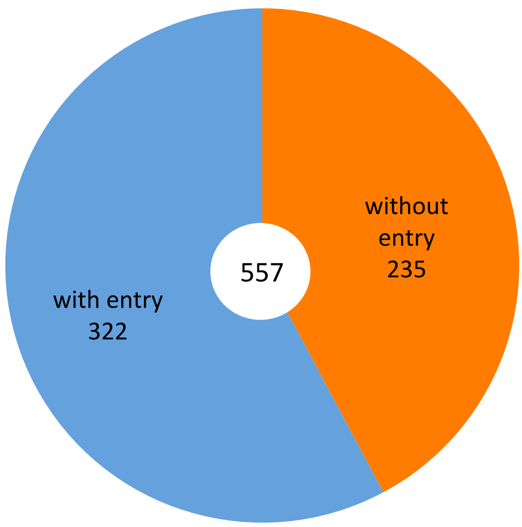


Figure 17. Number of indicators with or without an entry in pressures.

The number of indicators per pressure are listed in **Table 22** and illustrated in **Figure 18**. Highest number of indicators are related to “Nutrient and organic matter enrichment” (187), “Physical damage to habitats” (131), “Physical loss” (117) and “Others” (81). In this category, are located all indicators that are related to climate change. The lowest numbers of indicators occur for “Extraction of species: seaweed harvesting” (1), “Extraction of species: maerl” (5), “Marine litter” (9) and “Marine acidification”.

Analysing indicators specifically addressing only one pressure results in a completely different picture being more realistic in terms of direct relationships. No indicator is related specifically to physical loss although the assessment of seabed area lost by sealing in relation to the overall seabed area or habitat specific area should be an essential “pressure indicator” for seabed integrity and not too difficult to implement. Similarly, the number of indicators directly related to the pressure “Physical damage to habitats” is low but might be sufficient to serve as a “pressure indicator”. Descriptor 6 “Seafloor integrity” is defined as a combined “pressure and state descriptor in the MSFD with subordinate pressure and state criteria and indicators. This results in a significant overlap with Descriptor 1 “Biological diversity” in the context of state indicators for seabed habitats. This vague differentiation between D1 seabed biodiversity and D6 seafloor state indicators causes numerous problems for the development, classification and assessment aggregation process. As mentioned in section 3.2.1 already, it is strongly recommended to re-define D6 “Seafloor integrity” as pressure descriptor instead of state descriptor. All criteria and indicators describing and relating to the state of the benthic communities and habitats or areal extent of habitats without any direct relation to physical loss or damage (as ratio between impacted and non-impacted area for example), should be classified, developed and assessed only in relation to D1 “Biological diversity”.

The number of pressure specific indicators is highest for nutrient and organic matter enrichment (28) and non-indigenous species (16). Direct relationships with nutrient-enrichment have been proven for many plant indicators during the implementation of the WFD resulting in that high number of specific indicators. However, the phytobenthic indicators may also be related to physical loss or physical damage to habitats. For non-indigenous species there are many pressure indicators (“Trends in arrival of indigenous species”, “Abundance, biomass of specific non-indigenous species (e.g. the mussel *Mytilus galloprovincialis* or the comb jelly fish *Mnemiopsis leidyi*”), which are then specifically linked to the pressure “non-indigenous species”.

The lack of indicators specifically related to marine litter, hydrological processes, contaminants in biota and marine acidification can be explained by the fact that those pressures are represented by specific pressure descriptors. Indicators directly related to those pressures might thus not be part of D1, D4 and

D6 catalogue. However, since there already is a visible overlap with descriptors D2, D3, D5, an adjustment and clarification with these other descriptors, their criteria and indicators is recommended.

Table 22. Number of indicators per pressure, divided into indicators specifically addressing one pressure and indicators addressing further pressures in addition [sum (operational/under development/conceptual/no status)].

Pressure	one pressure	several pressures
Physical loss (PL)	0	117 (63/44/9/1)
Physical damage to habitats (PD)	15 (12/3/0/0)	131 (72/48/10/1)
Underwater noise (UN)	1 (0/1/0/0)	13 (3/9/1/0)
Marine litter (ML)	0	9 (1/8/0/0)
Interference with hydrological processes (HP)	0	117 (63/36/17/1)
Contamination by synthetic compounds (CS)	0	65 (28/24/12/1)
Contamination by non-synthetic substances and compounds (CNS)	0	69 (31/26/11/1)
Contamination by radionuclides (CR)	0	29 (12/10/6/1)
Acute pollution events (PE)	0	69 (28/29/11/1)
Nutrient and organic matter enrichment (NE)	28 (11/14/3/0)	187 (90/66/30/1)
Introduction of microbial pathogens (MP)	0	27 (6/14/7/0)
Non-indigenous species (NIS)	16 (2/13/1/0)	56 (14/29/13/0)
Extraction of species: fish and shellfish (catch) (EC)	7 (3/3/1/0)	65 (18/34/13/0)
Extraction of species: fish and shellfish (by-catch) (EBC)	7 (0/7/0/0)	52 (9/36/7/0)
Extraction of species: fish and shellfish (discard) (ED)	0	33 (8/19/6/0)
Extraction of species: maerl (EM)	0	5 (3/2/0/0)
Extraction of species: seaweed harvesting (ES)	0	1 (0/1/0/0)
Extraction of species: other (EO)	4 (1/2/1/0)	27 (12/11/4/0)
Marine acidification (MA)	0	14 (7/5/2/0)
Other (O)	9 (6/3/0/0)	81 (34/32/15/0)

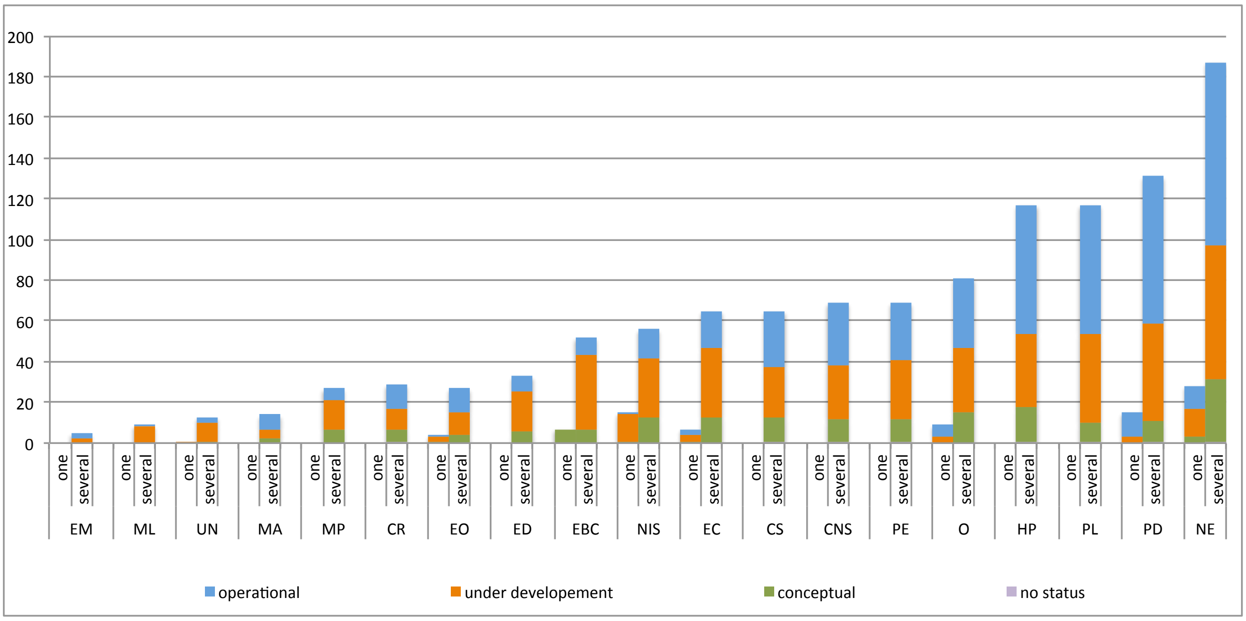


Figure 18. Number of indicators per pressure in ascending order with indicator status and divided into indicators addressing one pressure and further pressures in addition.

The differing approach between experts regarding pressure assignments makes a reliable gap analysis difficult. Although both approaches described above may be ecologically meaningful, an adequate gap analysis in the context of pressures needs a restriction to directly and scientifically testable relationships. Indicators assigned to multiple pressures should be treated separately from the ones addressing single pressures. Gaps for the pressures physical loss, marine litter, interference with hydrological processes, contamination, pollution, extraction of species and acidification are however assumed but need to be evaluated together with the respective pressure descriptors.

Conclusions

Biodiversity indicators connected to multiple pressures or with indirect relationships should be treated separately for the pressure assignment to enable a reliable gap analysis.

It is recommended to re-define Descriptor 6 "Seafloor integrity" as a pressure indicator. All criteria and indicators relating to condition or state of the benthic habitat/community should be integrated into the Descriptor 1 "Biological diversity" (for seabed habitats). This would solve the problematic overlap and redundancy between descriptors, criteria and indicator sets.

An adjustment for several pressure descriptors and D1, D4 and D6 indicators is suggested in order to identify gaps for pressures and avoid redundancy.

3.3.4. Spatial coverage

Indicators can be classified according to their spatial coverage. Part of this section covers a general analysis comparing the regional seas, whereas indicator analyses for specific regional seas are part of section 4. To analyse gaps in the indicator set in relation to spatial coverage the indicators should be classified to the marine regions:

- Baltic Sea
- Black Sea
- Mediterranean Sea
- North-East Atlantic Ocean
- Non EU regional seas

The catalogue also includes further subregions and subdivisions, but those that are irrelevant for this general overview.

Of the 557 indicators 534 have at least one entry for marine region and only 23 lack an entry (**Figure 19**). No entries were mainly given for indicators, which are conceptual (8) or under development (9) and therefore presently not yet tested with data sets of specific regions. Their basic concepts are applicable to many different regions like in "BTA – Biological Trait Analysis" or "Strength of bottom-up cascade in marine size spectrum".

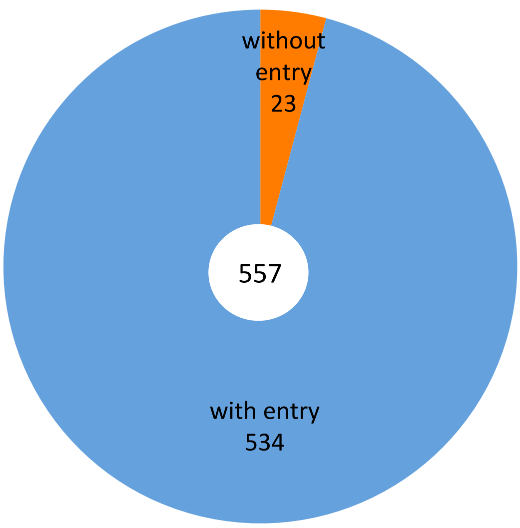


Figure 19. Number of indicators with or without an entry for marine regions.

The number of indicators differs markdly between regional seas (**Table 23**, **Figure 20**). Please note that the sum of indicators per regional sea is larger than the overall indicator number (666 ⇔ 557 indicators) as indicators can be related to more than one marine region.

The North-East Atlantic Ocean has the highest number of indicators (265) followed by the Baltic Sea (168), the Mediterranean Sea (139) and the Black Sea (94). Non-EU regional seas are covered by 9 indicators. This partly reflects the size and overall biodiversity pattern of the specific regional seas. The North-East Atlantic Ocean represents the largest marine region covering several climate zones and as a consequence hosting many different species and biotopes. Additionally, the number of neighbouring EU member states developing or adapting indicators for MSFD is high, as is the proportion of operational indicators.

Although the Baltic Sea represents a smaller area with less neighbouring countries and covers less climatic zones, the extreme range from polyhaline to oligohaline waters requires a relatively high number of indicators covering the different community characteristics. Also, anthropogenic pressures are more pronounced in such an enclosed marine region, which has favoured the development of adequate indicators within the HELCOM convention area.

The Mediterranean Sea covers a large area and has a high overall biodiversity, but the variations in terms of climate zones and large scale salinities are small. Furthermore, not all contracting parties are EU Member States resulting in a smaller overall number of indicators. In turn, the number of operational indicators is extremely high.

The Black Sea has the lowest indicator number of all EU regional seas and the proportion of operational indicators is low. The Black Sea represents the smallest regional sea and only two countries are EU members. These facts, together with a comparably poor overall biodiversity and a shorter tradition in environmental status assessment, may have resulted in a lower indicator number.

The numbers of indicators which address only one regional sea, follow more or less the pattern described above. However, the proportion of indicators specifically addressing the Black Sea is very high in terms of the proportion between one and several regions (see **Table 23**). This might possibly be explained by the unique ecosystem structure of the Black Sea requiring the development of specific indicators not easily adaptable to or from other marine regions.

Table 23. Number of indicators per regional sea, divided into indicators specifically addressing one regional sea and indicators addressing further regional seas in addition [sum (operational/under development/conceptual/no status)].

Marine region	one marine region	several marine regions
Baltic Sea	100 (37/36/21/6)	168 (68/72/22/6)
Black Sea	80 (14/62/3/1)	94 (24/66/3/1)
Mediterranean Sea	78 (70/2/1/5)	139 (126/7/1/5)
Non-EU regional seas	4 (1/3/0/0)	9 (6/3/0/0)
North-East Atlantic Ocean	158 (91/51/12/4)	265 (160/88/13/4)

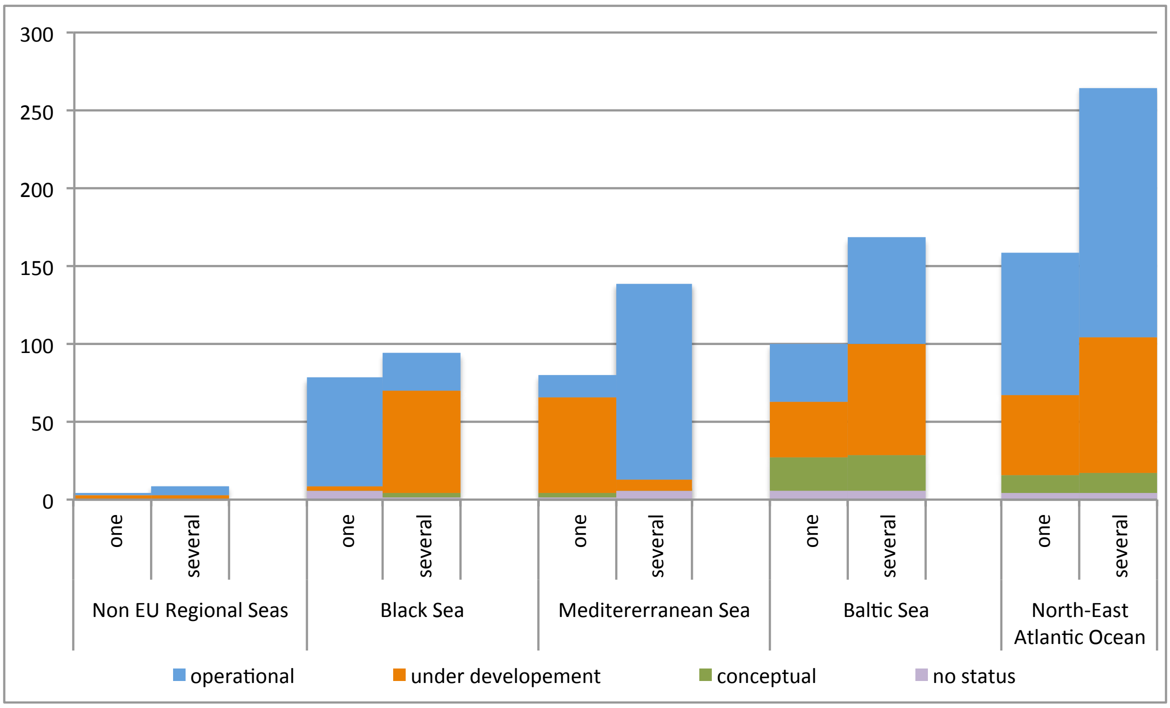


Figure 20. Number of indicators per marine regiona in ascending order with indicator status and divided into indicators addressing one marine region and further marine regions in addition.

A comparison of indicators related to biodiversity components for each regional sea (**Table 24**) also highlights the differences that can only partly be explained by the different ecosystem structures of the regional seas. E.g. the number of phytoplankton indicators for the Mediterreanean Sea is very low, even if taking into account that phytoplankton indicators might be of more relevance in the highly eutrophicated regions of the other regions. The same trend is apparent for zooplankton, although the differences to other regional seas are not as large as for phytoplankton. The Black Sea has a low number of indicators for angiosperms, but this might be explained by a low species richness for this group. The number of fish indicators for the Black Sea only comprises $^1/_4$ to $^1/_6$ of the indicator numbers of other regional seas. Indicators for marine mammals and birds are low or even missing for the Black Sea and Mediterrenean Sea. For other biodiversity components beside microbes missing indicators can be explained by the fact that the specific component is not part of the ecosystem of the respective region (i.e. reptiles in the Baltic Sea).

Table 24. Number of indicators per regional sea and biodiversity component, divided into indicators relevant for several regions and several biodiversity components / several regions and one component / one region and one component.

Biodiversity components	Baltic Sea	Black Sea	Mediterranean Sea	North-East Atlantic Ocean
Microbes	0	1/1/1	0	0
Phytoplankton	27/15/13	23/18/18	8/3/3	35/21/19
Zooplankton	17/2/1	15/10/9	7/2/1	26/13/9
Angiosperms	20/3/2	7/4/4	22/17/15	18/8/5
Macroalgae	35/26/10	19/15/13	16/9/5	25/15/11
Benthic invertebrates	32/13/9	29/27/25	23/15/8	40/29/21
Pelagic invertebrates	0	0	0	2/0/0
Fish	43/24/14	8/4/3	31/22/11	52/34/18
Cephalopods	4/0/0	3/0/0	5/0/0	16/4/4
Marine mammals	40/28/10	2/2/2	8/6/0	26/22/2
Reptiles	0	0	8/6/4	4/2/0
Birds	27/15/7	0	1/1/0	28/26/17

Conclusions

Most indicators are reported for the large marine regions that cover many climate zones and depths and subsequently are inhabited by many different biodiversity components.

4. Regional seas: ecosystem overview and indicators' capability

In this chapter we outline the key features of the ecosystems of the four regional seas, especially from the point of view of the biodiversity and functionality of those ecosystems and analyse the set of available indicators as compared to these features. The ecosystem overview in the beginning of each regional sea chapter is intended to give the reader a general understanding of the unique features of that regional sea and to help the reader understand why some indicators are or are not needed in this regional sea. Also, these sections analyse the gaps and needs in more detail than in the general overview, to give a more realistic picture of the current state of the indicator coverage and availability.

4.1. North-East Atlantic

4.1.1. Ecosystem overview

High human population densities in the central regions and on the coastline of mainland Europe create significant pressures on this area through introduction of nutrients (eutrophication), toxic substances and marine litter, smothering and substratum loss. The selective removal of target and non-target species from fisheries, along with abrasion effects on habitats from trawling activities are possibly the most significant pressures all over. The target species and types of fishing vary throughout the region and for the purpose of this report, we describe the Northern Atlantic divided into four main regions (**Figure 21**), as these are ecologically and geographically quite different and there are different challenges and pressures for the different regions.

The Arctic waters, the Barents Sea and the Arctic Ocean, are not included in this report, neither is zone V of the OSPAR division. Also Macaronesia was left out of this overview. Nonetheless, it is acknowledged that in the catalogue there are indicators for some of these areas, reported for by the respective MS (e.g. Portugal for the Azores islands and Spain for the Canarias islands).

For the following text we will refer to regions as in the OSPAR divisions, and area as in the ICES division (**Figure 21**).

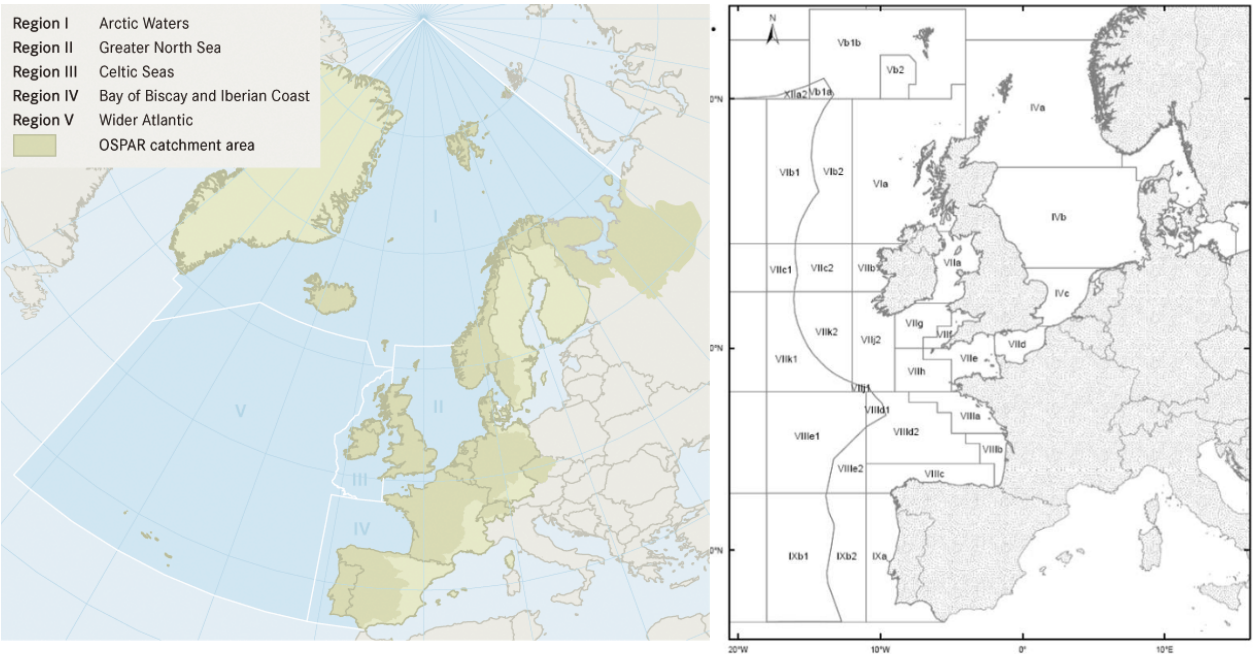


Figure 21. The OSPAR area is divided into five regions for the purposes of assessment (source: OSPAR, 2010) (left) while ICES divides the regions into smaller areas for the purpose of fisheries management (right).

Region I

The Norwegian Sea stretches from cape Stadt on the Norwegian coast to the North Cape and west to Bear Island. In contrast to the shallow North Sea further south, the larger area of the Norwegian Sea has an average water depth of about 2000 m. While close to shore, many islands and varying topography along with the relatively warm water temperatures, because of flow of Atlantic waters along the Norwegian coast, give good spawning areas for the North Atlantic cod stock. The winter fishery for stock fish in the Lofoten archipelago is one of the culturally and economically most important events in northern European marine history.

The spring spawning herring (*Clupea harengus*) is a pelagic lipid rich fish, and another commercially important fishery in the Norwegian Sea. This fishery has displayed enormous fluctuations and was from 1968 believed to have been fished out, before it re-established and started to increase again after a moratorium in the early 1980ies. There is a tight link between the herring and the cod as herring larvae are important food for cod juveniles. When the herring migrate in large schools, this attracts predators such as humpback whale (*Megaptera novaeangliae*), killer whales *(Orcinus orca*) and seabirds by the thousands. Coastal benthos along the Norwegian coast is highly varied, and ranges from typically hard-bottom to soft-bottom communities, with clear relationships with sediment type and water depth (and its co-variables). Offshore, the northern parts support extensive deep-water sponge assemblages, such as *Geodia* and *Aplysilla*. Coral gardens are highly typical in the central part of the Norwegian Sea (e.g. Haltenbanken area).

The most important pressure on biodiversity is the selective extraction of species from a high fishing pressure. Increasing petroleum activity in the Norwegian Sea since the 1990ies has potentially harmful effects on the marine environment, and especially the benthic communities in the local area through smothering of macrofauna with drill cuttings and introduction of non-synthetic compounds along with waste water. However, it has also led to an increased mapping of the seafloor, and cold water coral reefs, mainly *Lophelia pertusa*, have been discovered along the continental shelf of Norway. Protecting these habitats has become a major priority, as they are very important nursing grounds for many commercial fish stocks, as well as creating three dimensional habitats that have high effect on the biodiversity. Abrasion by demersal trawling is the main threat to these reefs as the gear damages the slow growing corals.

Region II

The North Sea (Areas IVa, IVb and IVc) is a marginal ocean between Norway, Denmark, Germany, UK, Belgium and the Netherlands. Because most of the ocean is only about 90 m deep, except for the Norwegian deep, the processes in the benthic community are tightly linked to processes in the pelagic. Surrounding the North Sea are the mountainous coastlines of Norway and Scotland in the north, and the sand- and mud flats of Denmark and The Netherlands in the south. The vast sandy sediment habitats support large populations of flatfish and Norway lobster (*Nephrops norvegicus*) as well as the burrowing sandeel (*Ammodytes marinus*). Sandeel is a very important prey species for many seabirds and commercial fish, and in later years, the management of sandeel has attained increased focus. Coastal benthic communities along the eastern UK and south-western Norway comprise both rocky shore and soft-sediment communities, whereas the southern parts (from Denmark and eastwards) are dominated by sand-dwelling communities. Offshore sediments also comprise largely fine sands and typically are dominated by the brittle-star *Amphiura filiformis* and associated fauna. The tube-dwelling polychaete worm *Galathowenia oculata* also often appears in extremely high numbers. Seapens and burrowing megafauna also characterize the offshore benthos.

The largest intertidal mudflat in the world is in the Wadden Sea area off the coast of the Netherlands and serves as an important feeding ground for millions of migrating seabirds, depending on the mussel beds of this area. Protecting these habitats is a major concern. To the north, the islands of Shetland and Orkney also support large seabird colonies.

The main pressures to the North Sea area are selective removal of target and non-target species through fishery and it has led to 29 species being under threat. Luckily, fisheries management is improving and some fish communities are starting to recover. Introduction of non-synthetic compounds such as mercury and PAHs is a matter of concern in the North Sea as a result of the high human population density in the adjacent areas. Marine litter also is a threat, especially to seabirds and mammals, through suffocation, entanglement and ingestion (OSPAR 2010).

The English channel (Areas VII d,e,h), Areas VIId, e and h bound to the North the English Channel, the southern connection of the North Sea to the Atlantic. They have average depth of 63 m, being deepest at Hurd's deep where it reaches 174m. The area is characterized by a mosaic of habitats, from fine muds, sandy muds and sand closer to the shore, and coarser, mixed sediment areas and bedrock offshore.

Being a main connection of the North Sea to the Atlantic, this is a key area for marine fishing and ferry traffic, being one of the busiest shipping routes in the world. This area is also a key resource for aggregate extraction. Both activities have significantly contributed to pollution and habitat degradation in the area threatening marine biodiversity. Near-future plans for expansion of wind energy infrastructure in the northern English Channel will mount to the current management of space use. Possible associated impacts on marine life may include alteration of habitat availability and increased substratum for invasive species.

The area offers key nursery grounds to several important North Sea species of commercial interest, including plaice and other flatfish, and scallops. The region represents an important southern boundary for cold water species which have been observed to be losing suitable habitat due to global warming, while few warm water species have been expanding their range posing new challenges to local biodiversity. These are also important areas of distribution for oysters, which have come under threat from recent expansion of the non-indigenous slipper limpet (*Crepidula fornicata*).

The recognition of the need to preserve Channel habitats has led to large efforts to raise the protection status of the region, parts of which now represent approximately half of the 28 recently designated UK Marine Conservation Zones.

Region III

The Irish Sea (Area VIIa) lies between Great Britain and the Island of Ireland. Predominantly shallow (< 100 m deep) is characterised by a large tidal energy input. Coarse, gravely sediments occur in a wide central belt running associated with strong tidal currents. Elsewhere sandy and muddy sediments occur in areas of mid and low energy environments. Bedrock outcrops also occur in the North Channel as well as south-west and west of the Isle of Man.

Pressures associated with fishing are widely spread as the area sustains a large shellfish fishery especially scampi, resulting in abrasion as mobile fishing gear alter seabed integrity, habitat destruction, by-catch and overfishing.

The Irish Sea is also affected by other activities resulting substratum loss in the area, possible deaths by collision, interference with species migration, noise pollution and potential introduction of alien species and translocation through ballast waters and fouling. These all related to the current rapid expansion of marine renewable energy, strongly promoted in the UK's territory, together with the heavy marine traffic in the area.

Localised organic and chemical pollution, changes in siltation, deoxygenation, introduction of alien species, and spread or introduction of pathogens are possible pressures associated with aquaculture developments practised in sheltered bays and sea loughs. Also of importance is the link between some aquaculture practices and fisheries, as is the case of mussel spat (juvenile mussels) collection for the industry.

Key habitats in the Irish Sea would include the North West mud patch associated with the Irish Sea gyre especially important for scampi. Coarser substrata such as gravel are important spawning areas of herring. Key species, although heavily depleted include cod (*Gadus morhua*), scampi, horse mussels (*Modiolus modiolus*) and brittle stars (several species).

Conservation priorities in the Irish Sea current involve the expansion of the UK offshore Marine Protected Area network to include a large area of mud substrata and several offshore rock outcrops. Conservation priorities in the Irish Sea include the protection of sheltered sea loughs, biogenic reef features (*Modiolus modiolus*) and rock outcrops. The rock outcrops surrounding Northern Ireland typically have a high biodiversity and hence conservation value.

The Celtic Sea (Area VIIg and h) lies south of Ireland and joins the Atlantic Ocean. It is connected to the Irish Sea (via St Georges channel), the English Channel and the Bay of Biscay. Most of the Celtic Sea lies above the continental shelf, with depths of 90 to 100 m with predominately by sandy and muddy substrata.

Widespread physical pressure (surface and subsurface abrasion, changes in turbidity, and changes in habitat structure) occurs through the use of mobile fishing gear, especially the beam trawl used locally to harvest demersal fish. This is coupled with selective extraction of target and non-target species and injury or death by collision. With the exception of sole (*Solea solea*), assessed commercial fish stocks are either not at full reproductive capacity or are not being harvested sustainably.

The region includes some attractive coastline ranging from exposed coasts to sheltered bays and inlets. As a result it is an important region for recreation particularly tourism, surfing and scuba diving.

Analysis of the animals that live on and partially within the sediment revealed many distinct communities. However, much of the conservation concern for this area relates to fishing pressures. These continue to increase and are having an impact on commercial fish stocks, demersal fish and seabed sediment habitats. Some improvements are seen on the demersal fish community but there is evidence of continuing pressure. Other concerns include dolphins, porpoises and grey seals being caught as fisheries by-catch.

The Bristol Channel (Area VIIf) is situated in the South west of the United Kingdom, encompassing the Severn estuary, the South Welsh coast and the north coasts of Devon and Cornwall. The area has the second largest tidal range in the world (14 m), giving rise to extensive intertidal habitats, mud-flats and sand-flats, rocky platforms and islands. Subtidal habitats include sandbanks and extensive bedrock platforms with kelp forest (depth < 100 m). Reef forming species like Ross worm (*Sabellaria spinulosa*) and blue mussel (*Mytilus edulis*), maerl (*Phymatoliton calcareum, Lithothamnion corallioides*) are common, as well as the short snouted seahorse (*Hippocampus hippocampus*), various Cnidaria, the pink seafan (*Eunicella verrucosa*) and seagrasses All this has granted several areas of the region international and national conservation designations (SAC, SPA, MCZ, SSSI).

Various pressures occur in the area. Abrasion and substratum loss associated with demersal fishing and aggregate extraction are potential pressures but of low intensity. The majority of fishing activity occurs towards the south west, outer area of this region. Inputs of nutrients, organic matter and, possibly, contaminants are present around the majority of the coastline, particularly in the inner Bristol Channel (Severn estuary) Two nuclear power stations (with proposed expansion) are present in the Bristol Channel, giving rise to localised thermal regime change and the introduction of radionuclides.

The Northwest coast of Scotland and Northern Ireland (Area Via) encompasses the northern coast of Northern Ireland, a section of the north-western coast of the Republic of Ireland, the west coast and the central part of the north Scottish coast (west of Orkney). The seabed is varied with extensive rock habitats present in most of the inshore areas and further offshore along the northern half of the west coast and the north coast of Scotland (depth typically 200 m to > 2000 m). Sponge and turf communities as well as kelp and seaweed communities can be found. Other parts of the region have mud in inner sealochs and sand, gravel, mixed sediments and maerl in the more exposed coastal and offshore areas, with associated seagrass, mussel and native oyster (*Ostrea edulis*) beds.

Abrasion of the seafloor and other physical disturbances associated with fishing represent the most significant pressure in this region, largely associated with the use of towed fishing gear, including beam trawling (commonly for *Nephrops*) and scallop dredging. Aquaculture (shellfish and finfish) is widespread in the West of Scotland, Northern Ireland and on the western Irish coast and may lead to changes in siltation, inputs and accumulation of organic matter and deoxygenation, ultimately leading to changes in substratum type and the associated communities.

International and national designations apply throughout the region, with a variety of complex habitats, resulting in a large number of species and communities of conservation interest in this area, an example is the cold water coral (*Lophelia pertusa*). Many of these species are long-lived and slow growing with low reproductive success, making them highly sensitive, considered to be threatened in this region.

Region IV

The Bay of Biscay and coast of Iberian Peninsula described here comprises the Bay of Biscay and Iberian Coast to the Strait of Gibraltar, including the European sector of the Gulf of Cadiz and the western Iberian margin (Region IV of **Figure 21**). The coastline is dominated mainly by rocky shores, beaches, marshes, estuaries and rias (coastal inlets formed by the partial submergence of unglaciated river valleys). The characteristics of the coast are highly related to the adjacent rivers and their basins. The subtidal area includes a high diversity of habitats such as channels, canyons, seamounts, banks, pockmarks or ridges. The geomorphological characteristics of the continental shelf vary along the area, being noticeably wider in the French region (up to 140 km off the coast of Brittany) than in the Spanish and Portuguese ones. The continental slope (transition between the continental shelf and the deep-sea environment) is relatively steep and narrow throughout the area. The deep-sea environment is mainly dominated by abyssal plains.

There are a range of marine uses within the region (e.g. fishing, mariculture, shipping, tourism and recreational activities, sand and gravel extraction, etc.), which exert a diverse gradient of physical, chemical and biological pressures on marine ecosystems (OSPAR Quality Status Report 2010). The pressure gradient in this area directly derives from high population densities in the Iberian coast, the very active shipping routes, and fisheries. Hence, main problems are related to eutrophication (0.6% of the area, mainly small bays and estuaries), with overfishing some fish stocks, and pollution (hazardous substances and oil spills, e.g. [Prestige] oil spill, NW Spain, 2002). Within some specific subareas, other pressures such as abrasion (damage to the seafloor habitats caused by demersal trawling) and introduction of non-native species (mainly due to shipping) have been of noticeable importance.

The area includes a wide range of species and habitats from coastal to the deep-ocean ecosystems. A detailed research on threatened and/or declining species and habitats was carried out by OSPAR in 2008 (OSPAR List of Threatened and/or Declining Species and Habitats, Reference Number: 2008-6). This OSPAR List includes within the Bay of Biscay and the Atlantic Iberian coast birds (e.g. black-legged kittiwake or roseate tern), fishes (e.g. European eel (*Anguilla anguilla*), Portuguese dogfish (*Centroscymnus coelolepis*) or bluefin tuna (*Thunnus thynnus*)), reptiles (e.g. loggerhead turtle (*Caretta caretta*) and leatherback turtle (*Dermochelys coriacea)*, with by-catch being their main cause for mortality) and mammals (e.g. blue whale (*Balaenoptera musculus*) and Northern right whale (*Eubalaena glacialis*)). The dog whelk (*Nucella lapillus*) is also included, being its decline in some areas related to changes in water temperature (e.g. due to increasing sea temperatures in the SE Bay of Biscay) and chemical pollution (e.g. due to its high sensitivity to tributyltin, a chemical component that has been used in antifouling paints until recent years).

Among habitats, there are included coral gardens and deep-sea sponge aggregations, among others. There are also of high interest the submarine canyons due to their diversity and they provide refuge and nursery areas. Canyons are by-passing or erosive zones with currents that are supposed to be related to deep internal tides. These systems include habitats, such as cold-water corals, that are scarce at the Bay of Biscay and the Atlantic Iberian Margin.

Within the area there are several areas with different categories/levels of protection and management. As of 31st of December 2012, the OSPAR Network of Marine Protected Areas (MPAs) comprised a total of 333 sites, of which 13 have been declared by France and two by Spain. Conservation priorities differ among sites, but in general, they are focused on maintaining the biodiversity, charismatic species or rare habitats. As an example, one of the biggest MPAs in the area, El Cachucho (Banco Le Danois), is a highly vulnerable ecosystem and a very important one to the breeding of commercially fished species (including blue whiting, white hake, monkfish and bluemouth). Moreover, this MPA includes four out of the fourteen threatened habitats listed by OSPAR Convention (i.e. deep-sea sponge aggregations, cold-water coral reefs, seamounts and, sea-pen and burrowing megafauna communities).

4.1.2. Indicators availability and capability

In this section, we explore the DEVOTES indicator catalogue with a special focus on the North-East Atlantic Sea. We systematically investigate the number and distribution of indicators of Descriptors 1, 2, 4 and 6 from the MFSD as well as biodiversity components, habitats and pressures covered by or responding to such indicators. Currently, the DEVOTES Catalogue of Indicators includes 256 indicators for the North-East Atlantic.

Descriptors and criteria

Descriptor 1. Biological diversity

In the catalogue there are 218 indicators that are assigned to at least one of the eight criteria related to Descriptor 1 (**Figure 22**). Most of the indicators are related to abundance, biomass, distribution, diversity and richness. Some of the indicators were developed within the WFD requirements, including multimetric indeces. The Criterion 1.1 (“Species distribution”) includes 41 operational indicators, eg. "Distributional range of pelagic fish",in addition to other 29 under development and one conceptual. Criterion 1.2 (“Population size”) includes 47 operational indicators, eg.,"abundance of demersal fish", in addition to other 42 under development and one conceptual. Criterion 1.3 (“Population condition”) includes 22 operational indicators e.g. "breeding success of kittiwakes", in addition to other 22 under development and two conceptual. Criterion 1.4 (“Habitat distribution”) includes 18 operational indicators, eg. "WFD MarBIT - Marine Biotic Index Tool", which also covers 1.6 "Habitat condition" and 1.7 "Ecosystem structure”.

Criterion 1.5 (“Habitat extent”) includes 19 operational indicators, e.g. "Depth limit of macrophytes", in addition to other 12 under development. Criterion 1.6 (“Habitat condition”) includes 55 operational indicators (in addition to other 47 under development and eight conceptual). Criterion 1.7 (“Ecosystem structure”) includes 40 operational indicators (in addition to other 35 under development and seven conceptual). Criterion 1.8 (“Ecosystem processes and function”) includes one operational indicator and one under development. Whereas "habitat condition" is the criteria for which there are a higher number of indicators, "habitat distribution" and "habitat extent" are the ones for which there are the fewest number of indicators in total and operational. It is worth noting, that for those criteria for which there is already a relative high number of indicators, they are also the criteria for which a higher number of indicators are under development. Opposite, those criteria with less number of operational indicators do also have less number of indicators under development.

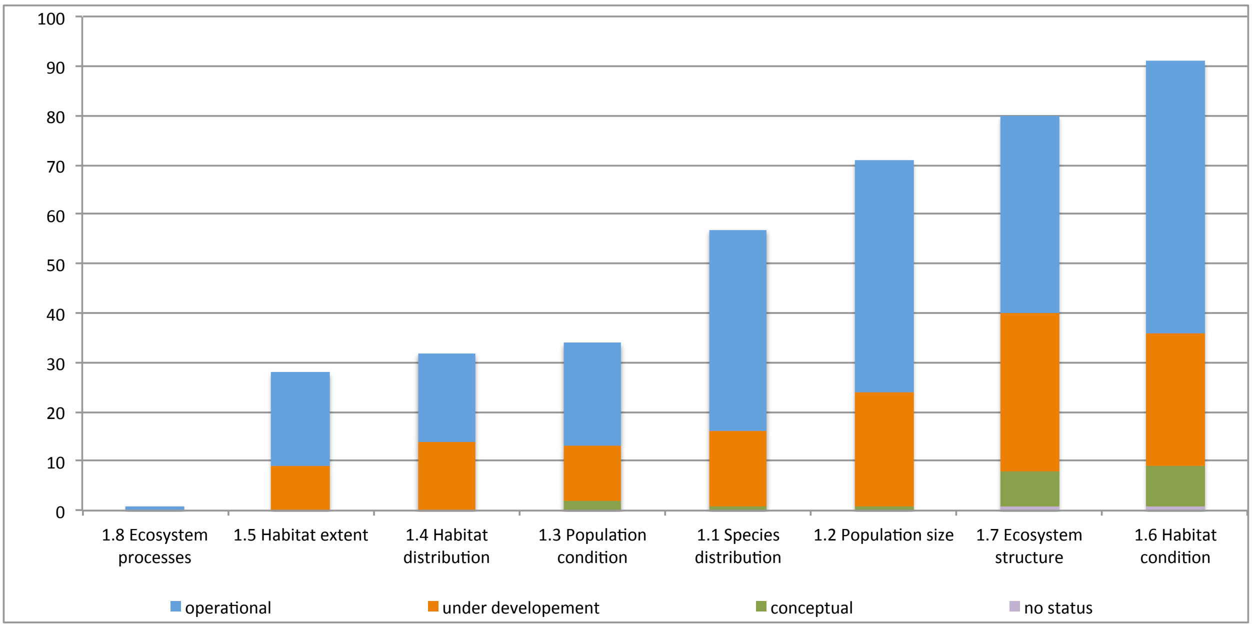


Figure 22. Number of indicators per D1 criteria in ascending order with indicator status.

Descriptor 2. Non-indigenous species

The current catalogue of indicators includes only three indicators for Descriptor 2 in the North East Atlantic. These three indicators are applied under criteria C2.1 "Abundance and state characterisation of non-indigenous species, in particular invasive species", being two of them are operational (i.e "Trends in arrival of new non-indigenous species per pathway" and "Biomass of *Mnemiopsis leidyi*") and one is under development (i.e "Number of species of Black List of Invasive Alien Species").

Descriptor 4. Food-webs

When the catalogue filtered the indicators associated with Descriptor 4 (Trophic webs) in the North-East Atlantic, a total of 89 were found (**Figure 23**). Most of them (46 operational, 32 under development and 7 conceptual) cover criterion C4.3, "Abundance/distribution of key trophic groups/species". Criteria C4.1 "Productivity (production per unit biomass) of key species or trophic groups" and C4.2 "Proportion of selected species at the top of food-webs" on the other hand have very poor coverage with 7 and 5 indicators, respectively. There are two additional indicators assigned to Descriptor 4 that have not been assigned to any of the three available criteria.

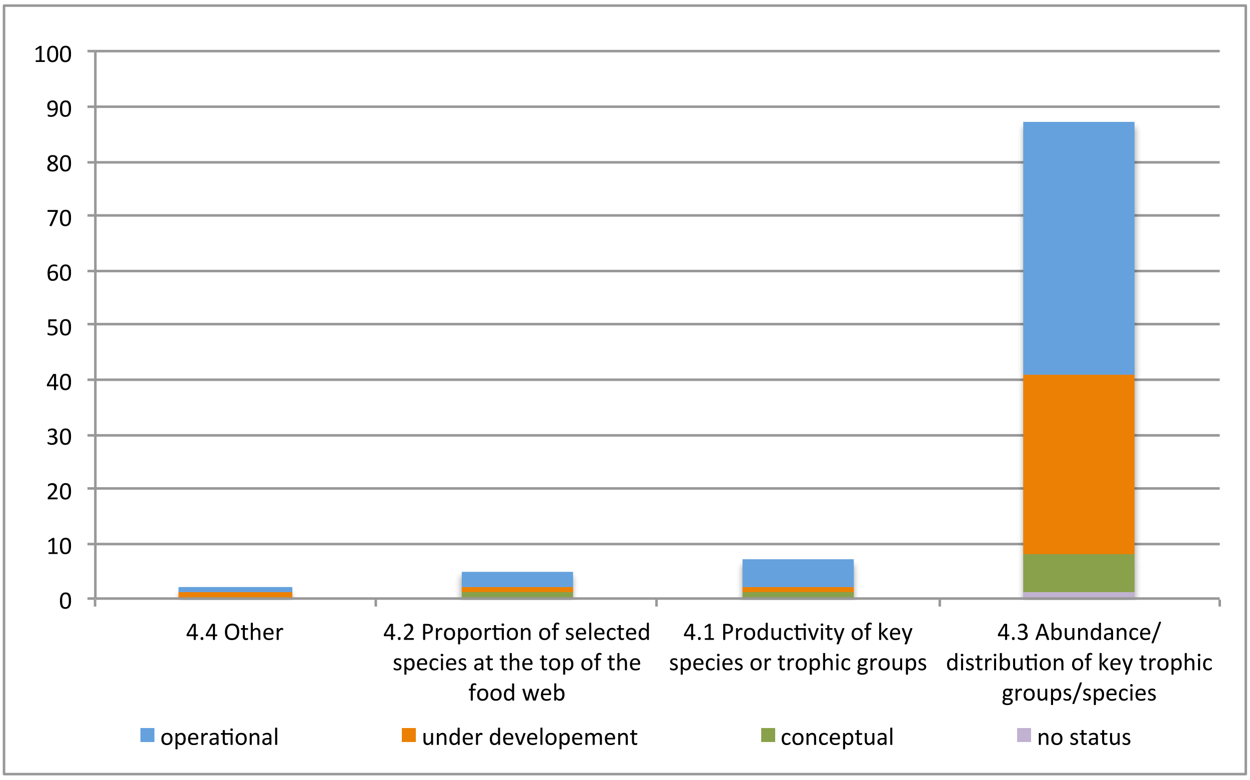


Figure 23. Number of indicator number per D4 criteria in ascending order with indicator status.

Descriptor 6. Seafloor integrity

A total number of 95 indicators are applied to Descriptor 6 in the North-East Atlantic (**Figure 24**). These indicators tackle criteria 6.1 "Substrate characteristics – physical damage", e.g. "Areal extent of selected habitats" and 6.2 on "Condition of benthic community", e.g. "Species diversity of benthic communities". Although there is not a large difference between the number of operational indicators of the two criteria, a higher number of indicators are under development for criterion 6.1 "Substrate characteristics – physical damage".

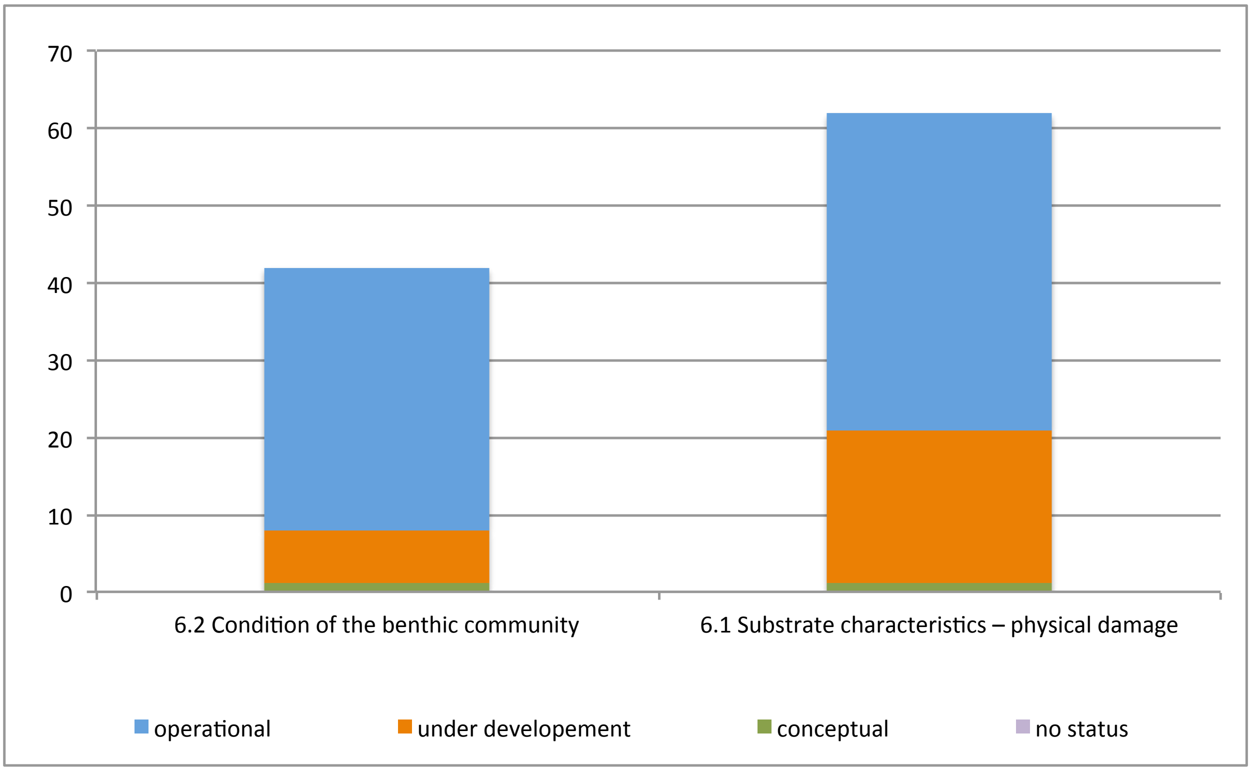


Figure 24. Number of indicators per D6 criteria in ascending order with indicator status.

Biodiversity components

The number of indicators per biodiversity component, within the North East Atlantic Ocean is shown in **Table 25**.

Table 25. Number of indicators per biodiversity component, divided into indicators specifically addressing one or several biodiversity components [sum (operational/under development/conceptual)].

Biodiversity component	One or several components
Microbes	0 (0/0/0)
Pelagic invertebrates	1 (1/0/0)
Reptiles	4 (3/1/0)
Cephalopods	17 (8/9/0)
Angiosperms	18 (14/4/0)
Marine mammals	24 (8/16/0)
Zooplankton	25 (18/5/2)
Macroalgae	25 (20/5/0)
Birds	28 (15/13/0)
Benthic invertebrates	28 (21/12/5)
Phytoplankton	32 (22/4/6)
Fish	51(27/23/1)

Overall, in the North-East Atlantic fish, benthic invertebrates, and phytoplankton are the three biological components for which there is the highest number of operational indicators available (**Figure 25**). This reflects the large efforts on research and data collection of these groups. However, it is interesting to note that the focus is not only on these three biological components, as a high number of indicators are under development for marine mammals, birds and angiosperms. Microbes, pelagic invertebrates and reptiles are again the biological components for which there is the fewest number of indicators, both operational and under development.

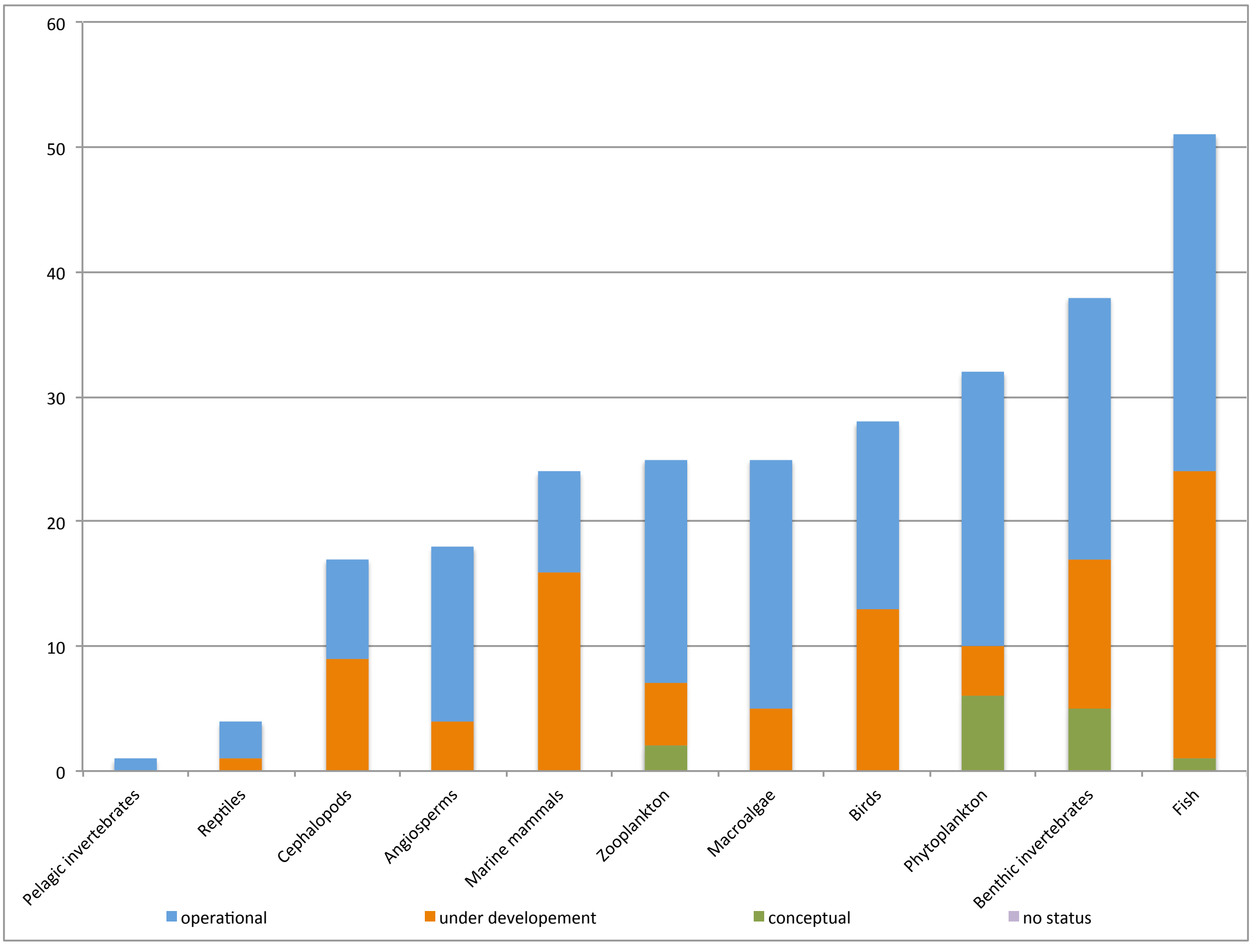


Figure 25. Number of indicators per biodiversity component in ascending order with indicator status.

Habitat types

There are 90 indicators that have been identified as relevant for seabed habitats in the North-East Atlantic, and 90 that are relevant to the water column. Of these, 154 are exclusive to one habitat, while 13 are relevant to both habitats. A total of 89 indicators are not assigned to any specific habitat, and no indicators are relevant to ice habitats.

Pressures

Out of the total 256 indicators of the North East Atlantic, 149 respond to one or more pressures. Opposite to nutrient/organic matter, physical damage, hydrological processes, and physical loss, few indicators respond to pressures such as such as: acidification, underwater noise, marine litter, extraction of maerl, extraction of seaweed (**Figure 26**). It may be worth exploring not only the number of indicators responding to the different pressures, but also their quality (e.g. there may be few indicators but good quality) and their capacity to respond to more than one pressure and synergistic effects.

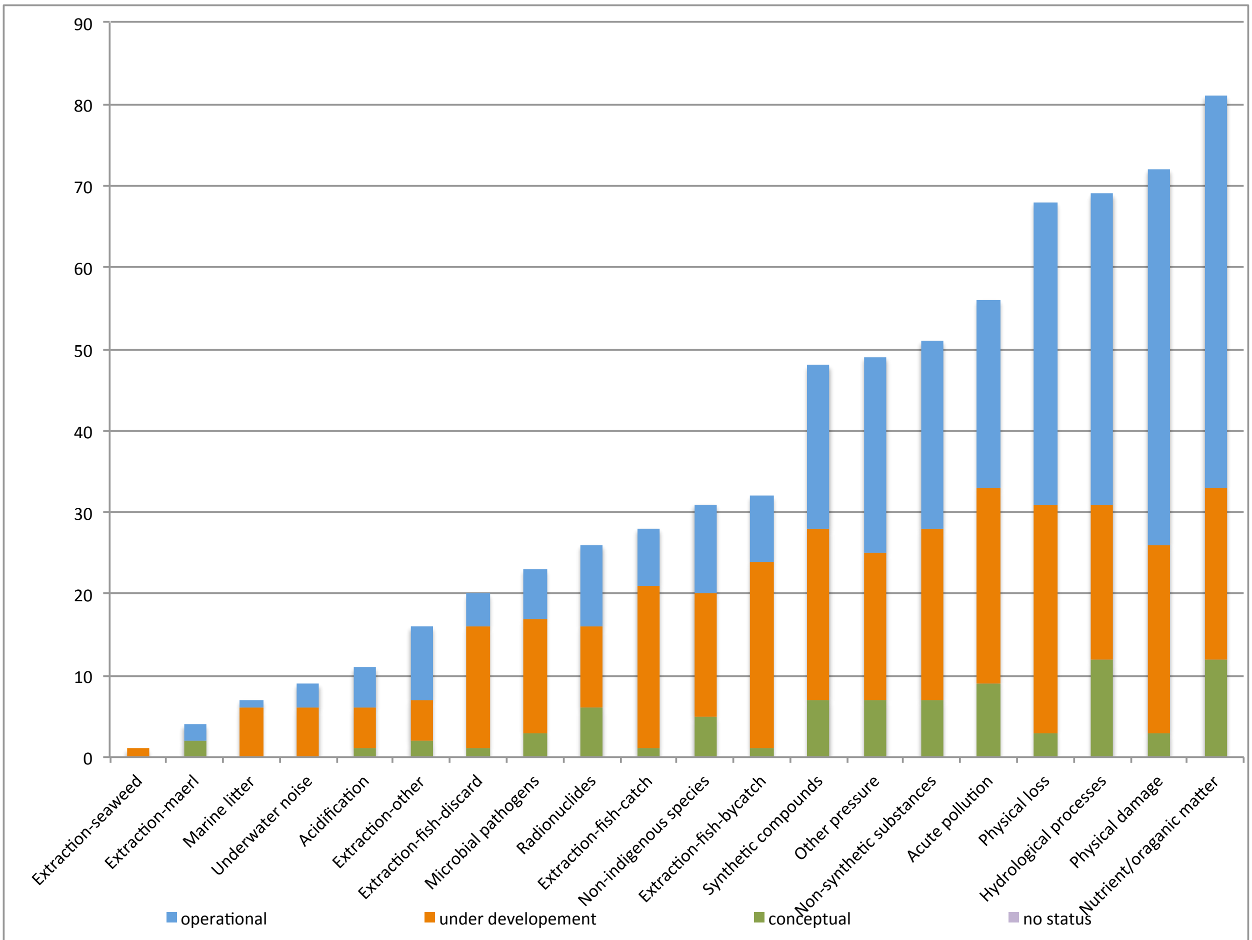


Figure 26. Number of indicators per pressure in ascending order with indicator status.

Regional subdivisions

Out of the total 256 indicators identified for the North-East Atlantic, 161 only cover one subregion and 75 indicators cover several subregions, meaning that 20 indicators have not been appointed to any subregion. The Bay of Biscay and Iberian coast has the highest number of operational indicators, while there are a lot of indicators under development for the Greater North Sea region (**Figure 27**).

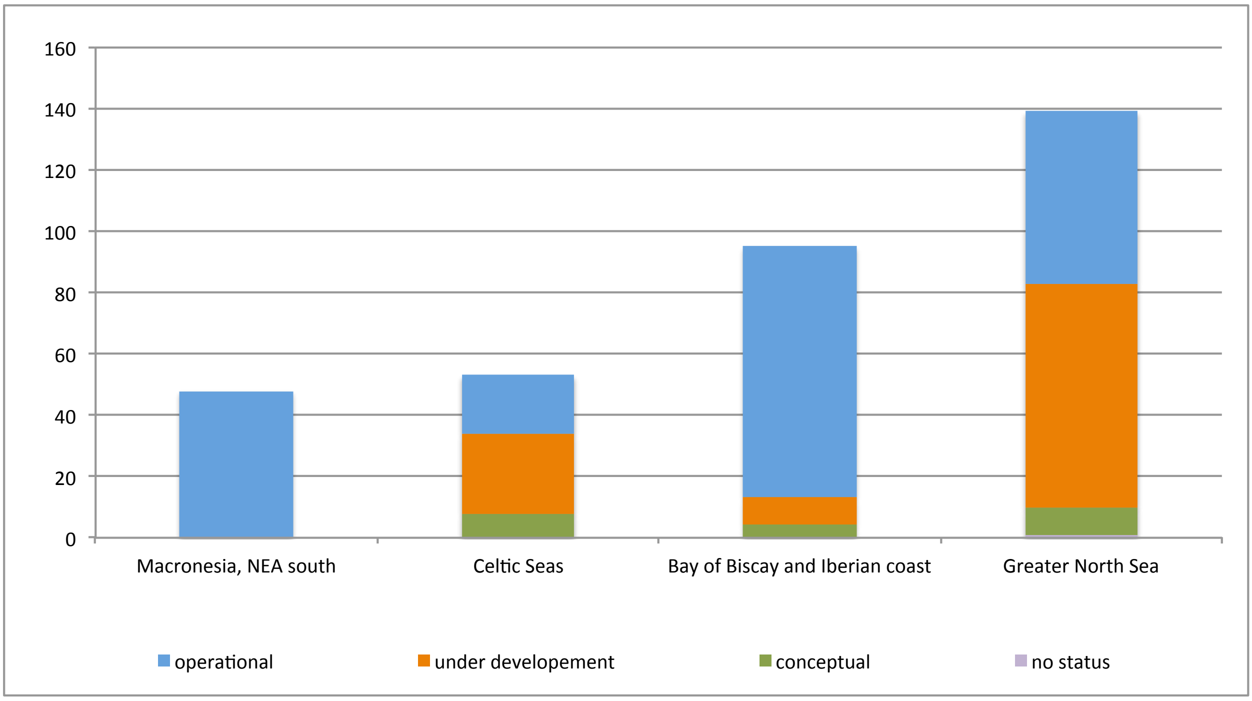


Figure 27. Number of indicators per subdivision in ascending order with indicator status.

4.1.3. Gaps in the North-East Atlantic

The analysis performed in this section focused on indicators associated with Descriptors 1, 2, 4 and 6 in the North-East Atlantic. It is clear from this analysis that the number of indicators associated with the different descriptors, as well as their response to pressures and coverage of subregions is uneven.

There is a very good coverage of Descriptor 1 "Biological diversity". However, there is only one operational indicator covering criterion C1.8 "Ecosystem processes and functions". This is the BEQI (Benthic Ecosystem Quality Index) developed in The Netherlands (van Hoey *et al*. 2007) for the WFD, and it uses the relationship between macrobenthic biomass and ecosystem productivity. This indicator targets EU indicator 1.8.1 (Interactions between structural components). No operational indicator exists for EU indicator 1.8.2 (Services provided) and in total, only two existing indicators are present.

Although there is a good coverage of D1, there is a need for more indicators related to Descriptor 2 "Non-indigenous species", and a clear scope for development in all four descriptors studied here.

Of the biological components, we would like to emphasize the need for developing indicators that relates to the pelagic invertebrates, as there is an entire region of open deepwater in the wider Northeast Atlantic. This region encompasses the Macaronesian archipelagos of Azores, Madeira, Salvage and Canaries islands, as well as offshore waters to the west of Portugal, Spain, France, United Kigdom and Ireland. Microbes and reptiles also have very poor coverage of indicators, and currently, it seems like few indicators are under development.

Few indicators responding to pressures such as: acidification, underwater noise, marine litter, extraction of maerl, extraction of seaweed. It may be a matter of testing for their quality and not just for the number of indicators, as checked here.

Not all indicators used in the North-East Atlantic have been tested against pressures, so this should be done in the near future, as well as developing indicators that respond to pressures and test for synergetic effects of different pressures.

There is the fewest number of operational indicators for the Celtic Seas, 19 operational, but there are 26 under development and 8 conceptual. It is worth noting that there are no indicators under development for the region Macaronesia and the southern part of the Northeast Atlantic.

For some criteria of certain descriptors there are few indicators, and it is noted that there are also few indicators under development. We have not checked for subregional differences in for example indicators relating to different biodiversity components or different pressures.

4.2. Baltic Sea

4.2.1. Ecosystem overview

This ecosystem overview aims to outline the main features of the Baltic Sea ecosystem from the point of view of biodiversity, food-webs, seafloor integrity and non-indigenous species. The overview relies heavily on previous work; mainly on the Baltic Sea Ecosystem Overview by ICES (2008), the HELCOM Red List assessment (HELCOM 2013c), Ojaveer *et al*. (2010) and the food-web focused report produced by the EU-funded Interreg IVA project GES-REG (Uusitalo *et al*. 2013) which tried to identify key or representative species from all the trophic levels of the food-web. They proceeded to review literature on effects of various pressures on key food-web components, aiming to identify which pressures are most often cited as having an effect on these species.

Key characteristics and habitats

The Baltic Sea is a large brackish-water pool, characterized by narrow and shallow straits connecting it to the North Sea, and a large drainage basin bringing a large amount of fresh water runoff into the sea. The mean annual freshwater inflow of about 481 km^3 almost equals the volume of saline water inflows from the North Sea (Ojaveer *et al*. 2010). The water exhibits a strong east-west and north-south salinity gradient, with the most saline water in the western bays and belts and least saline in the northern bays. The Baltic Sea is shallow, with ca. 30 % of its area less than 25 m deep, mean depth of 60 m and maximum depth of 459 m (ICES 2008). The northern parts of the sea experience annual ice cover with extent and duration varying corresponding to the severity of the winter. In summer, water temperature in some coastal areas can exceed 25 °C (Ojaveer *et al*. 2010).

The coastal habitat types vary in different parts of the sea. The northern and western shores (Scandinavian) are rocky with extended archipelagos and still lifting after glacial retreat, while the eastern and southern coasts are dominated by fine sediments and are prone to inundation by rising sea levels (ICES 2008). Intensive agriculture, high-nutrient runoff and poor sewage treatment in eastern European countries have caused strong eutrophication in coastal regions of the Baltic Sea, especially in the three coastal lagoons: Odra lagoon, Vistula lagoon and the Curonian Lagoon and with less emphasize also in the eastern lagoons and inlets of Germany (Small Haff, Bodden of Rügen, Darß-Zingst Bodden Chain, Peene estuary). Eutrophication has led to an excessive increase in suspended organic material, which causes organic enrichment of sediments. In combination with the natural slow water flow in coastal lagoons, this nutrient enrichment results in very soft and unstable sediments (Fenske *et al*. 2013) and a conspicuously reduced light penetration. The high eutrophication levels resulted in an ecosystem shift in shallow bays and lagoons from comparably stable conditions with dominance of rooted macrophytes (angiosperms and charophytes) to unstable conditions dominated and thriven by intensive phytoplankton blooms. The Baltic Sea coastal lagoons and inlets are also characterized by well-emphasized salinity gradients resulting in varying community structures (from brackish to freshwater species dominance).

The upper water layer is separated from the more saline deep water layer by a permanent halocline located at depths of about 70–100 m. There is no halocline in the shallower areas in the north-eastern Baltic (for example, the Gulf of Bothnia and Gulf of Riga) or the Western Baltic (for example, the Kiel Bight or Belt Sea). A strong permanent halocline and seasonal thermocline in summer (also occurs in shallow areas) substantially hampers vertical mixing of the water column which induces formation of oxygen-depleted zones in several locations, essentially in the deep areas of the central Baltic (Ojaveer *et al*. 2010).

The oxygen-deficient waters are replaced occasionally through inflow of saline water from the North Sea through the straits. This, however, requires specific weather conditions. These strong inflows were frequent prior to mid-1970s (ICES 2008), but have been much scarcer since. The estimated residence time of the Baltic Sea water is 25–35 years (Ojaveer *et al*. 2010). The oxygen deficiency leads to phosphorus being released from the sediments and being recycled back to the water column, thus feeding the primary production. The recurring oxygen deficiency and other hydrographic factors affect the deep water soft bottom fauna which tends to be dominated by few species (Laine 2003) and has shown high variability and significant changes along the decades (Laine 2003 and references therein).

Key biodiversity components

Plankton

The primary production features a strong seasonal variation, with an intense spring bloom and a late-summer maximum. The species composition of the phytoplankton community varies between seasons and areas. The highest phytoplankton species diversity (1565 species) is found in the Gulf of Finland (Ojaveer *et al*. 2010), probably partly due to long-term dedicated taxonomic efforts in the area. Planktonic algae produce the majority of energy entering the Baltic Sea pelagic food-webs (Furman *et al*. 1998) and the phytoplankton composition has implications to the functioning of the food-web, both in reference to their edibility and due to the toxins produced by some of the taxa. In addition, the microbes decomposing the soluble organic matter are particularly crucial for the functioning of the pelagic ecosystem (Furman *et al*. 1998). Mass occurrences of nitrogen-fixing cyanobacteria are a recurring phenomenon in the central Baltic Sea, Bothnian Sea, Gulf of Finland and Gulf of Riga (ICES 2008). A list of potentially harmful phytoplankton in the Baltic Sea contains over 60 species with effects connected to toxicity, mechanical disturbance, bloom formation and water coloration (Ojaveer *et al*. 2010). It has been proposed that many recent changes in the phytoplankton could be related to climate variation, which directly and indirectly influence water temperature, salinity and loading from the catchment in the Baltic Sea area.

According to present-day knowledge, the most species-rich component of the Baltic Sea zooplankton is microplankton (ciliates and rotifers) (Ojaveer *et al*. 2010). The mesozooplankton community is dominated by calanoid copepods and cladocerans and varies along the salinity gradient. Changes in the zooplankton community have been attributed to changes in salinity and temperature (Viitasalo *et al.* 1995; Vuorinen *et al.* 1998; Ojaveer *et al.* 1998, Möllmann *et al.* 2000, 2003a; Schmidt *et al*, 2003; Alheit *et al.* 2005; Möllmann *et al.* 2005). The mean size of zooplankters has decreased (Gorokhova *et al.* 2013). The copepods *Pseudocalanus elongatus*, *Temora longicornis* and *Acartia spp*. are considered to be the main prey items of the dominating pelagic fish species sprat *(Sprattus sprattus*) and small-sized individuals of Baltic herring (*Clupea harengus membras*) (e.g. Szypula *et al.* 1997a; Flinkman *et al.* 1998; Möllmann and Köster 1999, 2002; Viitasalo *et al.* 2001; Casini *et al.* 2004; Rönkkönen *et al.* 2004; Casini *et al.* 2006). These zooplankton taxa were therefore also identified as key species in the food-web.

Benthos

The benthic invertebrate composition mainly depends on salinity, water depth and substrate type. On hard substrate in shallow waters, suspension-feeding mussels are dominant, while on soft bottoms and in deeper waters, deposit feeders and burrowing forms dominate (ICES 2008). The most diverse groups are the polychaetes, crustaceans and molluscs (mainly bivalves). Some taxonomic subgroups like sea squirts, echinoderms, sponges, sea anemones and corals are nearly exclusively restricted to the high salinity areas of the western and southern Baltic Sea (HELCOM 2013c). However, the number of freshwater species increases along the same gradient. Especially in the more or less freshwater inshore waters (e.g. Curonian Lagoon) and in the shallow offshore waters of the northeast, the number of freshwater species (mainly insects but also oligochaetes and molluscs) increases dramatically. Oxygen availability also limits species distribution because most benthic organisms are sensitive to long-term low-oxygen conditions. Therefore, macrobenthic life is often absent in the deeper basins below the halocline particularly after longer periods without saline water inflows. On the anoxic bottom of the Baltic Proper, only members of the meiobenthos are found that are able to withstand the stress exerted by the lack of oxygen (Ojaveer *et al*. 2010). The blue mussel (*Mytilus trossulus x M. edulis*) is a key zoobenthos species in the coastal food-web, also being an important habitat-forming species (HELCOM 2010, Kovisto 2011). Overall, approximately 1898 benthic invertebrate taxa occur within the Baltic Sea (HELCOM 2012) of which 19 were considered as threatened (e.g. the bivalve *Macoma calcarea* or the snail *Lunatia pallida*) and nine as near threatened (e.g. the bivalve *Mya truncata* or the amphipod *Corophium multisetosum*). Main threats for benthic invertebrates are eutrophication, and as a consequence the increasing oxygen depletion and number of anoxia events, as well as seabed damage due to bottom trawling and construction activities (HELCOM 2013c).

Salinity is also the main environmental factor controlling the wide-scale distribution of phytobenthic species in the Baltic Sea, while exposure, substratum type and light availability determine the structure of vegetation communities on the local scale. Macroalgae are the most diverse macrophyte subgroup. They need hard bottom for attachment which is scarce in some subregions (e.g. southern Arkona and Bornholm Basin). The most important habitat-forming phytobenthos species on hard bottoms are bladder wrack algae (*Fucus spp.*) and clawed fork weed (*Furcellaria lumbricalis*) and in the Western Baltic also red algae like *Coccotylus/Phyllophora* and *Delesseria sanguinea*. Higher plants and charophytes are distributed on soft bottom. Although this subgroup has a much lower species number than macroalgae, the brackish environment, soft bottom dominance and high areal extent of shallow bays and lagoons in the Baltic promote the occurrence and diversity of those subgroups. Eelgrass (*Zostera marina*) is the most important habitat-forming phytobenthos species on soft bottoms (HELCOM 2010) of moderate exposure levels. In coastal lagoons vegetation communities are characterized by tasselweed (*Ruppia* sp.), pondweed (*Potamogeton* spp.), milfoil (*Myriophyllum spp*.) and stoneworts

(*Chara* spp.). These species serve a key role in structuring the coastal ecosystems. Overall 531 macrophyte taxa are growing within the Baltic Sea (HELCOM 2012) of which three were regarded as endangered, four as vulnerable and also four as near threatened. The threatened species are characteristic of coastal lagoons and bays reflecting the high anthropogenic pressures (eutrophication, siltation, habitat alteration due to ditching) in these areas (HELCOM 2013c).

Fish

The Baltic Sea fish fauna comprises about 70 % marine, 20 % freshwater and 10 % migratory species. The fish and lamprey checklist of the Baltic Sea includes about 239 species, which is a comparably low number (BSEP 140). The dominating fish species in the pelagic/benthic ecosystem are cod (*Gadus morhua*) and sprat, which together comprise approximately 80 % of the total fish biomass. Some flatfish species are commercially important and the biomass appears to be moderately high, e.g. flounder (*Platichthys flesus*). Several migratory species such as salmon (*Salmo salar*), trout (*Salmo trutta*), eel (*Anguilla anguilla*), vimba bream (*Vimba vimba*) and smelt (*Osmerus eperlanus*) are of high commercial value too (Ojaveer *et al.* 2010). Cod feeds on benthic meio- and macrofauna and fish (e.g. Uzars 1994; Harvey *et al.* 2003) and is the main predator of sprat and herring (Köster *et al.* 2003a). Large herring feed on zooplankton and nektobenthos (Casini *et al.* 2004; Möllmann *et al.* 2004) while sprat and small herring are zooplanktivorous; the copepods *Pseudocalanus elongatus*, *Temora longicornis*, and *Acartia spp.* are considered to be their main zooplankton prey (e.g. Szypula *et al.* 1997a; Flinkman *et al.* 1998; Möllmann and Köster 1999, 2002; Viitasalo *et al.* 2001; Casini *et al.* 2004; Rönkkönen *et al.* 2004; Casini *et al.* 2006). In the coastal zone, the distribution of fish species is largely governed by salinity. The most common and abundant freshwater species found in a majority of coastal areas of the Baltic Sea are perch (*Perca fluviatilis*), roach (*Rutilus rutilus*), bream (*Abramis brama*), bleak (*Alburnus alburnus*), ruffe (*Gymnocephalus cernuus*), ide (*Leuciscus idus*), pike (*Esox lucius*) and whitebream (*Blicca bjoerkna*). These fish are more abundant in areas where salinity is lower such as in the northeastern Baltic Sea, including large gulfs and lagoons (Ojaveer *et al.* 2010). Of the 239 fish species of the Baltic Sea, two species are regarded as regionally extinct (American Atlantic sturgeon – *Acipenser oxyrinchus*, common skate – *Dipturus batis*), four species as critically endangered (e.g. eel – *Anguilla anguilla*, spurdog – *Squalus acanthias*), three as endangered (e.g. Atlantic wolf-fish – *Anarhichas lupus*, whitefish – *Coregonus maraena*), seven as vulnerable (e.g. salmon, trout) and nine as near threatened. Main threats for fish are fishing (either targeted commercial, recreational or as by-catch), eutrophication and climate change. For migrating fish also barriers in estuaries and rivers are forming a major threat (HELCOM 2013c).

Mammals

The marine mammals occurring in the Baltic Sea are grey seal (*Halichoerus grypus*), ringed seal (*Phoca hispida*), harbour seal (*Phoca vitulina*) and a small population of harbour porpoise (*Phocoena phocoena*). Together with human fishery activities and piscivorous birds, these species are the top predators of the Baltic Sea ecosystem, feeding on available fish species (Routti *et al*. 2005; Suuronen and Lehtonen 2012). The latest HELCOM Red List assessment has verified a threat status for all Baltic Sea marine mammals (vulnerable or critically endangered) beside the grey seal and a subpopulation of the harbour seal in the southern Baltic Sea (least concern). Main threats for marine mammals are incidental by-catch in fishing gear but also environmental pollution (contaminants) which negatively affects health and fertility as well as anthropogenic disturbance (noise, traffic) at their nursing, moulting and feeding grounds (HELCOM 2013c).

Birds

The Baltic Sea hosts a variety of sea birds feeding from the sea (Furman *et al*. 1998) and is an important wintering area for many bird species (ICES 2008) like divers, grebes and sea ducks, which are the most characteristic species in the Baltic Sea (HELCOM 2013c). The high variety of coastal habitats results in a high species diversity of sea birds, e.g. dabbling ducks breed in brackish lagoons, sea ducks preferring rocky coasts, wading birds favouring sandy open coasts and auks breeding on rocky coasts. Common eider (*Somateria mollisma*), a common species breeding on the offshore islands, can be considered as s keystone species according to HELCOM (2010). Common eider feeds mainly on blue mussels and has been assessed as being vulnerable in the HELCOM Red List assessment. A total of 58 breeding birds have been assessed in the HELCOM Red List Project, 23 were red-listed. For wintering birds 63 species have been assessed of which 16 are regarded as threatened or near threatened. Main threats for sea birds are habitat destruction (breeding and feeding grounds), incidental by-catch in fishing gear but also environmental pollution (contaminants) as well as anthropogenic disturbance (noise, light, traffic) (HELCOM 2013c).

Non-indigenous species

Although the first human-mediated introduction of species in the Baltic Sea occurred in the eleventh to twelfth century, species invasions have become a problem during the past two decades, especially with intensified invasion of non-indigenous species from the Ponto-Caspian region. Since the early 1980s, over 100 non-indigenous have been recorded in the Baltic Sea (the Kattegat included) most of them being introduced via shipping (ballast water or hull fouling) or spread from their primary sites of introduction in adjacent freshwater bodies. It is assumed that some 70 species have been able to establish and maintain self-sustaining populations (Zaiko *et al*. 2007). Non-indigenous species are abundant and even dominant throughout the shallow benthic and fouling communities of the Baltic Sea. At present, no shallow-water habitat is entirely free of human mediated invaders. Their number is lowest in the Bothnian Bay and highest in the high-salinity Kattegat area (Ojaveer *et al*. 2010).

Non-indigenous species have no direct value as food resources in the Baltic, as none of them supports commercial fisheries and invertebrates are not harvested for food because of their small size. However, on the basis of existing knowledge, approximately 30 non-indigenous species (i.e. less than 30% of all introduced species) can be classified as nuisance organisms in the Baltic. Only 9 of them have caused measurable damage. These are 4 Ponto-Caspian species (*Cercopagis pengoi*, *Cardylophora caspia*, *Dreissena polymorpha* and *Neogobius melanostomus*), three North-American species (*Balanus improvisus*, *Gammarus tigrinus* and the American mink *Mustela vison*), the Japanese swim-bladder nematode *Anguillicola crassus* and the ''shipworm'' mollusk *Teredo navalis*, believed to be of Indo-Pacific origin.

The influence of the most recent and potentially harmful invader, the non-indigenous ctenophore *Mnemiopsis leidyi*, on the pelagic food-web of the Baltic Sea seems to be spatially restricted to the southern Baltic Sea, where amongst other prey (Gorokhova *et al*. 2009).

Main pressures

Based on published literature, changes of salinity and thermal regime were identified as the main factors behind many of the changes in the Baltic Sea food-web (Uusitalo *et al*. 2013). The most recent overview on threats to the biodiversity of the Baltic Sea includes 10 major categories: fisheries, maritime activities (including shipping), physical damage and disturbance, recreational activities, eutrophication, hazardous substances, non-indigenous species, noise pollution, hunting and climate change. Overfishing, eutrophication, and drastic decline of marine mammals have been the most prominent changes in the Baltic Sea during the twentieth century. However, it is possible that the results are biased, since eutrophication has also been extensively studied in the last decades. The literature review does not indicate physical damage, physical loss or man-made changes in hydrological regime as relevant pressures for the Baltic Sea ecosystem.

All the other factors affecting the Baltic biodiversity are of relatively recent concern and have locally restricted impact, or information on their impact is poorly documented.

There are several human activities having increased significantly during the last decades. These include human-mediated bioinvasions, maritime transport (with increased risk of oil spills), extraction and disposal activities, a variety of technical installations in coastal areas and on the seabed (including sea cables and pipelines) and recreational activities. Elmgren (2001) pointed out that the scientific understanding of the ecosystem changes and their causes, as well as the importance of various pressures tends to change and develop along time and it may take decades to reach agreement. Therefore, the current view of main pressures should not be taken as an exclusive list.

4.2.2. Indicators availability and capability

As mentioned in section 3.3.4, 168 indicators cover the Baltic Sea region; 100 of them are specifically addressing the Baltic Sea. The number of indicators per descriptor is listed in **Table 26** and illustrated in **Figure 28**.

Most of the indicators address several descriptors at the same time, possibly indicating overlap in D1/D2/D4/D6, and on the other hand showing that many indicators may address pressure and its effect at the same time. The proportion of indicators specific for the Baltic Sea and D2 is very high, which can be explained by the high risk of an introduction of non-indigenous species as mentioned in the ecosystem overview. This has been one of the main focuses in this region.

Table 26. Number of indicators per descriptor, divided into indicators specifically relevant for one descriptor and indicators addressing several (one or more) descriptors [sum (operational/under development/conceptual/no status)].

Descriptors	one descriptor	several descriptors
D1	43 (14/20/9/0)	130 (60/59/11/0)
D2	11 (4/6/1/0)	12 (5/6/1/0)
D4	13 (3/3/7/0)	72 (32/32/8/0)
D6	6 (0/4/2/0)	45 (25/16/4/0)

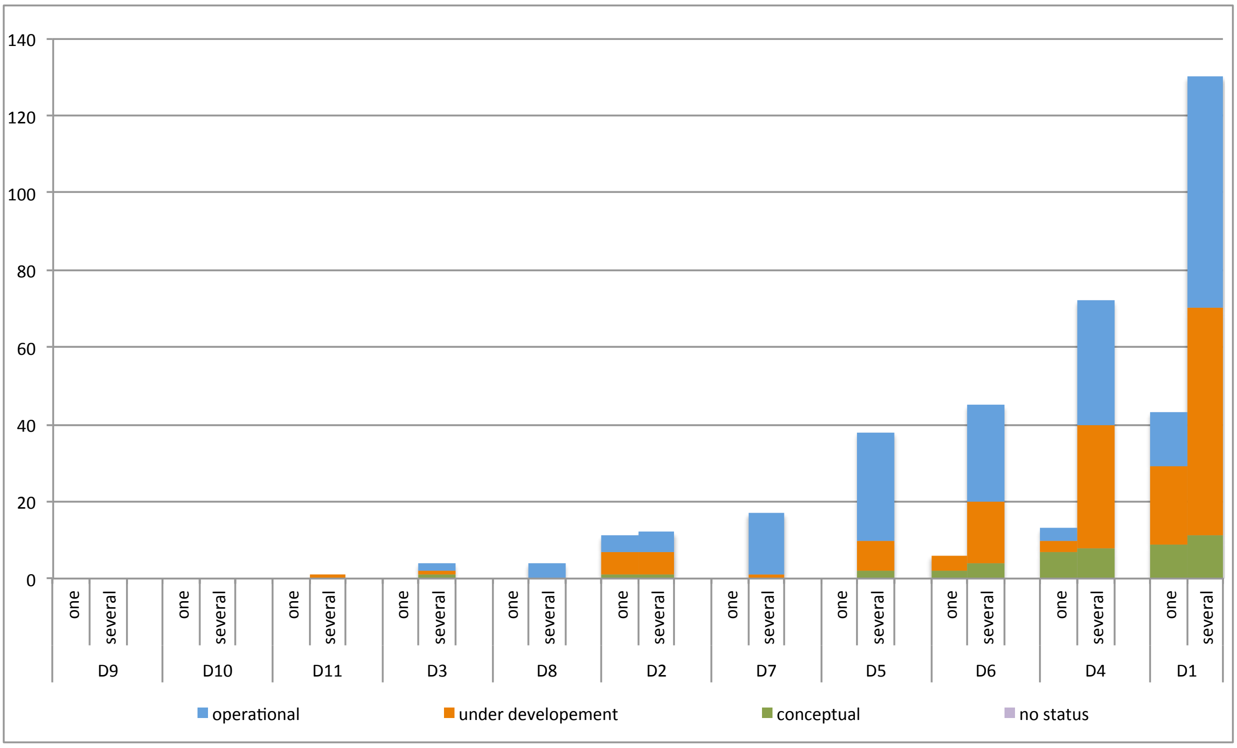


Figure 28. Number of indicators per descriptor in ascending order with indicator status and divided into indicators addressing one descriptor and several (one or more) descriptors.

Descriptors and criteria

Descriptor 1 criteria

Of the 168 indicators for the Baltic Sea a total of 130 indicators are related to D1 criteria. 65 of them are specific for the Baltic Sea. The distribution of the indicators across the eight D1 criteria is listed in **Table 27** and illustrated in **Figure 29**.

The criteria "species distribution", "population size" and "population condition" which primarily address mobile biodiversity components like fish, mammals and birds are well covered by indicators, although the number of Baltic Sea specific indicators is low. However, the mobile species occurring in the Baltic Sea are not so unique, justifying their treatment separately from populations in the neighboring North East Atlantic. The criteria related to habitats, i.e. "habitat distribution", "habitat extent" and "habitat condition" show a low number of indicators for "habitat extent" (15) while "habitat condition" (53) is covered by the highest number of indicators among all D1 criteria. The definition of "habitat extent" of selected habitats is an essential part of the MSFD process, as assessments need to be based on the different habitat types. Thus, the number of 15 indicators seems to be a comparably low number to cover this criterion properly. Of the D1 criteria on ecosystem level ("ecosystem structure" and "ecosystem processes") only the first is well covered (34) but no indicators for "ecosystem processes" exist. Taking into account the ecosystem approach of the MSFD, indicators on ecosystem processes would be of special relevance. Furthermore it could be expected that indicators on ecosystem level are often specific for each regional sea.

Except for the criterion "population condition" the proportion of operational indicators is high. This outlier might be explained by the fact that in this class indicators often are addressing marine mammals. In the past, monitoring for those species was concentrating on the species distribution and population size aspects. In addition condition is often only measurable on dead individuals restricting the number of usable data sets.

The number of indicators addressing only one criterion is low for criteria related to distribution and/or extent, which is unproblematic as those criteria are connected with each other and therefore often based on the same indicators with identical data sets and monitoring. Although the proportion of criterion-specific indicators is higher for the "condition" criteria, an even higher proportion could be expected. As mentioned above this "rule" should be even more evident for the ecosystem criteria.

Table 27. Number of indicators per D1 criteria, divided into indicators specifically addressing one criterion and indicators addressing several further criteria in addition [sum (operational/under development/conceptual/no status)].

D1 criteria	one criterion	several criteria
1.1 Species distribution	4 (1/2/1/0)	32 (23/8/1/0)
1.2 Population size	5 (1/4/0/0)	39 (22/17/0/0)
1.3 Population condition	10 (0/8/2/0)	23 (7/13/3/0)
1.4 Habitat distribution	1 (1/0/0/0)	24 (17/6/1/0)
1.5 Habitat extent	1 (1/0/0/0)	15 (12/1/2/0)
1.6 Habitat condition	9 (3/4/2/0)	53 (31/19/3/0)
1.7 Ecosystem structure	8 (4/2/2/0)	34 (23/7/4/0)
1.8 Ecosystem processes	0	0

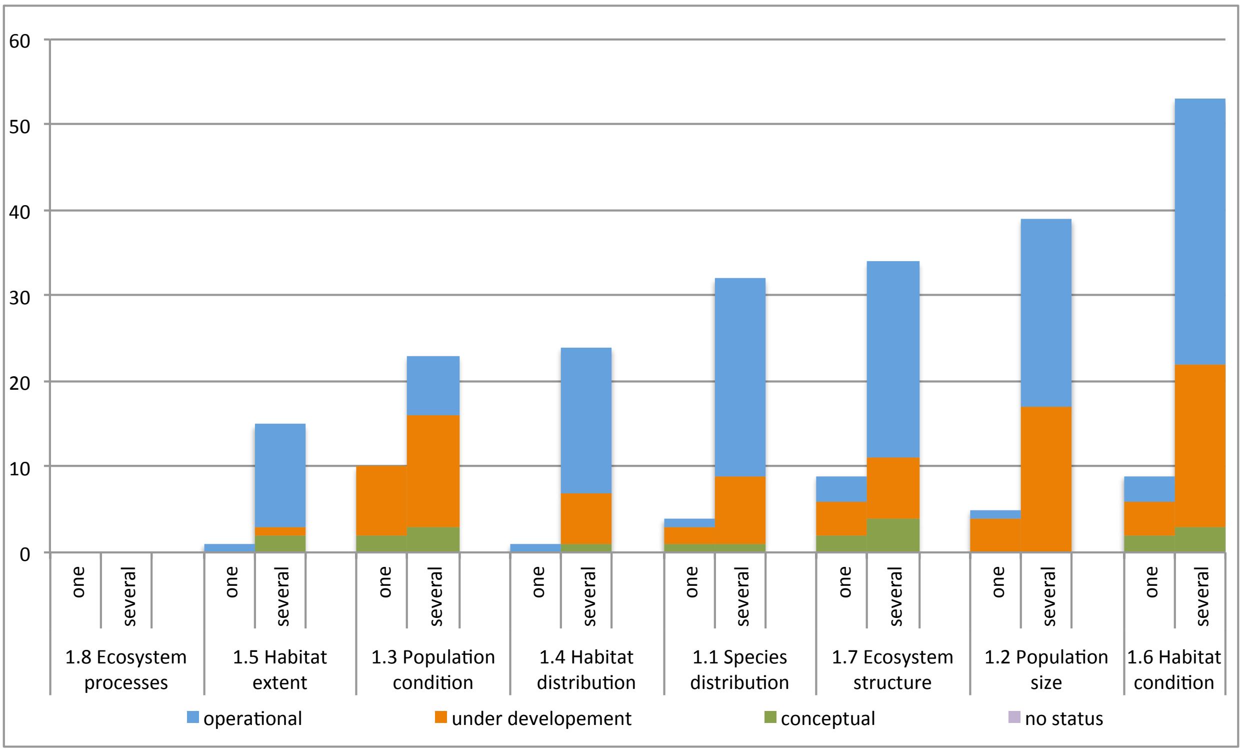


Figure 29. Number of indicators per D1 criteria in ascending order with indicator status and divided into indicators addressing one criterion and futher criteria in addition.

Descriptor 2 criteria

Of the 168 indicators for the Baltic Sea a total of 11 indicators are related to D2 criteria. Nine of them are specific for the Baltic Sea. One indicator is related to Descriptor 2, but without an assignment to a specific D2 criterion. The distribution of the indicators across the two D2 criteria is listed in **Table 28** and illustrated in **Figure 30**.

All indicators are addressing only one criterion. Most countries as well as HELCOM have developed indicators for non-indigenous species and impacts recently and already in the context of the MSFD. The two criteria can also be seen as the division of pressure (abundance and species characterization of non-indigenous species) and state/impact (environmental impact of invasive non-indigenous species) requiring the development of criteria-specific indicators. The pressure criteria can be assessed with a variety of indicators of which four are already operational. In contrast, the state/impact criteria are only covered by two indicators, which are still under development.

Table 28. Number of indicators per D2 criteria, divided into indicators specifically addressing one criterion and indicators addressing further criteria in addition [sum (operational/under development/conceptual/no status)].

D2 criteria	one criterion	several criteria
2.1 Abundance and state	9 (4/4/1/0)	0
2.2 Environmental impact	2 (0/2/0/0)	0

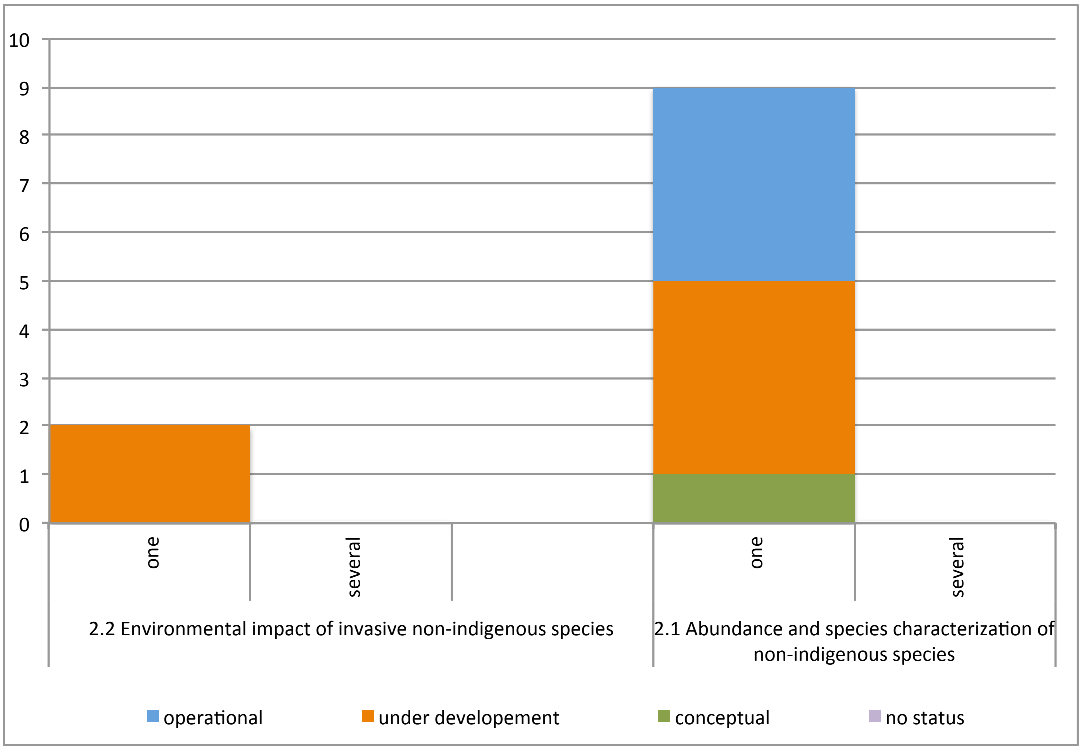


Figure 30. Number of indicators per D2 criteria in ascending order with indicator status and divided into indicators addressing one criterion and further criteria in addition.

Descriptor 4 criteria

Of the 168 indicators for the Baltic Sea a total of 72 indicators are related to D4 criteria. 34 of them are specific for the Baltic Sea. The distribution of the indicators across the four D4 criteria is listed in **Table 29** and illustrated in **Figure 31**.

Most indicators are addressing the criterion "abundance and distribution of key trophic groups/species" (57) with 26 operational indicators. As mentioned in section 3.2.2, it may not be advantageous to also include habitat-forming species in this context as this creates much overlap with D1 and D6 descriptors and criteria and hides possible gaps for trophic groups. Accordingly, the proportion of indicators on habitat-forming species (angiosperms, macroalgae) is higher compared to other components having a higher relevance in many food-webs. Only few indicators are actually concentrating on trophic groups.

The low number of indicators addressing both D4 and D3 together highlights that there seems to be too few indicators on trophic groups impacted by commercial fishery.

The "productivity" criterion is covered by 13 indicators, of which eight are operational indicators and four are specifically addressing this criterion only. Productivity patterns are of specific relevance for food-webs and it is doubtful that the indicator set covers all aspects especially as only very few indicators exist that are specific to this criterion. The criterion "proportion of species at the top of the food-web" is covered by 9 indicators, of which six are operational indicators and two are specifically addressing this criterion only. A certain overlap with "abundance and distribution of trophic groups" exists for this criterion which might explain the low number of criterion-specific indicators. The category "Other" includes the indicator "Blubber thickness of stranded seals" which has an indication for the food-web descriptor without a direct relation to the other D4 criteria.

Table 29. Number of indicators per D4 criteria, divided into indicators specifically addressing one criterion and indicators addressing further criteria in addition [sum (operational/under development/conceptual/no status)].

D4 criteria	one criterion	several criteria
4.1 Productivity of key species or trophic groups	4 (1/1/2/0)	13 (8/2/3/0)
4.2 Proportion of selected species at the top of the food-web	2 (2/0/0/0)	9 (6/2/1/0)
4.3 Abundance/ distribution of key trophic groups/species	17 (5/4/8/0)	57 (26/26/5/0)
4.4 Other	0	1 (0/1/0/0)

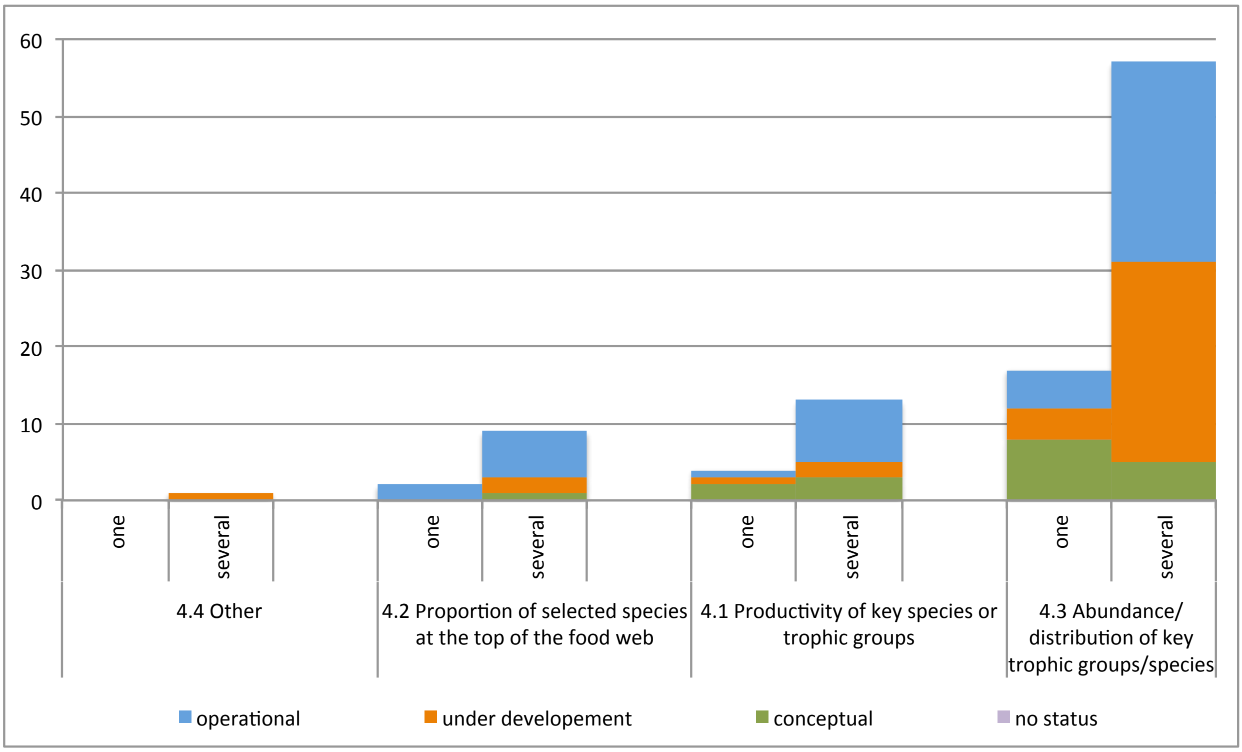


Figure 31. Number of indicators per D4 criteria in ascending order with indicator status and divided into indicators addressing one criterion and further criteria in addition.

Descriptor 6 criteria

Of the 168 indicators for the Baltic Sea a total of 45 indicators are related to D6 criteria. 34 of them are specific for the Baltic Sea. The distribution of the indicators across the two D6 criteria is listed in **Table 30** and illustrated in **Figure 32**.

Indicators are evenly distributed across the two criteria with 32 indicators addressing "condition of the benthic community" and 30 indicators addressing "substrate characteristics – physical damage". The proportion of operational indicators is > 50 % for both criteria. The number of indicators addressing only one criterion is low as both criteria exhibit a high subject-specific overlap:

- D6 criterion "condition of the benthic community" ⇔ D1 criterion "habitat condition"
- D6 criterion "substrate characteristics – physical damage" with subordinate indicator "biogenic substrate distribution and extent" ⇔ D1 criteria "habitat distribution" and "habitat extent"
- D6 criterion "substrate characteristics – physical damage" with subordinate indicator "biogenic substrate distribution and extent" ⇔ D4 criteria "abundance/distribution of key trophic groups – abundance trends of functionally important selected groups/species – habitat-defining groups/species"

As mentioned in sections 3.2 and 3.3.3, the overlap of descriptors D1 and D6 and the vague differentiation of the subordinate criteria as well as the mixture of pressure and state criteria in D6 cause problems for the assessment aggregation process. Under these circumstances, a lack of indicators for specific impacts is difficult to identify, but it seems that too many indicators are related only to the distribution and extent of biogenic substrates and too few on the pressure indication of D6 (physical damage).

Table 30. Number of indicators per D6 criteria, divided into indicators specifically addressing one criterion and indicators addressing further criteria in addition [sum (operational/under development/conceptual/no status)].

D6 criteria	one criterion	several criteria
6.1 Substrate characteristics – physical damage	6 (0/3/3/0)	30 (16/11/3/0)
6.2 Condition of the benthic community	1 (0/1/0/0)	32 (24/7/1/0)

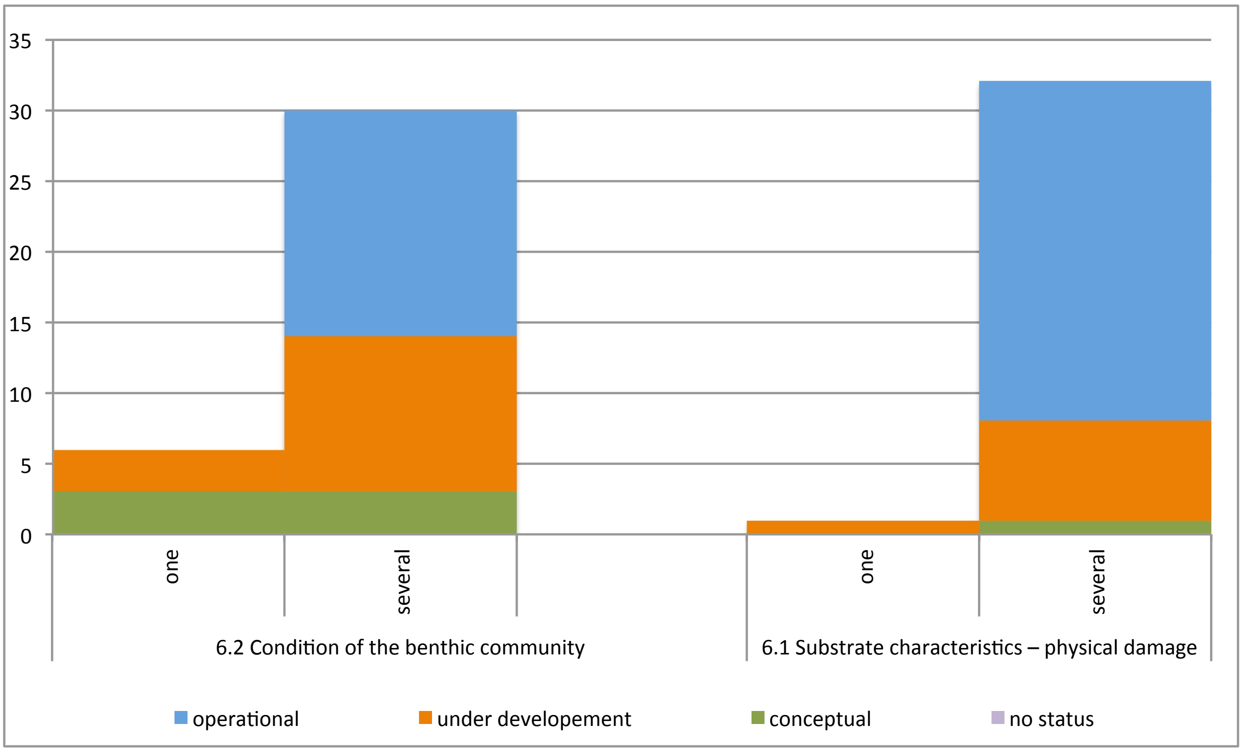


Figure 32. Number of indicators per D6 criteria with indicator status in ascending order, divided into indicators addressing one criterion and further criteria in addition.

Biodiversity components

The distribution of indicators across the biodiversity components is listed in **Table 31** and illustrated in **Figure 33**. In contrast to the general indicator analysis, the number of indicators for marine mammals is very high. Among indicators addressing one biodiversity component only, it is even the highest number. Taking the lower species diversity of this group into account (compared to other regional seas), this is an unexpected result. However, as all marine mammal species of the Baltic Sea are red-listed and contained in the annexes of the Habitats Directive, the attention and concern for them is traditionally high. The proportion of indicators under development is also high. In the past, the focus was set on the assessment of the distribution of mammal populations and the overall individual numbers. With the implementation of the MSFD also indicators for the D1 criterion “population condition” and D4 criteria “proportion of selected groups (such as top predators)” and “productivity of trophic groups” has to be met. Therefore a set of new indicators is investigated.

Also the number of macroalgae indicators seems to be comparably high (35). Many of them are related to benthic habitats and only 15 are addressing this component specifically. The varying salinity and subsequently differing distribution of macroalgae species across the Baltic Sea may have led to this high number of indicators. However the brackish water character of the Baltic Sea enables a comparably high number of higher plant species to grow and this is a specific feature of the Baltic Sea ecosystem, which should result in a higher proportion of angiosperm indicators compared to other regional seas. Nevertheless, this is not reflected in the indicator set.

Fish and benthic invertebrates are covered by a variety of indicators and about 50 % of them are specific for the biodiversity component. Oxygen depletion in bottom waters is presently a characteristic aspect of the Baltic Sea negatively impacting the benthic communities. In this respect, the number of indicators on benthic invertebrates might be too low.

The importance of the Baltic Sea for migrating and breeding birds is reflected by a high number of bird indicators (27), of which 15 are specifically addressing only this component. But the number of operational indicators is low.

The Baltic Sea is primarily driven via the pelagic system resulting in a high number of indicators on phytoplankton. At the same time, the lack of microbe indicators might indicate a gap for this component, especially as the small plankton fractions are of special relevance in reduced salinity conditions. As mentioned in section 3.3.2, it has to be analysed in detail if those small fractions are already represented by the available phytoplankton indicators to fulfil the specific needs of the Baltic Sea ecosystem structure. Similar to the results from the general analysis in section 3.3.1, the number of zooplankton indicators is low and most of them are not operational.

No ice-associated communities for fish, birds or mammals have been assigned to any indicator, although seasonal ice cover is characteristic for the northern Baltic Sea area. Indicators for reptiles, cephalopods and pelagic invertebrates are irrelevant for the Baltic Sea as those groups are not part of the ecosystem or play only are negligible role.

Table 31. Number of indicators per biodiversity component, divided into indicators specifically addressing one component and indicators addressing further biodiversity components in addition [sum (operational/under development/conceptual/no status)].

Biodiversity component	one component	several components
Microbes	0	0
Phytoplankton	15 (3/5/1/6)	27 (8/10/3/6)
Zooplankton	5 (1/3/1/0)	17 (6/8/3/0)
Angiosperms	3 (2/1/0/0)	20 (13/7/0/0)
Macroalgae	14 (9/5/0/0)	35 (20/12/3/0)
Benthic invertebrates	13 (7/5/1/0)	32 (14/12/6/0)
Pelagic invertebrates	0	0
Fish	24 (11/8/5/0)	43 (18/18/7/0)
Cephalopods	0	4 (2/2/0/0)
Marine mammals	28 (7/19/2/0)	40 (11/27/2/0)
Reptiles	0	0
Birds	15 (8/6/1/0)	27 (12/14/1/0)

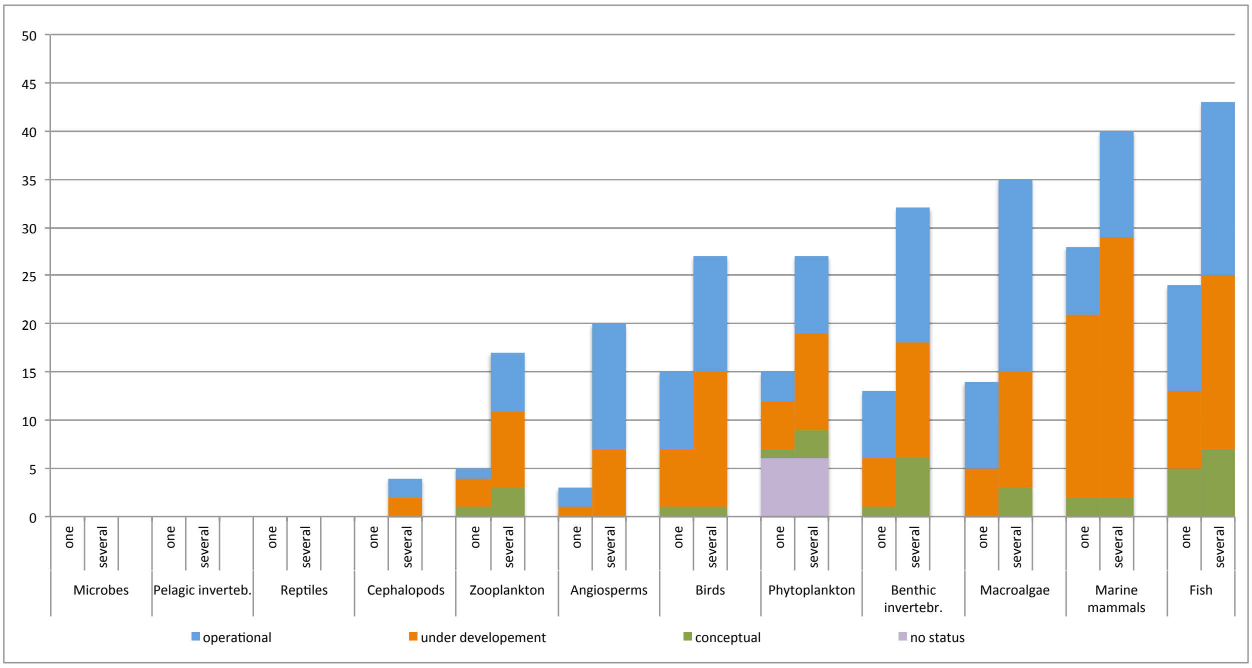


Figure 33. Number of indicators per biodiversity component in ascending order with indicator status and divided into indicators addressing one biodiversity component and further components in addition.

Habitat types

The distribution of indicators across habitat types is listed in **Table 32** and illustrated in **Figure 34**. Compared to the general indicator analysis for habitat types (section 3.3.2), the number of indicators focussing on the water column and the seabed is more equally distributed between those types. As described in the ecosystem overview, the Baltic Sea is primarily driven by water column processes and faces a high eutrophication pressure. Eutrophication impacts can first be measured in the water column. However, the effects of eutrophication may be more pronounced in the benthic environment (e.g. oxygen depletion, lower depth distribution of phytobenthos). The proportion of habitat type-specific indicators is high since the different habitat types inhabit totally different communities and biodiversity components. The proportion of operational indicators is higher for seabed habitats. The reason has already been discussed in section 3.3.2, i.e. the mobile water column communities make indicator development and target setting more difficult compared to stationary (benthic) communities. Furthermore, indicators for zooplankton have a rather short tradition.

Although seasonal ice cover is a characteristic feature of the Northern Baltic Sea, no indicators addressing ice habitats exist. As already discussed in section 3.3.2, the classification of certain biodiversity components and their related indicators needs to be clarified.

Table 32. Number of indicators per habitat type, divided into indicators specifically addressing one habitat type and indicators addressing further habitat types in addition [sum (operational/under development/conceptual/no status)].

Habitat type	one habitat type	several habitat types
Seabed	51 (28/16/7/0)	61 (32/22/7/0)
Water column	43 (13/19/5/6)	53 (17/25/5/6)
Ice habitat	0	0

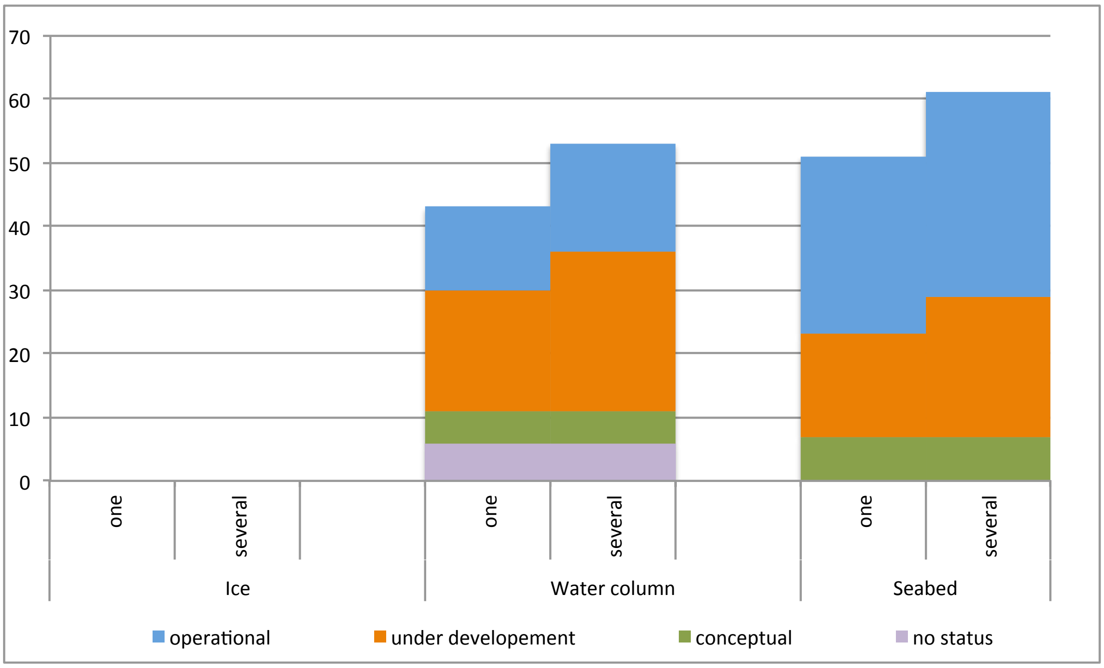


Figure 34. Number of indicators per habitat type with indicator status in ascending order, divided into indicators addressing one habitat type and further habitat types in addition.

All water column indicators for the Baltic Sea should minimally be categorized into salinity reduced waters, a further division and analysis on subtype basis is not reasonable. Concerning the seabed indicators, analyses of bottom type and depth zone have been conducted in accordance to the general seabed habitat type analysis in section 3.3.2.

Bottom type

The distribution of indicators across bottom types is listed in **Table 33** and illustrated in **Figure 35**. The number of soft bottom indicators is highest (39) with a very high proportion of operational indicators (34). This matches well the characteristic substrate distribution in the Baltic, which is dominated by soft bottoms especially for the depth zones "shallow sublittoral" and "shelf sublittoral". Pure hard bottoms occur regionally restricted and specifically in the littoral zone resulting in a high indicator number (24), also with a high proportion of operational indicators. Mixed bottoms are characteristic for the south-western and southern coastlines. The number of related indicators is low (9) as the clear delineation of mixed bottoms and the mapping of habitats characterised by mixed bottoms is difficult. But as mentioned already in the general habitat type analysis, mixed bottoms (especially in the shallow sublittoral) are characterised by a high biodiversity. They host soft and hard bottom communities of macrophytes, benthic invertebrates and demersal fish within a comparably small spatial scale. Only few indicators are related to only one bottom type and are missing for mixed bottoms although the specific features of this type might typically require specific indicators.

Table 33. Number of seabed indicators per bottom type, divided into indicators specifically addressing one bottom type and indicators addressing further bottom types in addition [sum (operational/under development/conceptual/no status)].

Bottom type	one bottom type	several bottom types
Mixed bottom	0	9 (7/2/0/0)
Hard bottom	8 (6/2/0/0)	24 (20/3/1/0)
Soft bottom	5 (5/0/0/0)	39 (34/4/1/0)

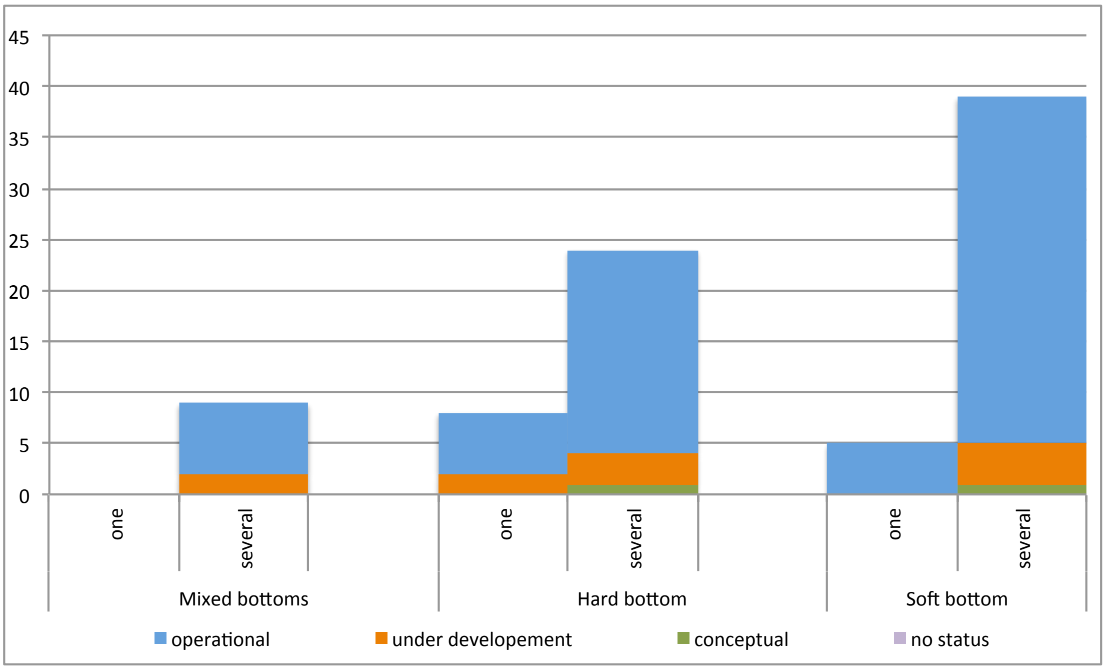


Figure 35. Number of seabed indicators per bottom type with indicator status in ascending order, divided into indicators addressing one bottom type and further bottom types in addition.

Depth zone

The distribution of indicators across depth zones is listed in **Table 34** and illustrates in **Figure 36**. Nearly all seabed indicators are addressing the shallow sublittoral zone (30). Only four indicators are addressing the littoral zone and six are related to the shelf zone. Bathyal and abyssal zones are not present in the Baltic Sea. The low number of indicators related to the littoral zone cannot be interpreted as a gap. The Baltic Sea is tideless and water level changes occur wind-induced only. They are irregular and not as pronounced as in other regional seas. Those conditions do not result in a corresponding differentiation of "littoral" and "shallow sublittoral" communities making a differentiation of indicators into those zones unnecessary.

The shelf zone is lacking indicators addressing benthic macrophytes and related habitats, subsequently resulting in a lower number of indicators. But as oxygen depletion events are most pronounced in the shelf zone it could be expected that the number of indicators should be higher and also that some indicators might address solely this depth zone. In contrast, only indicators specific for the shallow sublittoral exist. The proportion of operational indicators is high as many of the WFD assessment systems are assigned to the shallow sublittoral. Those assessment systems should all be operational by now.

Table 34. Number of seabed indicators per depth zone, divided into indicators specifically addressing one depth zone and indicators addressing further depth zones in addition [sum (operational/under development/conceptual/no status)].

Subtype	one depth zone	several depth zones
Littoral	0	4 (3/0/1/0)
Shallow sublittoral	13 (11/2/0/0)	30 (25/5/0/0)
Shelf sublittoral	0	6 (5/1/0/0)
Bathyal	0	0
Abyssal	0	0

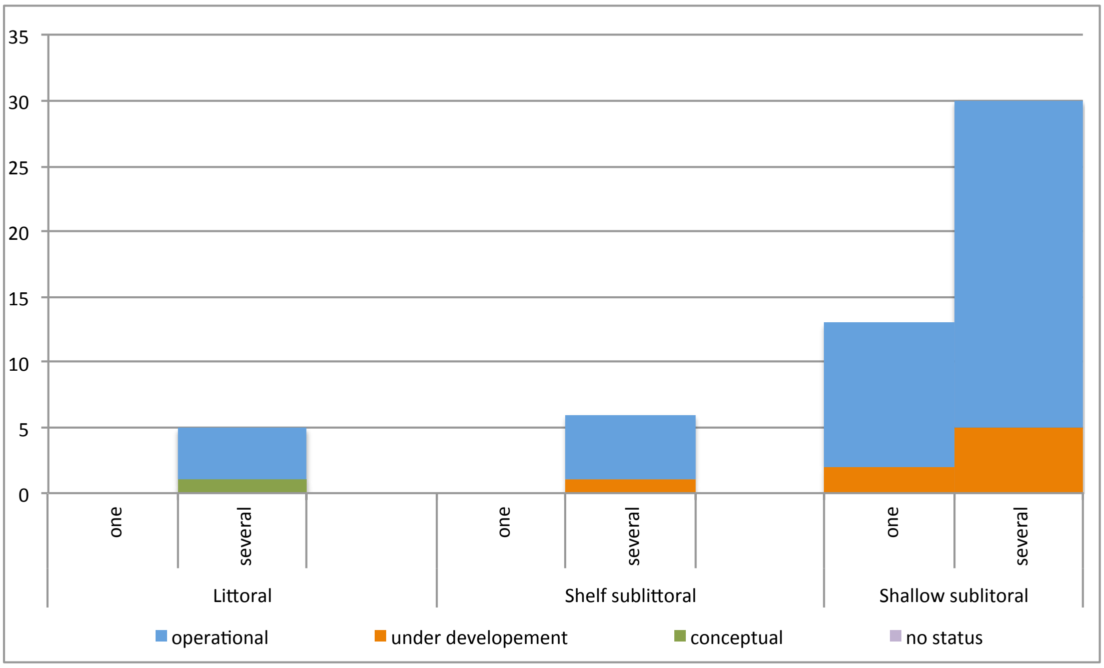


Figure 36. Number of seabed indicators per depth zone with indicator status in ascending order, divided into indicators addressing one depth zone and further depth zones in addition.

Pressures

The distribution of indicators across pressures is listed in **Table 35** and illustrated in **Figure 37**. It follows the patterns described in the general analyses (section 3.3.3). The number of indicators related to "nutrient and organic enrichment" is high (76): 42 indicators are already operational and 13 indicators are addressing solely this pressure. The high number matches well with the high eutrophication pressure described in the ecosystem overview. A high number of indicators are related to "physical loss" (47), "physical damage" (45) and "hydrological processes" (40) as well as "extraction of species – catch" (40). If those indicators are related to those pressures but are not assigned to the respective descriptors D3 or D7, the relationship can be assumed to be an indirect one. This is also reflected in the low numbers for pressure specific indicators. Most other pressures are only addressed by a low number of indicators and nearly any indicators exist which are related to one pressure only. However, it has to be kept in mind that the assignment of indicators to pressures has been done in a very inconsistent way between experts. Pressure related analyses can therefore only give a rough picture of the real circumstances.

Table 35. Number of indicators per pressure, divided into indicators specifically addressing one pressure and indicators addressing further pressures in addition [sum (operational/under development/conceptual/no status)].

Pressure	one pressure	several pressures
Physical loss (PL)	0	47 (29/13/5/0)
Physical damage to habitats (PD)	0	45 (25/14/6/0)
Underwater noise (UN)	1 (0/1/0/0)	13 (3/9/1/0)
Marine litter (ML)	0	6 (1/5/0/0)
Interference with hydrological processes (HP)	0	40 (26/9/5/0)
Contamination by synthetic compounds (CS)	0	32 (16/11/5/0)
Contamination by non-synthetic substances and compounds (CNS)	0	29 (15/11/3/0)
Contamination by radionuclides (CR)	0	4 (4/0/0/0)
Acute pollution events (PE)	0	16 (8/7/1/0)
Nutrient and organic matter enrichment (NE)	13 (5/6/2/0)	76 (42/19/15/0)
Introduction of microbial pathogens (MP)	0	6 (1/5/0/0)
Non-indigenous species (NIS)	5 (1/4/0/0)	10 (3/5/2/0)
Extraction of species: fish and shellfish (catch) (EC)	5 (2/2/1/0)	40 (16/13/11/0)
Extraction of species: fish and shellfish (by-catch) (EBC)	2 (0/2/0/0)	23 (7/11/5/0)
Extraction of species: fish and shellfish (discard) (ED)	0	10 (2/4/4/0)
Extraction of species: maerl (EM)	0	0
Extraction of species: seaweed harvesting (ES)	0	0

Extraction of species: other (EO)	2 (1/0/1/0)	15 (9/4/2/0)
Marine acidification (MA)	0	3 (3/0/0/0)
Other (O)	6 (6/0/0/0)	35 (23/9/3/0)

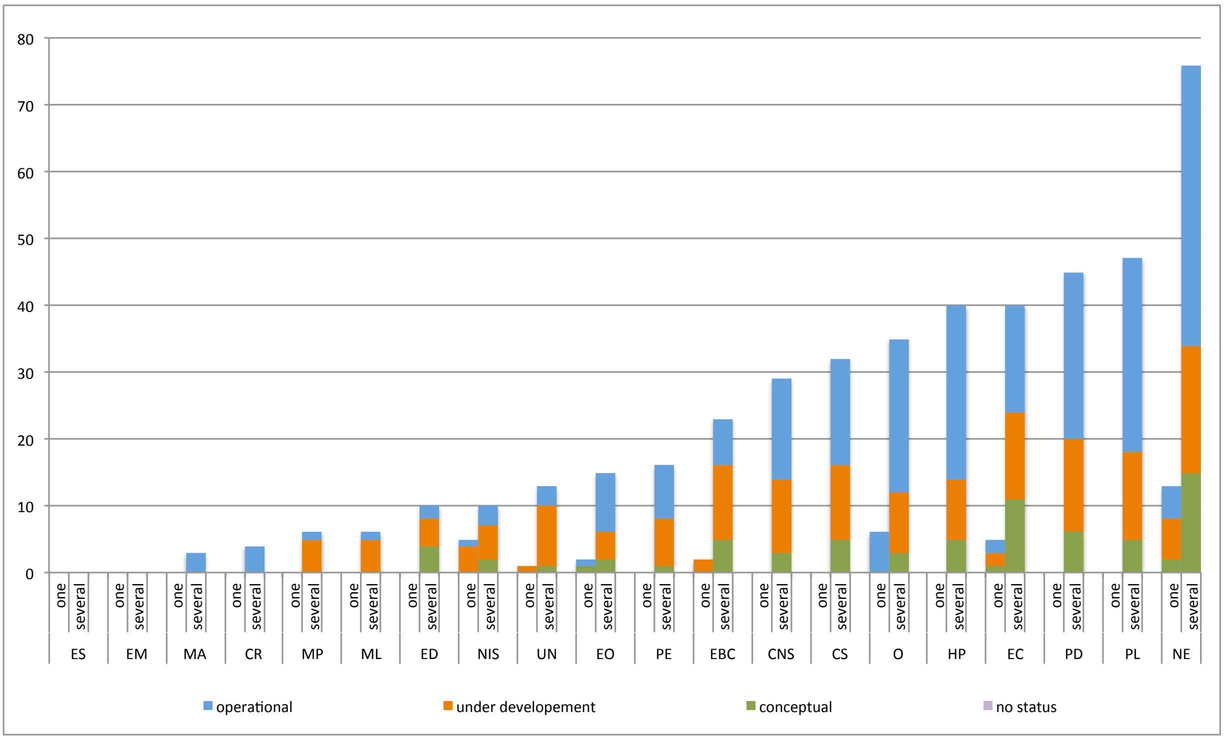


Figure 37. Number of indicators per pressure with indicator status in ascending order, divided into indicators addressing one pressure and further pressures in addition.

Regional subdivisions

In order to analyse spatial coverage of indicators within the Baltic Sea, the possibility of assigning subdivisions was given in the indicator catalogue. **Table 36** gives an overview of the available classes for spatial entries, which could be chosen for the Baltic Sea.

Table 36. Classes of marine subdivisions and optional member state subdivision for the Baltic Sea.

Marine subregion	Marine subdivision	Member state subdivision (examples)
Baltic Sea	Bothnian Bay (A 1.1.1)	
	The Quark (B 1.1.2)	
	Bothnian Sea (C 1.1.1)	
	Åland Sea (D 1.1.4)	
	Archipelago Sea (E 1.1.5)	
	Gulf of Finland (F 1.2)	

	Gulf of Riga (G 1.3)	
	Northern Baltic Proper (H 1.4.1)	
	Western Gotland Basin (I 1.4.2.1)	
	Eastern Gotland Basin (J 1.4.2.2)	
	Southern Baltic Proper (K 1.4.3)	
	Gulf of Gdansk (L 1.4.3.1)	
	Bay of Mecklenburg (M 2.1)	Federal states Mecklenburg-Western Pomerania and Schleswig-Holstein
	Kiel Bay (N 2.2)	
	Little Belt (O 2.3)	
	Great Belt (P 2.4)	
	The Sound (Q 3)	

As DEVOTES includes an indicator assessment for pilot areas in each regional sea, one purpose of the differentiation into subdivisions was to highlight potential indicator gaps for pilot areas. Unfortunately not every expert fully used the assignment of indicators to subdivisions. Nearly 50 % of the 168 indicators lack an entry for subdivisions and this includes a variety of operational indicators, for which the spatial applicability should be known.

As there are not experts representing each country and marine subdivision included in DEVOTES, there is a clear tendency of higher numbers of indicators for regions with expert participation. Analyses of indicators on subdivision level are therefore not very reliable.

In total 22 indicators, of which 50 % are operational, cover the pilot area “Gulf of Finland”. The strong emphasis on the upper levels of the food-web and the ecosystem is also evident for the Gulf of Finland: Six indicators are addressing marine mammals, two birds and five fish of which three are only relating to one fish species (sea trout). Five indicators cover the benthic communities: macroalgae and benthic invertebrate metrics WFD assessment. No real phytoplankton indicators have been assigned to the Gulf of Finland. Phytoplankton is only respected in the context of non-indigenous species, which are covered by four indicators.

The Southern Baltic Proper represents the subdivision covered by the highest number of indicators (45). Several experts have entered data for this subdivision resulting in that high number. Eight different WFD assessment systems for this area already exist. A variety of phytoplankton and zooplankton indicators is included for this subdivision and it should be checked if they are not also applicable to the Gulf of Finland. Also the northern subdivisions like Bothnian Bay and Sea as well as south-western subdivisions like Kiel Bay and Bay of Mecklenburg are covered by a variety of indicators (23–25).

Table 37. Number of indicators per subdivision, divided into indicators specifically addressing one pressure and indicators addressing further pressures in addition [sum (operational/under development/conceptual/no status)].

Subdivision	one subdivision	several subdivisions
Bothnian Bay (A 1.1.1)	0	24 (10/8/6/0)
The Quark (B 1.1.2)	0	24 (10/8/6/0)
Bothnian Sea (C 1.1.1)	0	23 (10/7/6/0)
Åland Sea (D 1.1.4)	0	6 (4/1/1/0)
Archipelago Sea (E 1.1.5)	0	19 (8/6/5/0)
Gulf of Finland (F 1.2)	1 (1/0/0/0)	22 (11/6/5/0)
Gulf of Riga (G 1.3)	0	8 (6/2/0/0)
Northern Baltic Proper (H 1.4.1)	0	23 (11/8/4/0)
Western Gotland Basin (I 1.4.2.1)	0	8 (7/1/0/0)
Eastern Gotland Basin (J 1.4.2.2)	0	10 (8/2/0/0)
Southern Baltic Proper (K 1.4.3)	11 (5/5/0/0)	45 (32/11/1/0)
Gulf of Gdansk (L 1.4.3.1)	0	3 (3/0/0/0)
Bay of Mecklenburg (M 2.1)	0	25 (21/3/1/0)
Kiel Bay (N 2.2)	0	24 (20/3/1/0)
Little Belt (O 2.3)	1 (0/1/0/0)	9 (8/1/0/0)
Great Belt (P 2.4)	0	8 (8/0/0/0)
The Sound (Q 3)	0	11 (10/1/0/0)

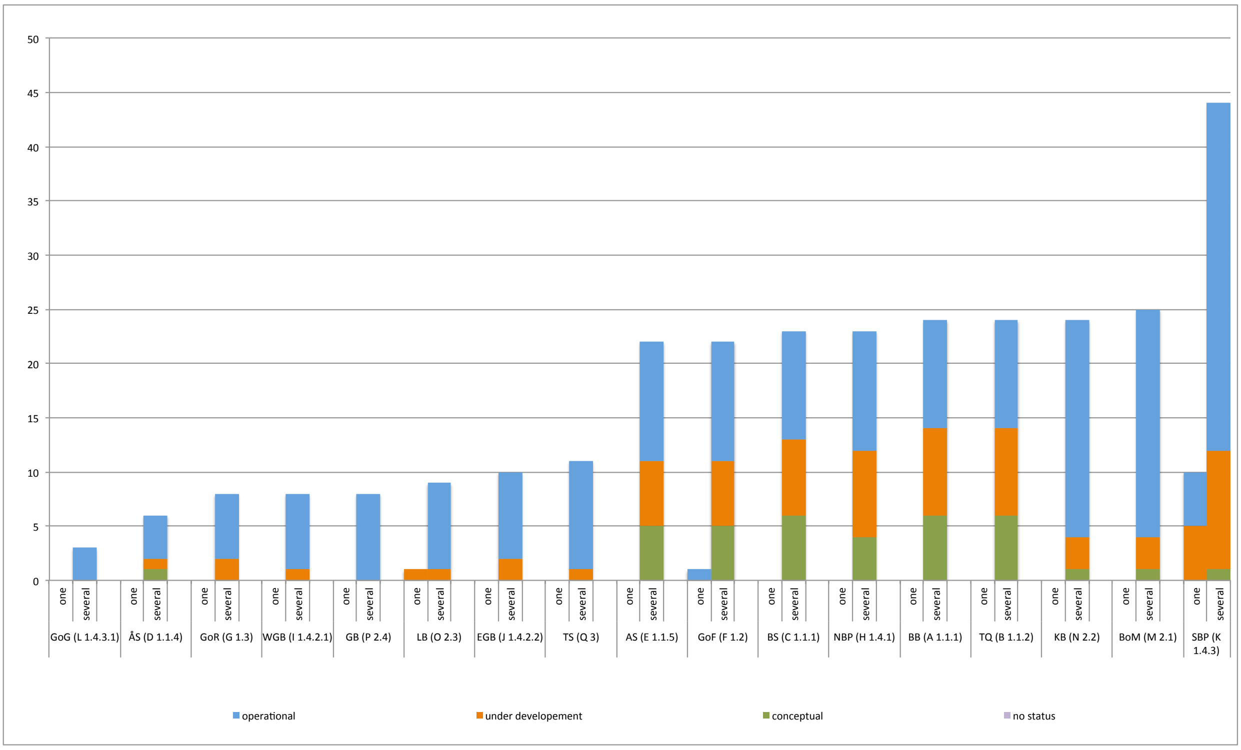


Figure 38. Number of indicators per subdivision with indicator status in ascending order, divided into indicators addressing one subdivision and further subdivisions in addition.

4.2.3. Gaps in the Baltic Sea

The Baltic Sea is one of the most intensively studied regional seas in the world. Some continuous datasets go back to the early 1950s. Despite this, substantial gaps in knowledge are still present. Gaps are discussed in the context of descriptors, criteria, biodiversity components, habitat types, pressures and regional subdivisions with respect to the ecosystem characteristics of the Baltic Sea.

Descriptors and criteria

No gaps could be identified on descriptor level. D1, D4 and D6 are each covered by high numbers of indicators. However, it can be argued that a higher proportion of D4 "Food-web" indicators should also address D3 commercial fish and shellfish, since the commercial fishery of the Baltic Sea largely targets species that are abundant and hence playing an important role also in the food-web dynamics, such as cod, sprat and Baltic herring which are key species in the Baltic pelagic food-web. Therefore, the link between and the compatibility of D3 and D4 indicators needs to be more closely scrutinized.

For D1 "biodiversity" a concentration of indicators related to criteria for species/population distribution and size was found. Although this matches the high conservation status of marine mammals and birds, which are mainly targeted by those indicators, and the long monitoring/assessment tradition for those groups, this also reveals an unbalanced consideration of the different Baltic Sea ecosystem levels. The bottom-up control of ecosystems need to be assessed as detailed as the top-down control. Indicators addressing the criterion "ecosystem processes" need to be developed to identify shifts in the ecosystem described in the ecosystem overview. Indicators for "ecosystem structure" should be developed that are specific to the Baltic Sea in order to meet the specific needs. Too few indicators are related to habitat extent (15). HELCOM has established a biotope classification based on EUNIS in 2013, which meets the specific classification criteria of the Baltic Sea and respects all biotopes of the Baltic Sea (HELCOM 2013a) and has performed a red list assessment for biotopes, habitats and biotopes complexes HELCOM 2013b). This classification and assessment could serve as the basis for mapping habitat extent of selected biotopes. E.g. there is a need for additional geographically representative field data on benthic vegetation and blue mussels to provide good coverage of a variety of different habitats. The extent of habitat-forming species relates also to D4 (abundance of habitat-defining groups) and D6 (biogenic substrates) criteria. However this repetitions and overlaps between criteria are also source of some critical aspects of the integrated MSFD approach. As noted earlier, macroalgae indicators exist for the Baltic Sea, but angiosperm indicators, suitable for soft bottoms, need to be developed.

For D2 "non-indigenous species" a sufficient number of indicators exist to assess the pressure aspect of this descriptor ("abundance and species characterization of non-indigenous species"). However, the status aspect ("environment impact of invasive non-indigenous species") of D2 is nearly missing completely. In the past, the focus was very often set only on the "impact" of those species on human activity, assessing or analyzing only the economic damage of shipworm *Teredo navali*s or fouling organisms like *Balanuns improvisus*. For the MSFD the focus has to be set on the "damage" to the ecosystem, which is, of course, a particular challenge as this implies that the natural ecosystem processes are known with a level of detail and understanding to evaluate the impact of non-indigenous species. E.g. in the Baltic Sea, it has been reported that the invasive polychaetes *Marenzelleria spp.* in fact reduces hypoxia and thus providing better environmental conditions also for native benthic species (Norkko *et al*. 2012).

Although the number of indicators for D4 "Food-web" shows no gaps, a strong concentration of indicators exists on the distribution of habitat-defining species. This results in a strong overlap with the D1 criterion "habitat/benthic species distribution" and the D6 criterion "biogenic substrates distribution/extent criteria". Although habitat-defining species might have their relevance for food-webs (as food resource, feeding, spawning and nursery ground for trophic groups) this complicates the gap analysis and the repetitions make the overall evaluation of GEnS difficult, as the risk of double assessments is high. Too few indicators exist covering the productivity criteria that are essential for the D4 "Food-web" descriptor.

The number of indicators for D6 "Seafloor integrity" seems to be sufficient. As already described before, a strong overlap with D4 and especially with D1 exists. To avoid double assessments, indicators for D6 should only focus on the pressure and status aspects of D6. There is a need to further develop indicators addressing the impacted area caused by different pressures to the seabed like bottom trawling, sediment extraction or construction activities (pressure aspect of D6). Nearly all of the existing indicators related the pressure aspect are in conceptual or in development status. To assess the status aspect of seafloor integrity, more focus on the condition of the benthic communities in relation to the physical damage is needed. The sensitivity of species or communities towards certain pressures or impacts should be pushed in the development. The criterion "distribution and extent of biogenic substrates" is too inefficient to assess the state aspect and is already part of D1.

Biodiversity components

So far, diversity of the biota of the Baltic Sea has been routinely described for dominant species of certain groups. Especially the number of indicators for marine mammals, fish and birds is high. As mentioned before, this reflects a one-sided picture of the Baltic Sea ecosystem. Smaller planktonic organisms, like unicellular and colony-forming picocyanobacteria, which could make up a substantial part of phytoplankton biomass or microzooplankton are certainly poorly studied. There is also a lack of information for groups such as bacterioplankton. This is reflected in the indicator set with missing indicators for microbes and a concentration of phytoplankton indicators on traditional monitoring subgroups like diatoms and dinoflagellates. Although mass occurrences of cyanobacteria during summer are a known phenomenon of the Baltic Sea, the catalogue includes no indicator relating to the cyanobacteria blooms or their relevance in nutrient cycling. A lack of zooplankton indicators could be identified in the general analysis and is also present for the Baltic Sea indicators. Zooplankton plays an important role as link for the Baltic Sea ecosystem between phytoplankton and the fish predators but also in nutrient cycling. The zooplankton sampling catches the mesozooplankton, most importantly copepods and cladocerans, but smaller zooplankton such as ciliates and flagellates may not be properly represented in sampling or in indicators. Also, the role of gelatinous zooplankton such as comb jelly (e.g. the Arctic comb jelly *Mertensia ovum*) and the common jellyfish (*Aurelia aurita*) is not sufficiently understood. Due to the brackish conditions of the Baltic Sea the ecosystems hosts a variety of higher plants typically distributed in freshwater. Those benthic macrophytes are naturally distributed within the shallow lagoons and bays of the southern and eastern coast, which partly face an extreme eutrophication pressure. This specific aspect of the Baltic Sea ecosystem is not reflected in the indicator set. The number of indicators for angiosperms is low, whereas the number of macroalgae indicators is extremely high. This may raise the need of a more balanced development or adjustment of indicators addressing the benthic macrophytes in respect to the key characteristics of the Baltic Sea.

Although seasonal ice cover is a typical phenomenon of the northern Baltic Sea no indicators for ice associated communities exist. The ringed seal gives birth to its young on nestls built on ice, and therefore should be considered as ice associated species, but it is not clear from the definitions given in the MSFD and interpretation reports (EUR 24337 EN - 2010), if there exists a specific need to assess those species and communities separately.

Habitat types

As there are no indicators addressing ice-associated communities, also no indicators are related to ice habitats. This needs to be discussed in accordance with the problem of ice-associated communities and needs to be adjusted in the indicator catalogue if necessary.

No clear gaps could be identified for bottom types. Although mixed bottoms are very characteristic for specific regions of the Baltic Sea and increase the biodiversity on the local scale, combining hard and soft bottom communities, this may not justify the development of specific indicators for mixed bottoms on a Baltic wide scale.

No gaps could be analysed for the shallow sublittoral. As the shallow sublittoral and littoral zone are not clearly distinguishable in the Baltic Sea the low number indicators for the littoral zone marks no gap. Only few indicators are addressing the shelf zone of the Baltic Sea. As oxygen depletion is characteristic for the shelf bottoms and the expansion of anoxic bottoms, as well as frequency and duration of oxygen depletion, seem to intensify, indicators specifically addressing the impact on benthic communities of this depth zone might be needed. This makes eventually an expansion of the benthic invertebrate component to meiobenthos necessary.

Pressures

The most relevant pressures for the Baltic Sea are covered by a large number of indicators. As the DEVOTES project is primarily targeting D1, D2, D4 and D6 indicators, the lack of indicators for many pressures is partly explainable. However, a contradiction is present in context with the pressures "physical damage", "physical loss" and partly also "interference with hydrological processes". Although many different indicators address those pressures, no indicators are present which are directly related to them. Although those pressures are regarded as major pressures for the Baltic Sea (HELCOM 2010), literature reviews do not indicate that they are relevant for the Baltic Sea ecosystem. To identify the impact of those pressures for the Baltic Sea ecosystem, there is an urgent need to develop indicators, which assess the pressure itself but also the specific sensitivity of the habitats and species towards those pressures.

Regional subdivisions – pilot area

Gaps on the subregional level are not very reliable, as the subregional aspect was not recorded for many indicators. Nevertheless, analysing the indicator set for the pilot area "Gulf of Finland" revealed at least some of the gaps already mentioned before. The focus on marine mammals is apparent, whereas the others trophic levels of the ecosystem and food-webs (as phyto- and zooplankton) are underrepresented or even not existent in the indicator set. This matches with the focus on species/population criteria, as mammals, bird and fish indicators have a large proportion. Indicators for benthic habitats are underrepresented. There are no indicators for angiosperms but several for macroalgae. There is also a gap regarding the food-web criterion "productivity" and the pressure aspect of seafloor integrity. It is obvious that there will be much more indicators applicable to the Gulf of Finland and that many gaps are just caused by an incomplete spatial assignment by experts. However, as some of the identified gaps match with the gaps analysis for the Baltic Sea and the general gap analysis, some relevance for the pilot area might be given.

4.3. Black Sea

4.3.1. Ecosystem overview

This ecosystem overview aims to outline the main features of the Black Sea ecosystem from the point of view of biodiversity, non-indigenous species (NIS), food-webs, and seafloor integrity.

Key characteristics and habitats

The Black Sea is an almost enclosed basin connected to the Aegean and Mediterranean Seas via the narrow Bosphorus Strait only. It covers an area of 436,000 km^2, volume of 555,000 km^3, and max depth of 2258 m, with a large variety of topography over narrow shelf areas except at the northwestern section where three large rivers flow in. Low surface salinity (average 18, maximum 22), presence of hydrogen sulfide and absence of oxygen at depths below 150 m (about 87 % of the volume) high freshwater input (especially in the NW part) draining through approximately 5 times area larger than the sea surface (Ludwig *et al*. 2009) and creating high vertical stratification are the unique features that precondition high productivity and low biodiversity of the basin as compared to the Mediterranean Sea. Shelf areas (depths up to 200 m) occupy up to 25 % of the total area of the seafloor with the greatest width (more than 200 km) in the north-western section of the sea. It reaches a few tens of kilometers of width in the western part of the sea, along the eastern and southern coasts the shelf is narrowest (only a few kilometers). The north-western shelf waters are profoundly influenced by water discharges of the three major rivers in the region (Danube, Dnepr and Dniester). The rivers' discharge is not only a key driver for ecosystem functioning on the shelf area where it results in high abundances of the main commercial fish due to high productivity conditions occurring in the near-shore waters, but also for all basins in terms of primary production. The shelf region also provides vital activity of the majority of the Black Sea benthic organisms.

As an isolated and unique inland sea, the Black Sea contains the Earth's largest permanent anoxic water body (Gray 2010). Deeper waters are mostly isolated from the direct influence of river's discharge and have a unique hydrographic regime. A sharp and permanent pycnocline lies between the low salinity surface waters of river origin and high-salinity deep waters of Mediterranean origin that restricts the penetration of vertical mixing depth up to 100–150 m. The world's only known active undersea river enables the entrance of Mediterranean waters with high salinity (~38) flowing along the sea bed into the Black Sea by carving out channels much like a river on the land with a flow 350 times greater than the River Thames (Gray 2010). As a result, a two-layered chemo-stratification is formed which the dissolved oxygen is depleted below the upper layer (150–200 m). Signature of the Mediterranean waters in the interior parts of the basin is best monitored within the uppermost 500 m depth, where the residence time of the sinking plume varies from ~10 years at 100 m depth to ~400 years at 500 m (Ivanov and Samodurov 2001). Anoxic condition in the deeper waters bounds the distribution of flora and fauna with the exception of sulphate-reducing bacteria that are the only population of bacteria known in the deep-sea bed and water column habitats below the 200 m isobaths.

From the 18 benthic habitats outlined in the MSFD, only 12 (from littoral to shelf sublittoral) are inhabited by benthic flora and fauna in the oxygenic bottoms of the Black Sea. Information available on the majority of the Black Sea seabed biotopes have been compiled and analyzed according to EUNIS classification in the frame of MESMA project (MESMA D1 Report 2010). MSFD related habitats (benthic and pelagic) have been identified only by the EU member states (BG and RO). However, maps of habitats distribution in the Black Sea are not available. There are no remarkable tidal fluctuations in the Black Sea due to deep-continental location, as for example in the NE Atlantic, where the extent of the littoral, infralittoral and circalittoral habitats are largely determined by gravitational forcing (MESMA 2010), and this property makes possible to use a comparison of simple bathymetric maps with a map of bottom sediments distribution for obtaining a generic overview about habitats distribution in the sea.

The littoral zone in the Black Sea is rather narrow and usually limited with the splash area. Typology of the sea coast is suitable for designation spatial distribution of the littoral rock and littoral sediment habitat types. In mountainous areas (eastern and southern coasts, southern coast of Crimea), abrasive coasts dominate. In plain and low areas, the coasts are mostly accumulative. Lagoon and deltaic coasts are confined to the areas near river mouths. The marginal zone of the delta of the Danube River is rimmed by lagoon sandy bars and low marine terraces (about 2 m high). Coastal bars (sandy and sandy–coquina) are low with feature widths of 40–100 m. At present, accumulative coasts are gradually receding (Ignatov 2008).

A shallow sublittoral zone in the Black Sea could be extended from the coastline down to 50 m isobath. Association with *Cystoseira spp*., *Phyllophora* beds, *Mytilus galloprovincialis* mussel beds on bedrock and boulders are the most important biotopes occurring on the shallow sublitoral rock. Sublittoral seagrass beds, *Phyllophora nervosa* on shell gravel, *Donax trunculus*, *Chamelea gallina*, *Lentidium mediterraneum* and *Lucinella divaricata* in infralittoral sands are the main biotopes of shallow sublittoral habitats in the Black Sea (MESMA 2010).

Shelf sublittoral habitats occupy seabed between 50 m down to upper boarder of H_2S zone (125–140 m). They are characterized by lower dissolved oxygen, higher salinity and lower species richness compared to the coastal habitats. *Modiolula phaseolina* and *Mytilus galloprovincialis* are the most important habitat-forming species here. Higher salinity (18.5) of deeper waters relative to surface waters makes possible the development of small echinoderms that occur only in this biotope in the Black Sea (MESMA 2010).

In the Black Sea, pelagic habitats, according to their physical, chemical and hydrographical conditions have not been sufficiently described yet. However, it is clear that the physical and chemical conditions in the close vicinity of the river mouths are strongly influenced by the freshwater input creating lower salinity, higher nutrient levels and poorer transparency that can be favoured by some specific pelagic communities, e.g. plankton and small pelagic fish species. Hydrographical, altimeter, CZCS and SeaWIFS data reveal quasi-persistent and/or recurrent features of the circulation system, the meandering Rim Current system with several anticyclonic eddies along the coastal side of the Rim Current zone, bifurcation of the Rim Current near the southern tip of the Crimea, presence of a large anticyclonic eddy within the northern part of the north western shelf that determine the cross coastal-open sea water exchange driven mainly by the freshwater plume (Korotatev *et al.* 2003). Monitoring by floating profilers shed new insights into the seasonal variability of the subsurface oxygen maximum and mesoscale variability (Korotaev *et al.* 2006; Stanev *et al.* 2013).

Black Sea coastal waters and the continental shelf are predominantly eutrophic (rich in nutrients), the central part is mesotrophic (medium level of nutrients) in character, and significant parts are hypertrophic (high level of nutrients). The largest hypertrophic areas are located in the north-western part of the Black Sea where influenced by inflows of rivers (Danube, Dniester and Dnieper). High levels of chlorophyll in addition to nutrients are also characteristic for these areas. Phytoplankton reacts to anthropogenic impacts by alterations in species composition and abundance as well as the timing and duration of blooming events. The status of phytoplankton and zooplankton can be assessed using a range of indicators including abundance, biomass and community composition.

Key biodiversity components

The most recent figure for the total number of species in the Black Sea provided by Zaitzev (2008) is relatively small and stands at ~3,770 spp. The majority of the biota are composed of species of Atlantic-Mediterranean origin (80 %) and the rest have freshwater or Ponto-Caspian origin (Shiganova and Ozturk 2009).

Phytoplankton

Much of the diversity of the flora is attributable to unicellular algae. So far in the Black Sea checklist are listed about 1608 species from 24 classes among them Bacillariophyceae and Dinophyceae, contribute to up to 80 % of the total species number. High nutrient levels provide competitive advantage for mixo- or heterotrophic dinoflagellates against autotrophic diatoms, as indicated by high dinoflagellate to diatom ratio (Humborg *et al.* 1997). Originally the Black Sea is much more productive with lower species diversity in comparison with the Mediterranean Sea. In the western Black Sea shelf, the revision of phytoplankton check list in 1980–2005 documented 544 species which means more than two-fold increase as there were 230 species identified during 1954–1980 period. This is due mainly to improved sampling strategy, advances in microscopy technology, higher sampling frequency, on-going changes environmental conditions and introduction of NIS. More than 3-fold increase in the abundance of Dinophyceae species is apparent evidence. In the Southern Black Sea, the most important change observed within the last 10 years was the slight domination of dinoflagellate and other micro-nannoplankton species. The increase in the dinoflagellates proportion could be related to the individual and combined impacts of the change in nutrient balance and the temperature regime (BSC 2008). Phytoplankton communities manifest high seasonal and spatial variability in species composition and abundance. Dramatic biodiversity/successional alterations especially during the period of intensive eutrophication were documented, shifts in Bacillariophycea/Dinophyceae biomass ratio in spring, additional phytoplankton blooms in late spring-summer, while the period after 2000 marked further changes related to both climatic sygnal and reduction of anthropogenic pressure, blooms of the prymnesiophyte species Emiliania huxley emerging as a recent recurrent feature of the ecosystem (BSC 2008; Finenko 2008; Mikaelyan *et al.* 2011; Moncheva *et al.* 2012).

Among phytoplankton taxa, the dinoflagellates globally have more than 200 potential toxic/harmful species (Sournia 1995). About 20 species are listed in Black Sea as potentially toxic, but only few cases of toxicity have been reported (Bargu *et al.* 2002; Vershinin *et al.* 2005; Ryabushko *et al.* 2008; Alexandrov *et al.* 2012). The harmful effects are associated mainly to hypoxia conditions during bloom events (BSC 2008). Some dinoflagellates produce resting stages, i.e. cyst forming species. Forming cysts, which is an ability to withstand against unfavourable conditions, also provides an important advantage against the competing conspecifics. Most of the invasive NIS is able to form cysts which enable them to be spread via ballast waters.

Benthic flora

Microphytobenthos is represented by ~800 unicellular algae species, dominated by diatoms. Whereas, the species list of macrophytes is restricted to ~330 species from Chlorophyta, Phaeophyceae and Rhodophyta division (Milchakova 2007) and one division of the higher flowering plants such as *Zostera marina* Linnaeus*, Z. noltii* Horneman*,* Ruppia spiralis, *Potamogeton pectinatus* Linnaeus ve *Cymodocea nodosa* (Ucria) Ascherson(Aysel *et al.* 2004, 2005a, 2005b, 2008; Gonlugur-Demirci and Karakan 2006). Recent studies in Turkey's Black Sea coasts, a total 258 taxa were identified representing five classes: Cyanophyceae (13 species), Rhodophyceae (140 species), Phaeophyceae (53 species), Chlorophyceae (50 species) and Charophyceae (2 species) (Aysel *et al.* 1996, 2000, 2004, 2005; Erdugan *et al.* 1996). With new additions of algal taxa, this number increased later to 297 (Aysel *et al.* 2004). Among macrophytes, a few genera, i.e., *Cystoseira*, *Phyllophora* and *Zostera*, form the main shelf communities and their states define the coastal ecosystems function. The most drastic change in these ecosystems in 1980s was related to the sharp decrease in diversity of macrophytes and almost total disappearance of perennial algae (BSC 2008). The major features of microphytobenthos during the last several decades were decrease in number of species, domination of fast growing small-sized species, decrease in community biomass and waning. Today, the *Cystoseira* zones are narrowed within inshore strips shallower than 10 m. As *Cystoseira* zones were declining, the blooms were dominated by opportunistic macroalgae species, i.e. mainly epiphytic filamentous algae. Another sign of the transformations in macrophytobenthic communities was the loss of *Phyllophora* in the region known as "Zernov's *Phyllophora* Field" in the northwestern Black Sea (BSC 2008).

Fauna

The fauna of the Black Sea includes more than 2000 species referring to 22 phyla (Zaitse 2008). In comparison with the Mediterranean Sea, the fauna is remarkably different with its low number of species and the disappearance or decline in diversity of many oceanic groups, such as Sponges, Salps, Pteropods, Euphausiids, Nemertini, etc. (Shiganova and Ozturk 2009). Low salinity and the existence of an anoxic zone are largely responsible for the faunal impoverishment. However, the low species diversity combined with high habitat diversity can provide favorable conditions for the introduction of alien species (Shiganova and Ozturk 2009; BSC 2010).

Zooplankton

Ciliates and other protozoans compose a significant part of the microplanktonic fauna. The species list of meso- and macroplankton consists of ~ 250 species (or ~190 marine species if freshwater ones are excluded) nearly a quarter of which is a meroplankton. Copepoda and Cladocera are the most diverse groups of the zooplankton that can be preyed upon, and hence, they are crucial for the Black Sea food-web functioning. The Black Sea zooplankton community structure also exhibits a typical characteristic of higher abundance with lower diversity as compared with Mediterranean Sea. Many taxonomic groups such as Doliolids, Salps, Pteropods, Siphonophors, and Euphausiids which are widely distributed in the Mediterranean Sea are absent or rarely present in the Black Sea.

The drastic changes in species compositions among various zooplankton groups after the 1970s, onset of the eutrophication period, were the most important ecological observation implying structural and functional alterations in ecosystem. Some species completely disappeared (*Oithona nana* and *Acartia margalefi*), some dramatically decreased (*Anomalocera patersoni, Pontella mediterranea, Centropages ponticus*) while the others increased their abundance predominantly (*Aurelia aurita*, *Rhizostoma pulmo* and *Noctiluca scintillans*). These gelatinous planktonic species dominated the total zooplankton biomass by outbursts throughout 1980s (Shiganova *et al*. 2008). The zooplankton community has been also strongly affected by the outbursts of a ctenophore NIS, *Mnemiopsis leidyi*, after 1988 which puts intensive predation pressure on zooplankton (Vinogradov et al. 1989; Shiganova 1998). After 1998, *Mnemiopsis* biomass has started to be controlled by another NIS, *Beroe ovata* which praying upon it (Kamburska *et al.* 2006; Shiganova *et al.* 2008). Furthermore, some new copepod species were also established their population in the plankton fauna: *Acartia tonsa* and *Oithona davisae*, and recently, they are well distributed in the entire Black Sea.

Benthic fauna

In the Black Sea, the number of the benthic invertebrates species is several times as great as zooplankton ones. Sea worms Turbellaria, Nematodes, and Polychaetes are represented by no less than 450 species while bivalve mussels are about 100 species and most of them are sandy-bottom inhabitants. Among them, *Modiolus phaseolinus* is the most abundant species. A few species live on hard substrates such as widely spread *Mytilus galloprovincialis* and *Mytilaster lineatus*. The species diversity of these bivalve molluscs has declined about two-fold since the invasion of rapa whelk, *Rapana venosa*, in 1947. Gastropod molluscs are represented by 115 species. Among crustaceans, species belong to the orders of Isopoda (30 species), Decapoda (40 species) and Amphipoda (110 species) are widely distributed (Kiseleva 1979). The most remarkable changes in zoobenthos community during 1980s and 1990s in response to intensifying eutrophication and sustained organic enrichment of sediments were lower species diversity, declined abundance and biomass. The result was a more simplified community structure, domination of opportunistic and invasive species with higher abundance and lower biomass in total, increasing role of hypoxia-tolerant groups (bivalve molluscs), and population fluctuations with high amplitude (BSC 2008). On the other hand, the species diversity of zoobenthos is not known well along the Turkish coasts of Black Sea which is the longest segment. In the recent studies on zoobenthos 421 zoobenthic species, belonging 13 taxonomic groups are reported for Turkish coasts of Black Sea (Bat *et al*. 2011). The number of crustacean species comprises 69.8 % of the total number of Black Sea species (Gonlugur *et al*. 2004). *Ulva rigida* facies along coastline inhabits 115 faunal species (Gonlugur *et al*. 2004). The other suitable biotopes for zoobenthos, in particular for polychaetes, are *Cystoseira barbata* and *Mytilus galloproviancialis* facie (Cinar and Gonlugur 2005). An extensive review by Kurt Sahin and Cinar (2012), although it does not contain quantitative data, is an important reference for the Black Sea as the most up-to-date information on distribution of polychaetes all along coasts of Black Sea.

Fish

The Black Sea ichthyofauna includes nearly 200 species of cartilage and bony fish. About three quarters of them are marine species of Atlantic – Mediterranean and Boreal Atlantic origin. This group includes important commercial small pelagic planktivorous (sprat, anchovy) and pelagic (mackerels, *Scomber scombrus*, *S. japonicus*) and demersal fish (whiting, Merlangius merlangus *exinus*; turbot, *Scopthalmus maximus*) predators. The brackish-water species include 22 endemic and relicts that inhabit mainly the north-western shelf waters and/or waters near the Kerch Strait. Diadromous and semi-diadromous fish comprise 25 species and all have been profoundly affected by human activities. The loss of spawning and nursery habitats, established barriers on migration routes and over-fishing has resulted with heavily exploitation status of many valuable species including sturgeons (Acipenceridae), salmon (Salmo trutta labrax) and herring (*Clupea harengus*). Moreover, the occurrence seasonal migration of some larger predators such as bonito, Sarda sarda and bluefish, *Pomatomus saltarix*, has a very important role on the whole ecosystem function as well as on fisheries. The Black Sea is spawning and nursery ground for these two fish species.

Marine mammals

There are only four species of mammals in the Black Sea: three Cetacean (Odontocete) species - the bottlenose dolphin (*Tursiops truncatus ponticus*), the common dolphin (*Delphinus delphis ponticus*) and the harbour porpoise (*Phocaena phocaena relicta*) and one pinniped species, monk seal (*Monachus monachus*) which is on the verge of extinction. The population of dolphins in the Black Sea decreased from 1 million to less than 50,000–100,000 during 1950–1990 and still far from the state of recovery. The most common threats affecting cetacean populations are accidental mortality in fishing gears, habitat degradation causing the reduction of prey resources, water pollution and epizootics resulting in cetacean mass mortality events (ACCOBAMS 2012).

Sea birds

The Black Sea is located on the intensive East European migratory route of the birds and thus, Black Sea's ornithofauna is highly diverse. The river deltas, the numerous coastal swamps and lakes, the sea bays and the scattered islands in addition to the salubrious climate and the abundance of food provide ideal conditions for nesting, migration and wintering of thousands of seabirds (Nankinov 1996). The seabird fauna includes gulls (Larus) and terns (Sterna) which is enriched by numerous species of sandpipers and ducks during migration seasons (BSC 2007). More than 75 % of the Black Sea birds are concentrated in the coastal area of Romania, Ukraine and the Russian Federation from the Danube Delta to the Tamansky Peninsula in the Kerch Strait, and one third of their number inhabits the Danube Delta

(BSC 2007). In the Danube Delta there are 320 bird species including the most important species such as the pygmy cormorant, *Phalacrocorax pygmeus*: the red-breasted goose, *Branta ruficollis*; the white pelican, *Pelecanus onocrotalus*; the Dalmatian pelican *Pelecanus crispus*. The Southern Black Sea coasts (Turkey) also holds internationally important populations of Yelkouan Shearwater (Puffinus yelkouan), and the Mediterranean subspecies of the European Shag (Phalacrocorax aristotelis desmarestii). Puffinus yelkouan has recently been upgraded on the IUCN Red List to 'Near Threatened'. These two species are listed as Annex 1 species under the EU Birds Directive. Seabirds in the Black Sea region are protected in 22 parks, of which 6 in Bulgaria, 1 in Romania, 2 in Russia, 9 in the Ukraine, 2 in Georgia and 3 in Turkey, and these reserves are covering atotal area of ~ 10000 km^2 (Nankinov 1996).

Non-indigenous species (NIS)

Among NIS in the Black Sea, two thirds (68 %) are originated from the North Atlantic, 13 % are from the Indo-Pacific region, and 8 % from the Western Pacific. The main vector is by ship's ballast waters (Zaitsev and Ozturk 2001).

Main negative ecological effects of NIS are:

- Competition with other organisms
- Predation
- Hybridisation;
- Toxicity (HABs caused phytoplankton such as *Chattonella verruculosa*)
- Providing a reservoir/vector for parasites and pathogens
- Altering energy and nutrient flows (via nitrogen fixing)
- Altering the local food-web (i.e. shifting from suspension-feeding to deposit feeding)
- Altering the composition and functioning habitats and ecosystems (i.e. invasion, over growing and blocking water bodies)

Finally, all these effects can cause or lead to the extinction of native species (Kettunen *et al.* 2008).

Regarding invasion incidents, Global Invasive Species (GISD) and the EU funded DAISIE are international and regional IAS databases with considerable coverage. Each has the list of "Top 100 of the world's worst invasive alien species", however, the difference in their contents of these lists is considerable. A striking example is the comparison of marine species listed for Black Sea. GISD's list has only two marine species, *Polysiphonia brodie*, a macroalgae (Rhodophyceae) and *Alexandrium minitum* (Dinophyceae), a micro algae. Whereas, the DAISIE's list has 5 species, *Balanus improvises*, a barnacle (Crustacea), *Crassostrea gigas*, an oyster (Mollusca, Bivalvia), *Mnemiopsis leidyi*, a jellyfish (Ctenophora), and *Rapana venosa*, rapa whelk, (Mollusca, Gastropoda). According to Cinar *et al.* (2011) the list of macroalgae NIS species from the Turkish coasts of Black Sea are Rhodophytes *Asparagopsis armata, Colaconema* *codicola, Ganonema farinosum, Polysiphonia fucoides, Polysiphonia* paniculata, Heterokontophytes *Ectocarpus siliculosus* var. *hiemalis, Halothrix lumbricalis, Pylaiella littoralis, Punctaria tenuissima,* and Chlorophytes *Codium fragile* subsp. *Fragile, Ulva fasciata*.

Among alien zooplankton species two have become central to the Black Sea ecosystem in the last 2 decades, *Mnemiopsis leidyi* is notorious for its detrimental effect on the pelagic food-web and fisheries collapse, and *Beroe ovata* reputed to be assisting in the restoration of ecological balance by reducing the former through selective predation on it (Shiganova 2001; Kamburska *et al.* 2006; Shiganova *et al.* 2008).

The Japanese snail *Rapana venosa* is a habitat generalist and exploits practically every available prey. It has occupied an empty ecological niche in the Black Sea and has exerted significant predatory pressure on the indigenous malacofauna. Demand for Rapana meat on the international market increased the commercial value of this resource initially within Turkey (1980s) and then in Bulgaria (1990s) (TDA 2007; Konsulova *et al.* 2003).

Main pressures

There are six countries surrounding the Black Sea: Bulgaria, Georgia, Romania, Russia, Turkey and Ukraine. Nearly 18 sectors operate within the region that are exploiting the marine resources and are contributing to the current status of the ecological components. Among them shipping, fishing, agriculture, tourism, land based industry and infrastructure are the most important for the economic development of the region (Knight *et al.* 2011). The main anthropogenic impacts are eutrophication through agriculture, industrial activity and inputs of insufficiently treated sewage; contamination through input of harmful substances and especially oil products via maritime acitivities; introduction of alien species and destructive fishing practices (BSC 2008).

The north western shelf of the Black Sea is the most impacted region. First of all due to riverine discharges of Danube, Dnieper and Dniester which collect industrial, domestic, and agricultural runoff of more than 162 million people (Mee 1992). Nutrient surplus could lead to undesirable events through eutrophication, which can result in ecosystem disturbance and loss of biodiversity (BSC 2008). The discharges from rivers also deliver different contaminants that are accumulated in the shallow sediments, which results in additional stress on the biota.

Alterations in nutrient ratios have led to a change in community structure of the phytoplankton. Intensive and unregulated fisheries activities have led to over-exploitation of major fish stocks. The populations of several commercial and non-commercial species are in unfavourable status and/or exhibit serious abundance declines. Some relative recovery of populations has been observed since the mid-1990s. Commercial fishing led to mass destabilization of the marine food-web with the removal of important top predator fish species which drive the cascading alterations in the ecosystem along with the anthropogenic eutrophication (Llope *et al.* 2011). This was a factor in the rapid expansion of the invasive ctenophore, *Mnemiopsis leidyi* and reductions in native plankton species (Knight *et al.* 2011). Two invasive NIS, ctenophore *Mnemiopsis leidyi* and rapa whelk *Rapana venosa* have historically caused serious widespread ecological problems in the region. The ctenophore *M.leidyi* affected the physical properties by reducing the water transparency, and more significantly the biological properties by causing a cascaded effect through all trophic levels. It also had a positive feedback effect on the microplankton growth which caused excessive mucous excretion and led to more abundant bacteria population and hence, of their ciliates and zooflagellates predators (Shiganova *et al*. 2004). Despite a reduction in *M. leidyi* abundance after the introduction of ctenophore *Beroe ovata*, another NIS, it is still widely distributed and continues to cause local impacts in the region. The rapa whelk had put enormous predation pressure on the blue mussel *Mytilus galloprovincialis* beds, however the fishing pressure developed on rapa whelk provides a partial recovery for a new steady state for the stock of blue mussel stocks but which is far from the previous levels. Almost all marine mammal species in the Black Sea are in danger in terms of population size and distribution and have the potential to reach to state of extinction within the next decades. Most of the coastlines have been subject to anthropogenic pressures resulting in a decline in diversity and reduction in status, despite the extensive efforts for protection of habitats and management plans.

In addition, the entire planktonic system has been affected by the climatic signals - severe climatic cooling regime in the 1980s followed by similarly strong warming regime of the 1990s and the early 2000s (Oguz *et al.* 2006; Moncheva *et al.* 2012). Climate records dating from the 1950s indicate that winter temperatures have decreased along the Black Sea coast since 1951, but summer temperatures have increased in the western and southeastern regions (Tayanc *et al.* 2009). Since the 1960s, heat wave intensity, duration, and frequency have increased six to sevenfold (Kuglitsch *et al.* 2010). Autumn precipitation has increased in the interior and winter precipitation has declined in the more populated west.

A potential future threat is nuclear contamination and thermal pollution from Turkey's first nuclear power plant to be constructed at Sinop on the Black Sea coast Akkuyu (Ozyurt *et al.* 2001; Cigna *et al.* 2002).

The Sea of Marmara ecosystem overview

Although the Sea of Marmara is not currently considered an EU marine area, and thus not legally obliged to implement the MSFD, it is of extreme ecological importance for both the Mediterranean and Black Sea to which it is connected. Therefore an overview was also included in this report. Moreover, Turkey is a candidate country to the EU.

The Turkish Straits System (TSS, including the Bosphorus Straits, Sea of Marmara and Dardanelles Straits), together with the NE Aegean area, which is naturally connected, forms a "natural laboratory" with different water masses (Zervakis and Georgopoulos 2002). The less saline, colder and lighter, mesotrophic Black Sea waters (BSW) are exported southwardly to the upper layer of the Sea of Marmara, the dense Mediterranean waters originated from Levantine basin (Levantine Water, LW) of Aegean Sea enter the Sea of Marmara basin through the Dardanelles Straits and sink to a depth corresponding to its modified density and expand northwardly to Black Sea, as a function of seasonal input flux variations and interior stratification (Besiktepe *et al.* 1994). As a result, the Sea of Marmara presents a two-layer stratification system, driven by the density difference between the Black Sea and the Aegean Sea waters. In the Black Sea, fresh water sources have paramount importance for the two-layer stratification system. Because in the Black Sea, the Danube itself contributes about 210 $km^3\ yr^{-1}$ of water discharge, which is more than entire freshwater supply to the North Sea, additionally Dnieper and Dniester deliver about a total of 60 $km^3\ yr^{-1}$. The two-layer system finally reaches the saline, denser oligotrophic waters of the Aegean Sea. In the opposite direction a 10–20 m thick halocline separates cool, nutrient rich, brackish waters (salinity 22–26) in the thin upper layer of the Sea of Marmara (15–20 m) from the saltier, warmer and nutrient poor waters (salinity 38.5–38.6) in the massive lower layer throughout the year (Bizsel 1988; Besiktepe *et al*. 1994). The net inflow of fresh water to the Black Sea provides a barotropic pressure gradient across the Bosphorus, leading to southerly flow of less dense surface water. In opposite direction an underflow of dense water arises due to baroclinic pressure difference caused by the salinity difference between the Sea of Marmara and the Black sea. Along the way, the properties of the surface Black Sea water progressively change through encounter and diffusive mixing with the deeper layers of Levantine origin; referred to as modified Black Sea Water (MBSW). The brackish Black Sea flow spends 4–5 months (on average) in the productive upper layer of the Sea of Marmara during its transit to the Aegean Sea. The underflow spends about 6–7 years in the deeper layers of the Marmara basin (Besiktepe *et al*. 1994).

The Sea of Marmara is an intercontinental basin with the complicated bathymetry, with some 11 500 km^2 in area and total volume 3,378 km^3, plus the Bosphorus (average depth 35 m) which connects it to the Black Sea, and the Dardanelles (average depth about 50 m), which connects it to the Aegean Sea. There is a wide continental shelf (< 100 m depth) in the south, while in the north there are three depressions over 1000 m deep (maximum depth 1273 m in the central basin), separated by sills at around 700 m. The length of the Bosphorus strait is about 31.7 km. The width varies from 0.7 km to 3.5 km and the depth ranges between 25 m and 100 m (http://www-research.cege.ucl.ac.uk/Posters/2009PosterFair/PDF/64%20-S%20Hoarau.pdf). The water level difference between the Black Sea and the Sea of Marmara is on average about 0.33 m. When the water level difference of Bosphorus Strait exceed about 0.45 m the lower layer flow will be blocked by the barotropic pressure gradient, whereas the upper layer flow will increase considerably and the velocity can reach 2.5 m s^{-1} in some parts of the strait. For water level differences below about 0.10 m, typically occurring during strong SW winds, the upper layer flow may be blocked. (Besiktepe *et al*. 1994).

Studies carried out during 1990–1998 in the Sea of Marmara revealed that the average phosphate and nitrate concentration ranges in upper layer were respectively 0.02–0.25 µM and 0.02–4.10 µM (Coban-Yildiz *et al*. 2000). This is not only because of nutrient richness in Black Sea originated upper layer waters during the period between the months of November and April, but also because of winter vertical mixing and seasonal deficiency in solar radiation. The average phosphate nitrate and reactive silicate concentration ranges at the lower layer were respectively 0.7–1.1 µM, 7.8–10.7 µM and 32–39 µM (Polat *et al*. 1998). The minimum values were usually measured at the southern areas close to Dardanelles Strait while the maximums were at the northern areas close to Bosphorus Strait.

Regarding particulate organic matters at the upper layer, the ranges of POC, PON and PP ranged between 10–35 µM, 0.4–4.5 µM and 0.05–0.45 µM during the period of 1990–1998 (Coban-Yildiz *et al*. 2000). The thinness (15–20 m) of the euphotic upper layer does not limit the POM content. Instead it enriches POM as a storage unit of trap for the sinking particles. The POM of the lower layer is mainly composed of the particles penetrated and sunk from the upper layer and the bacteria that use these particles as substrates. The N:P ratio at the upper layer ranges between 7–12, while it is quite similar for the lower layer with a slightly narrower range. The ratio is reasonably in balance with those of Mediterranean (Polat *et al.* 1998; Coban-Yildiz *et al.* 2000). This feature reveals that the primary production is limited by the nitrate and the poorness of nitrogen in content of the POM sink to the lower layer. The annual flows of TN and TOC into the Sea of Marmara from the Black Sea (mainly river-borne C and N) are about three times of those flowing in opposite direction.

The depth of 1 % surface irradiance in the NE Aegean Sea reaches the 80–100 m depth (Ignatiades *et al*. 2002) whereas in the Sea of Marmara the light penetration hardly exceeds 30 m (Ediger and Yilmaz 1996). It is therefore that the solar radiation can only penetrate down to the depth of permanent halocline and thus, the photosynthesis and related POM production are restricted with this depth. In the two-layered eutrophic system, the phytoplankton and detritus in the upper layer will gradually settle to the bottom layer and be degraded. Although the Mediterranean originated lower layer of the Sea of

Marmara is oxygen rich (7-9 mg L^{-1}) and have an average residence time of 6-7 years, this bacterial degradation of organic matters sinking from the upper layer causes rapid consumption of oxygen and the lower layer of the Sea of Marmara suffers from a persistent depression of oxygen to a concentration of 1–3 mg L^{-1} (fish begin to escape at about 4 mg L^{-1}). The oxygen concentration can drop down to the value less than 1 mg L^{-1} in the warmer waters along coastal areas particularly summer period. Despite the biological production in the surface waters of the Sea of Marmara has been increasing as result of the remarkable escalation in organic pollution level for last 30 years, the dissolved oxygen levels were not significantly different from the levels observed in 1970's and 1980's (Bizsel 1988). The impact of pollution were more prominent at the upper layer so that the thickness of euphotic layer decreased and the dissolved oxygen concentrations at the depths just below the halocline exhibited sudden drops which is referred as "oxycline" (Tugrul *et al*. 2000). The level of pollution is briefly summarized below:

- The main source of the pollution was the untreated domestic and industrial discharges
- Over 10.000 industrial establishments and human population over $25*10^6$ are the main drivers creating intensive pressures on the ecosystem of Marmara Sea. Within the frame of domestic discharges, it has been noted that 32% of the municipalities around the Marmara Sea currently have not a sewage system. The very same ratio is also valid for the all along the Turkish coastlines, which comprises 1257 municipalities within 28 provinces
- This ratio means that $537*10^6$ m^3 untreated wastewater (~$1.5*10^6$ m^3 per day) out of $2*10^9$ m^3 total wastewater (~$56.7*10^6$ m^3 per day) has been discharged annually to the marine environments surrounding Turkey
- Regarding industrial discharges, only in the scale of Istanbul province where 4500-5000 industrial establishments discharge $3*10^5$ m^3 wastewater per year, and 50% of this annual total is untreated
- According to the some recent studies (Pekey et al, 2004; Pekey 2006), Izmit Bay is the most prominent hotspot in Marmara Sea
- Moreover, the Marmara Sea has daily been receiving considerably high quantities of heavy metals such as 6.6 kg lead (Pb), 43.2 kg zinc (Zn), 1.9 kg copper (Cu), 209 kg chromium (Cr) and 5.1 kg mercury (Hg) in addition to 10.9 tons of nitrogen and 30.8 tons of solid wastes (www.bursa.bel.tr/marmara-ya-gunde-2-milyon-metrekup-evsel-atık-su-desarj-ediliyor/haber/10700)
- The total domestic discharges to Marmara Sea from the capital cities of 8 provinces, including Istanbul, Bursa and Izmit, is $2.1*10^6$ m^3

The chlorophyll maxima have been observed at the 15 m where the photic layer matches up with the halocline. In general, the observed chlorophyll maxima at the upper layer, e.g. up to 10 µg L^{-1}, were found in February and March at the depths where the light intensity ranges at the levels between 10–1 % of the surface equivalent (Polat *et al*. 1998).

The Sea of Marmara is characterized by eutrophication induced strong and extended phytoplankton blooms and complex ecosystem structure as compared to the mesotrophic Aegean Sea and the oligotrophic Mediterranean Sea. Apparent decreasing trends in phytoplankton biomass, abundance and production from the Sea of Marmara to the NE Aegean Sea are remarkable (Zervoudaki *et al*. 2011). For centuries the human activities in the Sea of Marmara, has been gradually intensified in the neritic waters, like in whole Mediterranean Sea, there has been a sharp increase in the frequency of blooms due to eutrophication, and those with toxic and harmful ones were more widespread in the eastern Mediterranean, Aegean, and Black seas during and after the World War II (Nümann 1955). At the end of 1950s, only a few species of dinoflagellates were thought to produce red tides and harmful effects (Acara and Nalbantoglu 1960). A review on plankton studies in the Sea of Marmara since 1990s, (Balkis and Aktan 2004; Uysal 1996; Uysal and Unsal 1996; Balkis 2000; Balkis 2003) and 11 toxic/nuisance phytoplanktonic species have been identified. Harmful but non-toxic blooms were also very frequent in the eutrophic Black Sea, Sea of Marmara, and the eastern Aegean coasts. Massive mucilage event has been occurred in the Sea of Marmara. Mucilage formation was first observed in the Sea of Marmara in October 2007 as dozens of square kilometers of the sea surface was covered by mucilage (GFCM:SAC 13/2011/Inf.17). Results showed that there was a decreasing pattern in phytoplankton abundance from August till October in 2007, thus pointing to the presence of a planktivorous species in high amounts. In 2005, dense distribution of a non-indigenous species the jellyfish *Liriope tetraphylla* has been detected at bloom levels particularly at the northern parts. The dominance of the species over other macro gelatinous species was 63 %. The species outnumbered the most common and dominant species *Aurelia aurita* and *Mnemiopsis leidyi* which the latter had caused a drastic collapse in Turkish fisheries in 1990s. In October, following the mucilage matter production another new species for the region *Gonyaulax fragilis* was observed through the basin. Overfishing in the Sea of Marmara provided a ground for invasive and/or opportunistic species and an increase in abundance of planktivorous species. As a result, *Liriope tetraphylla* became more dominant in the disturbed environment of the Sea of Marmara (Kideys *et al*.2013).

The Sea of Marmara is populated by species from the North Atlantic (34 %), East Atlantic (1 1.3 %), West Pacific (33 %), and Indo-Pacific (11.4 %) regions. Probably, most of them have been transported by ships, but some species, e.g. *Rhizosolenia calcar avis, Mnemiopsis leidyi, Rapana thomasiana, Scapharca inaequivalvis,* probably, were introduced with the water current from the Black Sea (Zaitsev and Öztürk 2001).

Regarding macro flora, there are 5 seagrass (Phanerogamae) species: *Posidonia oceanica*, *Zostera noltii*, *Z. marina*, *Cymodocea nodosa*, *Halophila stipulacea*) around Turkish Coasts. *Halophila stipulacea* is a non-indigenous lessepsian immigrant species which enters through Suez Canal. It had alredy reached down to the Dardanelles Strait yet there is no record from the Sea of Marmara. There are also two Black Sea originated sea grasses: *Ruppia spiralis* and *Potamogeton pectinatus*. *Posidonia oceanica* is very scarsely distributed in the Sea of Marmara. The first isolated bed of *P. oceanica* has been found in the central southern part of the Sea of Marmara by Yuksek and Okus (2004). After that Meinesz *et al*. (2009) made the distribution map of *P. oceanica* at Dardanelle strait and the Sea of Marmara (**Figure 39**).

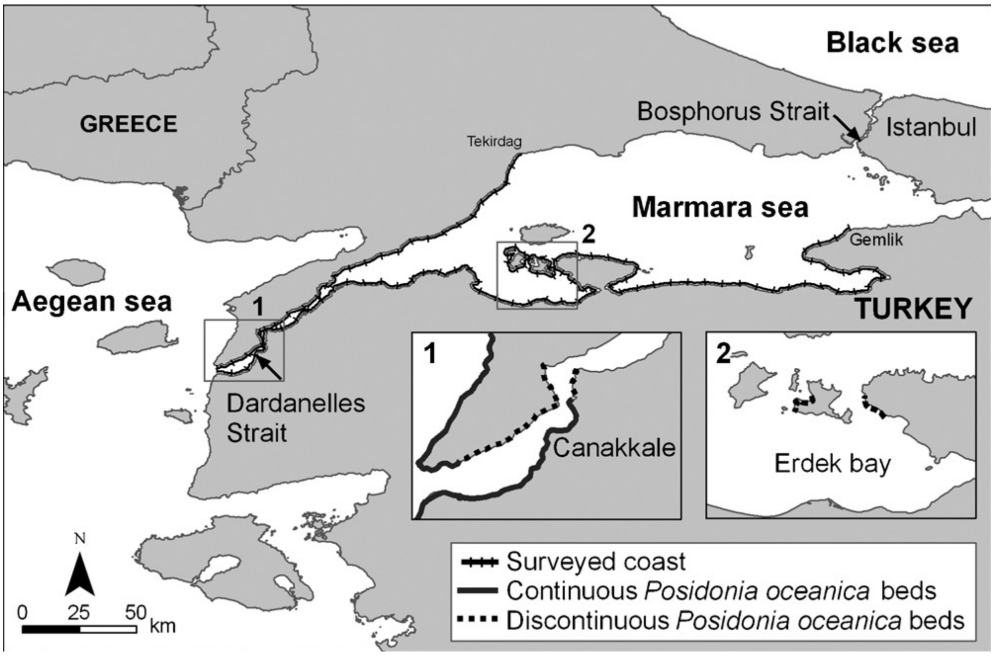


Figure 39. Distribution of *Posidonia oceanica* in the Dardanelles Strait and in the Sea of Marmara (from Meinesz *et al*. 2009).

According to Dural and Aysel (2007), there are 815 macroalgae species including subspecies levels such as varieties around Turkish marine waters distributed in four major taxa, however there is no any comprehensive study on their inventory and distribution in the Sea of Marmara. There are only some studies on the species which have economic importance (Aysel and Guner 1979, 1980, 1982).

There is no resulted research addressing the structure of macrozoobenthic communities in relation to environmental conditions in the Sea of Marmara. There are few studies on the taxonomy of certain benthic fauna. According to these studies, 77 species of Crustacean were identified (Bakır 2012), 22 species of 7 order of 5 classis also identified by (Palaz *et al*. 2010) in the southern part of the Sea of Marmara. 7 of exotic species of macro invertebrates were reported for the Sea of Marmara (Zaitsev and Ozturk 2001). Also, a special trophic relation on some symbiotic bivalves studied in certain cold-sweep in the Marmara basin (Ritt *et al*. 2010, 2012). Among the recent studies, since 2012, there is an ongoing project about biodiversity and the structure of benthic communities in the Sea of Marmara and straits supported by Turkish Science and Technology Research Council (TUBITAK-111Y268).

According to the Turkish Environment Ministry, 30 years ago, only along the Bosphorus, there were approximately 60 fish species. Out of those 26 were economically valuable, such as bluefin tuna, blue fish, swordfish, sea bass, sea bream, picarel, and mackerel. Today, their number is estimated as 20 fish and only 11 of those are economically important (http://www1.american.edu/ted/tunny.htm). More recent study reveals that fish species in the Sea of Marmara declined from over 100 species in the 1960s to tens of species today (Uras 2006). Among commercially important species, red porgy (Pagrus pagrus), leerfish (Lichia amia), forkbeard (Phycis phycis) are the most demanded ones. Nevertheless, the cause of the decline of these fish populations is not only related to overfishing, illegal fishing methods and ship originated pollution, but also to organic pollution, changing hydrological regime and other ecological factors. Regarding fisheries ecology, together with the straits the Sea of Marmara functions as a main passage and nursery ground for migratory species such as mackerel (Scomber scrombrus), bonito (Sarda sarda), bluefin tuna (Thunnus thynnus), bluefish (Pomatomus saltatrix) and swordfish (Xiphias gladius). However, it is very difficult to claim that the migrations of mackerel, bluefin tuna and swordfish have been regularly observed for the last few decades.

In spite of the severity of the impacts on ecosystem state of the Sea of Marmara, there are also promising developments in some major hotspots such as Golden horn and Izmit Bay. Today, several recreational activities like swimming, sports fishing are possible in these spots after some large scale environmental management initiatives was started (Tolun *et al.* 2012). An apparent recovery signs like local increases in the number of fish species and decrescent anoxic sea beds have been observed.

Hotspots

Izmit Bay is one of the most polluted and populated enclosed sea in Turkey. It has been the centre of industrial activities (more than 300 industries' effluents) for the last 30 years. Pollution problems have occurred since 1960. Since then, because of eutrophication, red tide mainly causing of Prorocentrum spp and fish mortalities, have been observed in some periods (Aktan 2005). In 1999–2000, 14 toxic/nuisance phytoplankton species were observed: *Ceratium furca*, *Dinophysis acuminate*, *D. acuta*, *D. caudata*, *D. sacculus*, *Gymnodinium sanguineum*, *Lingulodinium polyedrum*, *Noctiluca scintillans*, *Phalacroma rotundatum*, *Prorocentrum micans*, *P. minimum*; and diatoms *Pseudo-nitzschia delicatissima*. In addition to these species, *Prorocentrum lima* was also recorded as epipelic and epiphytic (on *Bryopsis hypnoides*, *Codium fragile*, *Cystoseira barbata* C. Agardh var. *barbata*, *Cymadocea nodosa* and *Zostera noltii*) in the littoral zone. *Prorocentrum lima* is a benthic dinoflagellate usually found attached to or associated with macrophytes, floating detritus, debris or other substrates and less commonly in plankton (Aktan 2005). Three major groups Dinoflagellata (about 60 %), Diatom (about 25 %) and others (about 15 %) were determined during 2009–2010 period (Kucuk and Aytekin 2011).

An extensive mucilage event in the Sea of Marmara, as mentioned above, was especially sighted in Izmit Bay in mid-autumn 2007 which extended from Izmit Bay to the Dardanelles during the calm weather period. It was denser and of longer duration in Izmit Bay, In February 2008 simultaneously with the diatom bloom (max value 3.9 x 106 cells L^{-1}), the dinoflagellate *Gonyaulax fragilis* became abundant in the mucilage, same as observed mucilage event in Adriatic Sea. Furthermore, a large scale increase of coccolithophores (especially *Emiliana huxleyi*) was also observed during the mucilage event off Istanbul. Four major mucilage event were recorded in the İzmit Bay (Sea of Marmara); October 2007, January 2008, September-October 2008 and December 2009. In almost all the recorded events, dinoflagellates either were more abundant or at comparable numbers with diatoms (all target species were recorded comparatively in higher numbers). Among them *Gonyaulax fragilis* or Gonyaulax sp. was distinctive. It can be concluded that in the Sea of Marmara, *Gonyaulax fragilis* has produced mucus (Tüfekçi *et al*. 2010).

Very recently, the System Approach Framework (SAF) has had positive effect on policy makers and urban planners concerning usefulness of science and policy integration for sustainable management of coastal zone (Tolun *et al.* 2012). Positive consequences of this progress is expected and monitored by all stakeholders.

Threats

The Bosphorus Strait, that is the seventh biggest chokepoint in the world's oil trade and industry, is highly narrow passage with a high risk of major maritime accidents to be resulted with massive oil spills. Turkey's densely populated coastal settlements have also initiated the acceleration of activities causing large-scale habitat loss, disturbance and pollution due mainly to rapidly increasing residential and tourism developments. The biodiversity of the Sea of Marmara has diminished significantly due to eutrophication and pollution from the industrial centers like Istanbul (Uras 2006; Güneralp *et al*. 2013). Sea grasses are key marine biogenic species in Turkey. *Zostera marina*, *Zostera noltii*, *Ruppia spiralis* and *Potamogeton pectinatus* occur in the Sea of Marmara and the Black Sea, *Posidonia oceanica* along the coastal waters of Aegean Sea and Eastern Mediterranean. All are declining. In Turkey marine environment plants and animal species are severely threatened by habitat degradation and destruction, pollution and overexploitation (especially overfishing). Species-specific studies show a decline in fisheries (Ozbilgin *et al*. 2004). Another important habitat-forming species is the Mediterranean mussel (*Mytilus galloprovincialis*) usually which densely covers large areas on the shallow rocky substrate in the Sea of Marmara and the Black Sea are under severe pressure of dredging and predation by an non-indigenous veined rapa whelk (*Rapana venosa*) which is considered among 100 worst non-indigenous species in Europe in Delivering Alien Invasive Species Inventories for Europe (DAISIE), (http://www.europe-aliens.org/).

Actually, the exotic and introduced species constitute an important part of Turkey's marine fauna. While introduced fish species often compete with and prey upon native species, other introduced taxa also have negative impacts on marine communities More than 380 marine exotics have been recorded, including 98 mollusc, 58 crustacean and 53 fish species (Cınar *et al*. 2005; Yokes and Galil, 2006; Zenetos *et al* 2008; Cınar 2009; Yokes 2009). Through the intensive maritime activity, the Sea of Marmara is open for different exotic aquatic organisms. The main factor related to this activity is the ballast water particularly which is a perfect media carrying cyst-forming dinoflagellates. Considering more than 80 marine and 15 freshwater species of modern dinoflagellates are able to form resting cysts (Kazumi and Yasuwo 2000), the possible risk of contamination can be imagined.

The protection of the biodiversity is important. This sea already suffers from the overfishing and pollution. Now 53 marine species are under the threat in the Sea of Marmara (Zaitsev and Ozturk 2001). Istanbul, which is Turkey's largest metropolitan city with a population of over 12 million, tries to solve its encountered environmental problems such as severe coastal erosion, shoreline recession and over pollution which it has been exposed to primarily in the last 20 years as a result of the coastal response to human activities.

A comparison was made between the usual fishing period (2006/2007) and the period within mucilage bloomed and caused a great loss in fisheries production (2007/2008). According to obtained data, the loss in amount of the landings and its corresponding cost was nearly three times of the one in usual period. The rate of loss was the highest in small pelagic fishes (purse seine fishery). This was followed by the fisheries of shrimp and demersal fishes (beam trawl and bottom trawl fishery). The jellyfish or algal blooms may be resulted in gelatinous masses affected the fishery areas of all the different levels which are inshore, offshore, surface, pelagic and benthic in the Sea of Marmara and a significant depletion occurred in fishery economics.

4.3.2. Indicators availability and capability

The following sections describe the indicators availability and capability of the Black Sea. A separate paragraph on the situation for the Sea of Marmara is provided on page 133.

Descriptors and criteria

In the catalogue 93 indicators are listed for the Black Sea. Out of these about 26 % (24) are operational, while most of them are under development (71 %), and only 3 (~3 %) are conceptual (**Figure 40**). The majority of indicators cover Descriptor 1 overlapping with Descriptor 6, about 19 % are related to D4 and less than 5 % to D2, most of which are under development.

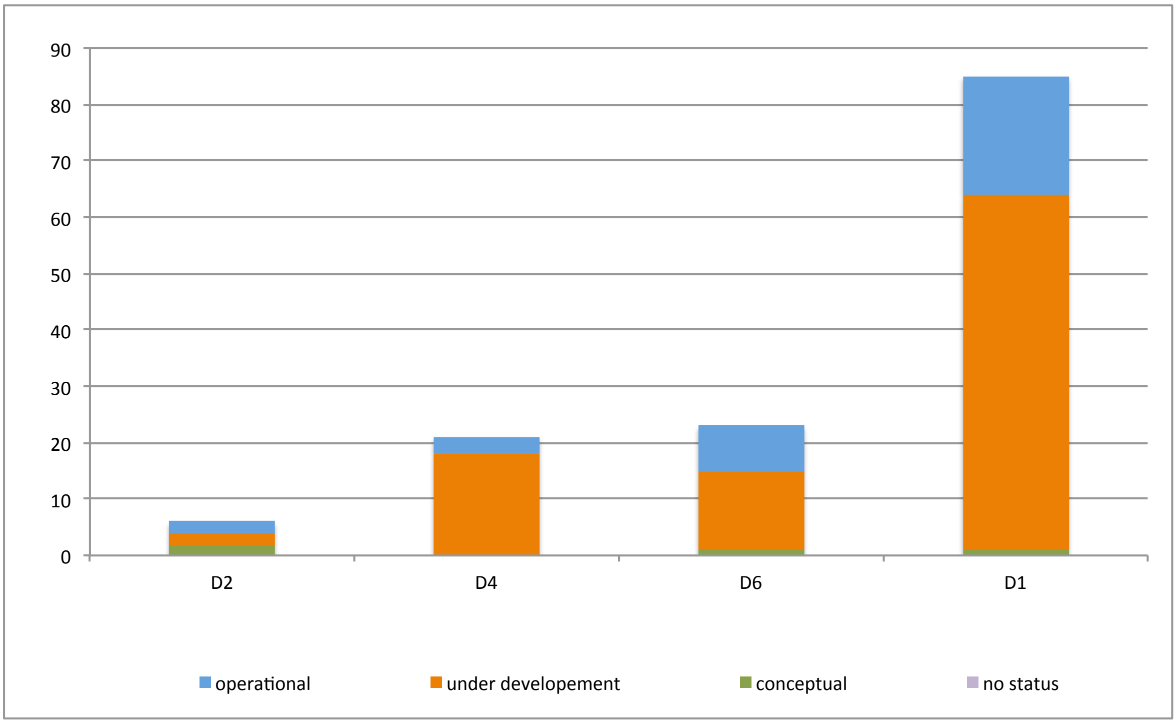


Figure 40. Number of indicators per descriptor in ascending order with indicator status.

Biodiversity components

Figure 41 shows the number of indicators targeting the different biodiversity components in the Black Sea. The highest number of indicators is relevant to benthic invertebrates (28) and phytoplankton (26). Then, 18 indicators are relevant to macroalgae, 15 indicators to zooplankton, 8 indicators to fish and 7 to Angiosperms. For the other biodiversity components there are less than 5 indicators. Most of the indicators are under development and the proportion is actually highest for the benthic invertebrates where only 4 indicators are operational. Among biodiversity components about half of the indicators are operational for macroalgae and a bit less for phytoplankton, while the proportion of indicators under development is between 45–100 % for all the other components. The higher proportion of operational indicators for macroalgae and phytoplankton could be related to indicators already implemented for the WFD.

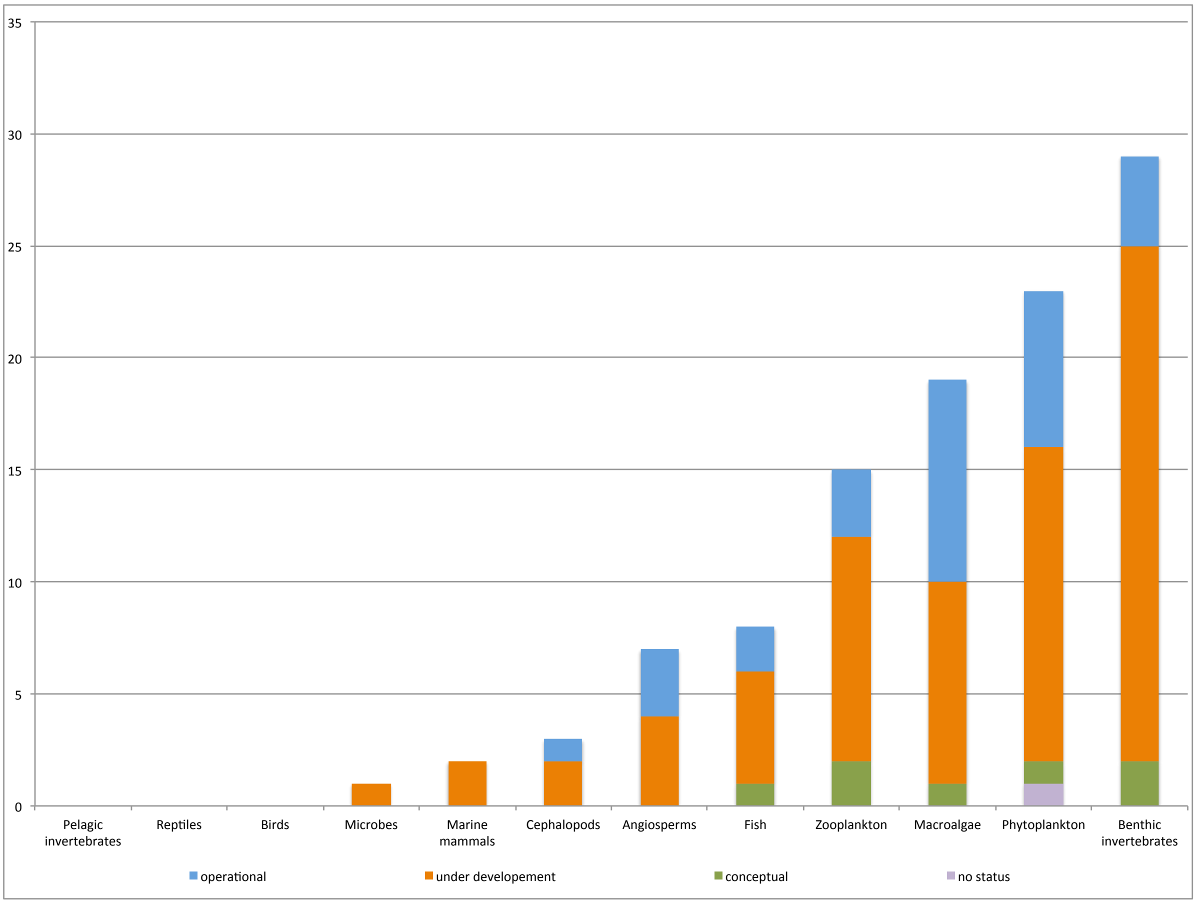


Figure 41. Number of indicators per biodiversity component in ascending order with indicator status.

Habitat types

Figure 42 and **Figure 43** show the number of indicators addressing the different habitats in the Black Sea. A higher number of D1 indicators is relevant to shelf marine waters (23) and coastal marine waters (15). For shallow sublittoral sand there are 15 D1 indicators listed in the catalogue, as well. Then, 11 indicators are relevant to shallow sublittoral rock and 7 indicators to littoral sediments. For the other habitats there are in general less than 5 indicators with exception of the littoral rock habitat, for which there are no indicators reported.

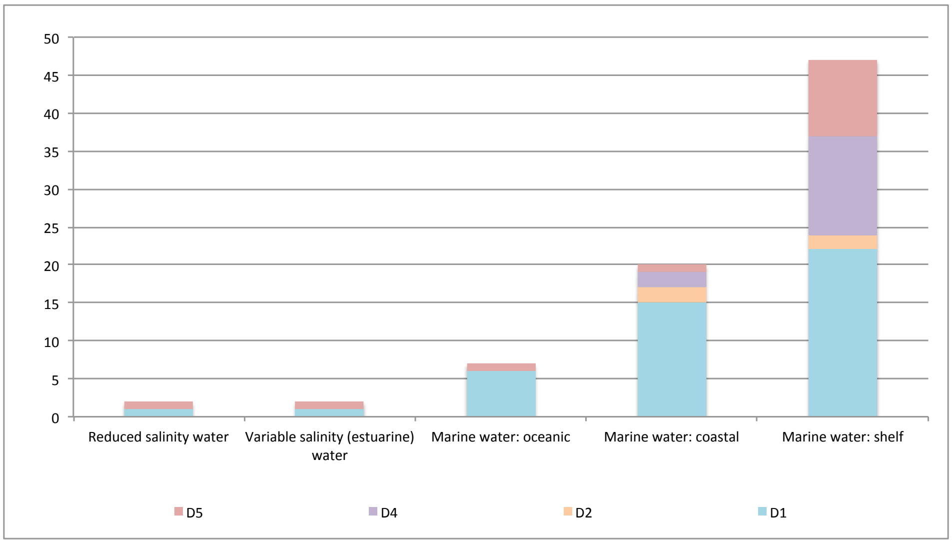


Figure 42. Number of indicators per water column habitat subtype in ascending order in relation to descriptors D1, D2, D4, D5 and D6.

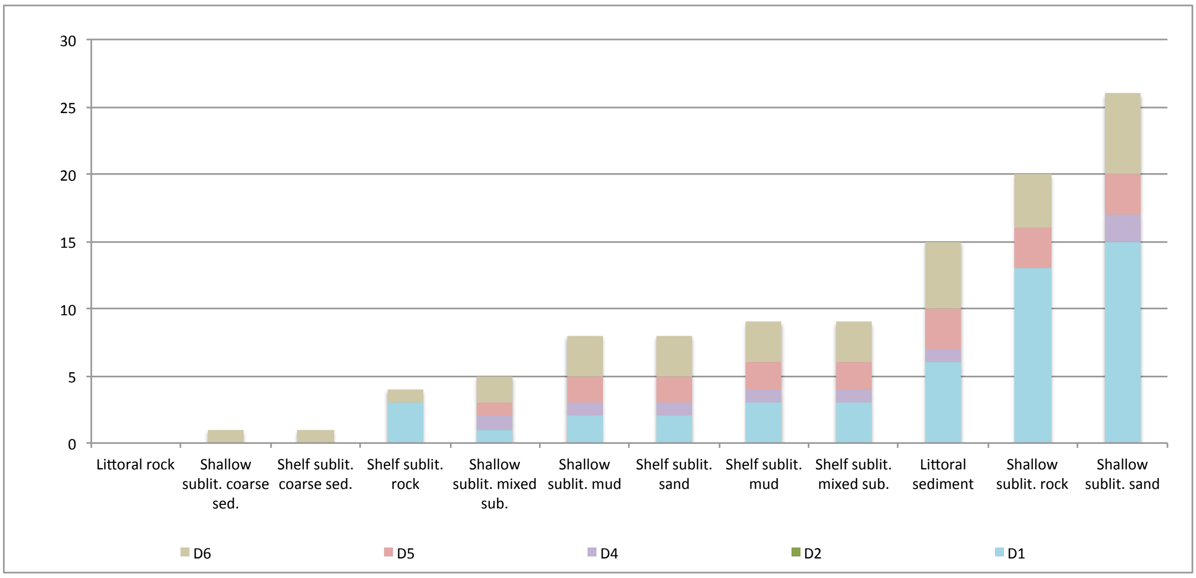


Figure 43. Number of indicators per seabed habitat subtype in ascending order in relation to descriptors D1, D2, D4, D5 and D6.

The relation between the different descriptors and the habitat types shows that the main part of the indicators are targeting descriptor D1 and are relevant to litoral sediments, shallow sublittoral rock, shallow sublittoral sand, shelf sublittoral rock, shelf sublittoral mixed sediment, variable salinity (estuarine) water, coastal, shelf and oceanic marine water. The other habitats are mostly covered by D6 (Seafloor integrity) indicators.

As expected, the proportion of taxon-specific indicators for seabed habitats is much higher (65 %) compared to the water column habitats (18 %). This reflects the natural features of the benthic communities as having more habitat-forming species (**Figure 44**).

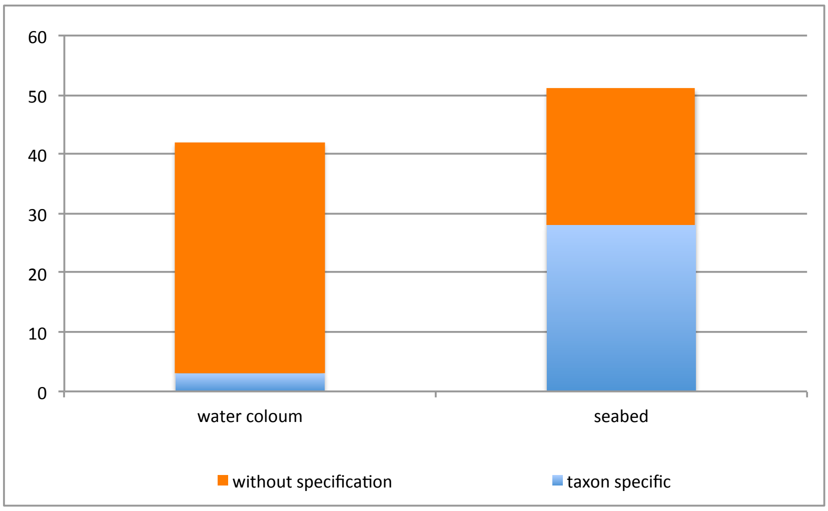


Figure 44. Number of indicators per habitat type, divided into taxon-specific and non-specific indicators.

Although the proportion of indicators listed in the catalogue with given target/threshold is high (over 50 % for water column habitats and 65 % for seabed habitats, see **Figure 45**) most of the target/threshold values are suggested in the literature or by expert judgment but without statistical validation.

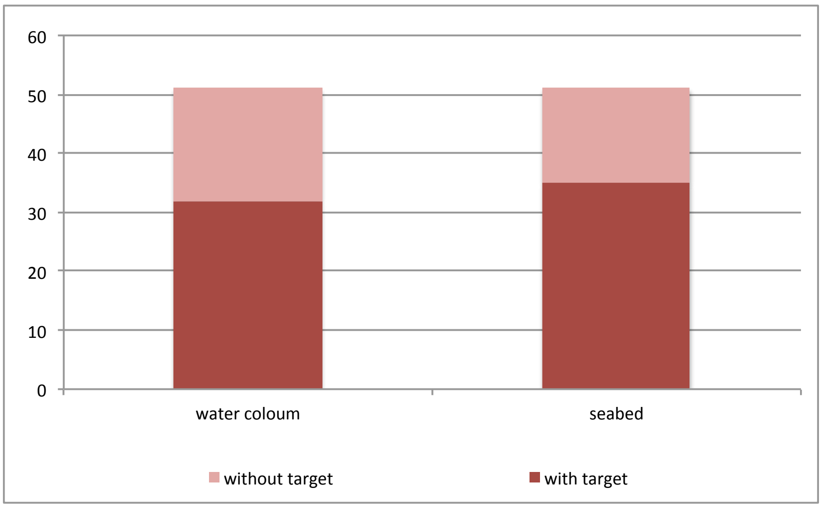


Figure 45. Number of indicators per habitat type, divided into indicators with existing target/threshold and without target.

This is well supported by the distribution of indicators by status among the major habitat groups (**Figure 46**). Both for seabed and water column habitats the number of indicators under development exceeds the operational ones (1.4 times for the seabed and about 2 times for water column habitats).

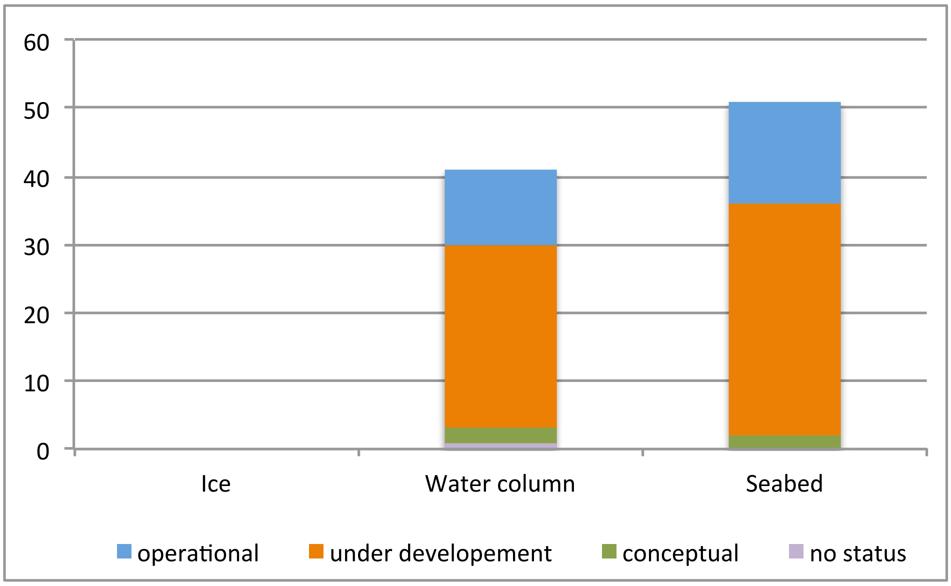


Figure 46. Number of indicators per habitat type in ascending order with indicator status divided into the three major habitat groups.

There is a high disproportion in the distribution of indicators among habitat types. In general, for most of them the number of available indicators is low or there are no indicators at all, which is reflected in the proportion of the indicators by status. Mostly the operational status is associated with multimetric/biodiversity indices (**Figure 48** and **Figure 48**).

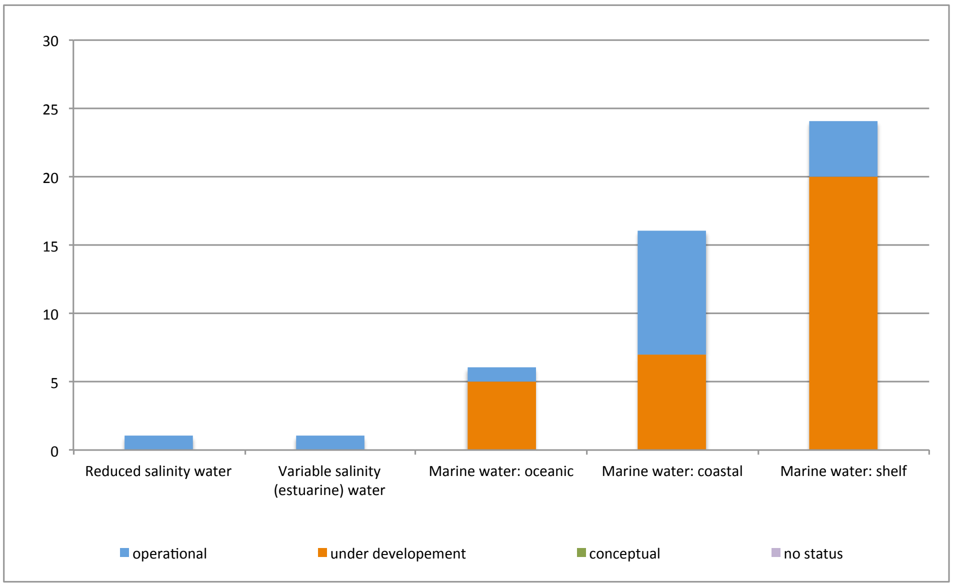


Figure 47. Number of indicators per water column habitat subtype in ascending order with indicator status.

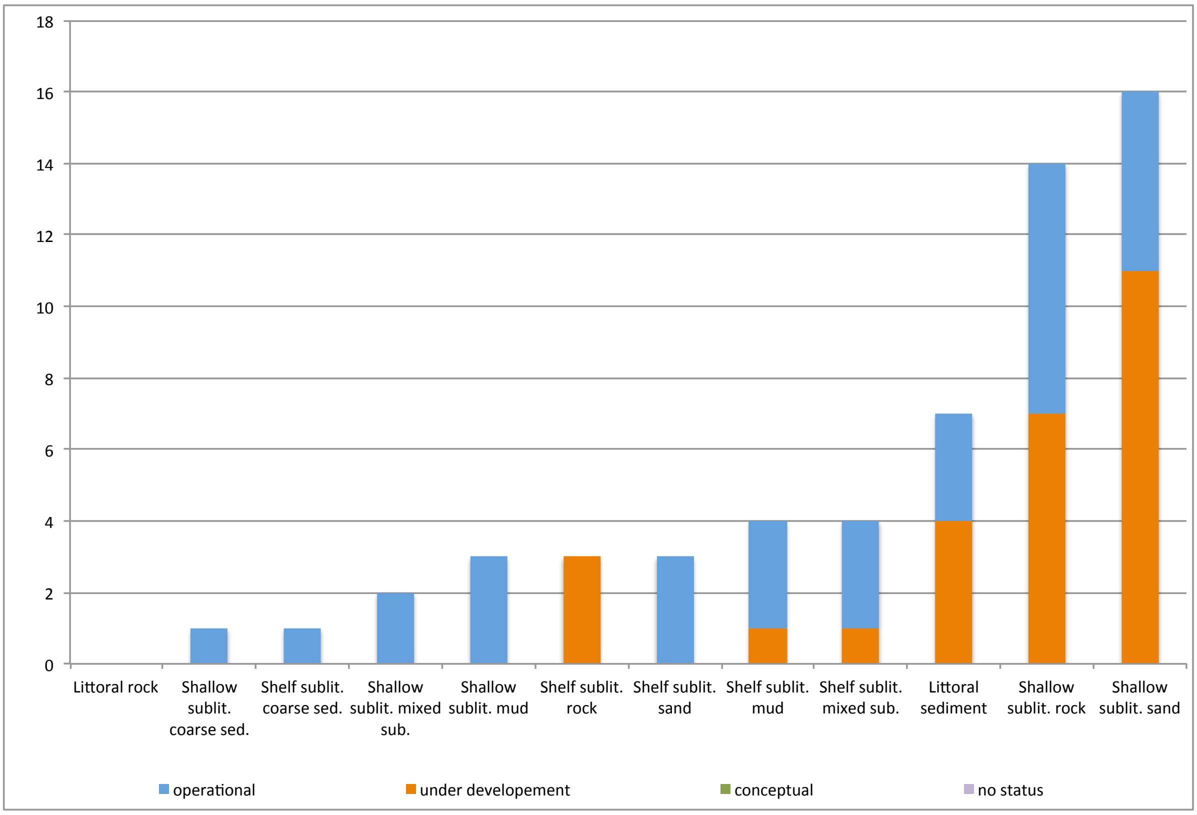


Figure 48. Number of indicators per seabed habitat subtype in ascending order with indicator status.

Pressures

The highest number of indicators (44) is related to the pressure “Nutrient and organic matter enrichment”. 18 indicators target “Hydrological processes”, 17 indicators “Physical damage” and 13 indicators “Non-indigenous species”. The remaining pressures are addressed by less than 10 indicators each. It should be noted that 16 indicators are sensitive to “Other pressures” which are mainly related to climate change.

The analysis of indicator status by pressures is rather unrealistic because not all indicators given in the catalogue are assigned to a pressure while on the other hand, one state indicator is related to several pressures (**Figure 49**). Even if the highest number of indicators are related to “Nutrient and organic matter enrichment” (44), which is the most studied pressure in the Black Sea and related to anthropogenic eutrophication, the number of operational indicators is not high (31 %). The low number of operational/under development status correspond to pressures that are less or even not studied in the Black Sea, such as “Marine litter”, “Marine acidification” and “Underwater noise”. Microbial pathogens are reported only for bathing water quality. Another reason is that the data for state indicators are rarely complemented by pressure data.

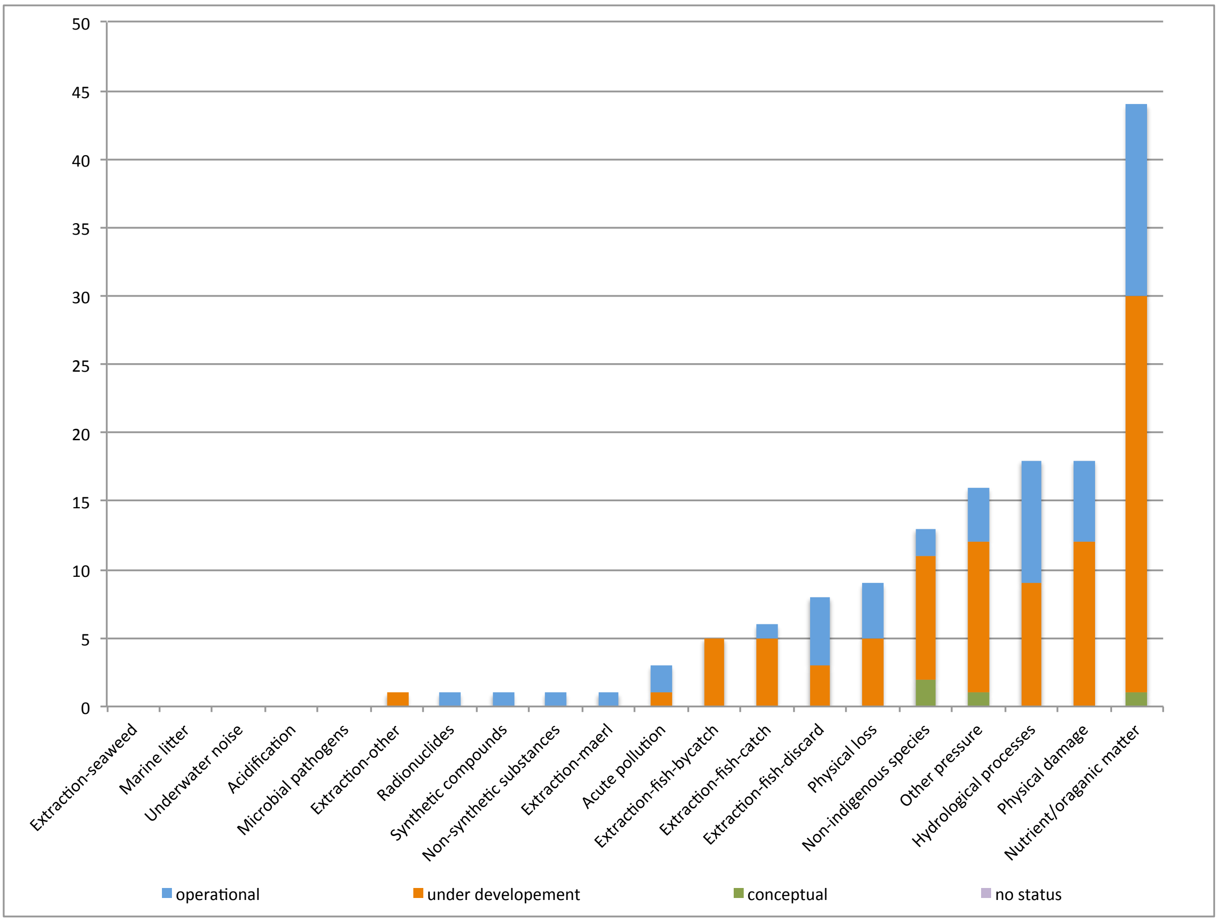


Figure 49. Number of indicators per pressure in ascending order with indicator status.

Indicators availability and capability – Sea of Marmara

Within the frame of the overview based on up-to-date literature, which is provided above, there is no comprehensive data set that enables us to analyze the biodiversity (within the context of MSFD Descriptors 1, 2, 4, and 6) since almost all available data sets, regardless whether they are accessible or not, are the ones that represents drivers and pressures rather that the state or impact. Nevertheless, there are some useful data on phytoplankton and zooplankton communities that can be processed with corresponding natural and human-induced drivers and pressures. However, it seems that this approach will provide information mostly related with eutrophication. The periodic range of the recording times of non-indigenous species, as an impact indicator, seems also exploitable via correlating with the data on relevant drivers and pressures such as eutrophication and the intensity of maritime traffic. For D6 “seafloor integrity”, although the data are so scarce and discrete, an ongoing research project which will end in 2015, covering the community structures and biodiversity of benthic systems in the Sea of Marmara and the straits, will produce the first and most comprehensive data set and information on the benthos of the Sea of Marmara (http://egefish.ege.edu.tr/detay/detay35/index.html). Regarding fish ecology and fisheries, the data sets are highly scattered and/or discrete but they may at least be sufficient for time-wise comparison of number of the species and their position in the food-web. In addition, the official data set on the variations in annual landing data of migratory species can be related to the relevant drivers and pressures, particularly with the meteorological and oceanographic fluctuations.

4.3.3. Gaps in the Black Sea

Most of the Black Sea countries have data from their national monitoring programmes and projects and also developed in the framework of the WFD and of the Habitat Directive implementation (for EU MS Bulgaria and Romania). Other data come from the Bucharest Convention or from scientific publications. However, there are many gaps for these biodiversity descriptors. Firstly, there is an important lack of data concerning offshore issues. The available data is limited to coastal waters, but this data is furthermore scarce, disperse and heterogeneous. There is lack of data on the extent, the intensity and the frequency of the pressures and on their impacts on biodiversity, as well as a lack of suitable monitoring network (Perseus Deliverable 5.2 2013).

At a regional level, the four priority transboundary problems for the Black Sea ecosystem outlined in the Black Sea Transboundary Diagnostic Analysis (TDA 2008) and by the Strategic Action Plan for the Environmental Protection and Rehabilitation of the Black Sea (SAP 2009) are: (1) eutrophication/nutrient enrichment, (2) changes in marine living resources, (3) chemical pollution (including oil), and (4) biodiversity/habitat changes, including alien species introduction. The Causal Chain Analyses in the 2008 Black Sea TDA found climate change to be a contributory factor to all four transboundary problems and concluded that the four transboundary problems cannot be dealt with individually. Even after emerging from its highly degraded state during 1980–1990s, the Black Sea ecosystem is still considered in a transitional phase which makes it particularly sensitive to external factors related to cooling and warming events (SoE 2008) as well as the continuous anthropogenic and natural pressures over the entire basin.

Understanding the value of all the various components of marine biodiversity (as the integrity of species, habitats, structure, function and the related ecosystem processes) it is essential if we are to minimise the negative impacts of human activities and adopt successful management policies.

In general, biodiversity in the Black Sea is fragmentarily studied:

- Data in the DEVOTES Catalogue of Indicators originate from two countries only (not representative enough), therefore gaps presented are based on expert knowledge rather than on a structured analysis of the catalogue itself
- Despite the recent progress in compiling Black Sea species check lists (phytoplankton, zooplankton, zoobenthos), comprehensive inventories of species are not finalized for some

groups (e.g. microzooplankton, meiobenthos). Also, there is no list of tolerant and sensitive species for all functional groups, which would be useful for biodiversity indicators calculation

- Serious gaps exist in the investigations of important phyla of marine biota (microbes and viruses, fungi)
- Many uncertainties exist in the proper taxonomic identification of species. Innovative methods of taxonomic revisions (genetic analysis) are of very limited application
- Deficiency in understanding the fundamental role of biodiversity for the ecosystem resilience and the provision of ecosystem services: energy transport through the food-web, plankton/benthic coupling, life cycle traits, role of secondary metabolites (infochemicals as mediators), functional biodiversity and synthesis of this knowledge into operation indicators addressing D4 (food-web), which are poorly represented in this catalogue
- Identify a list of habitats of regional Black Sea importance according to agreed common criteria
- Insufficiently studied biodiversity of specific Black Sea habitats such as gas seepages, mud volcanoes, oxic/anoxic layer, deep oceanic waters
- Insufficient development of indicators addressing criteria in Descriptor 1 with most indicators present for 1.6 "Habitat condition"
- Better understanding of the ecosystem structure and functioning supported by *in situ* experiments and integrated monitoring at required temporal and spatial scales would be of crucial importance to provide the information necessary to update the list and conservation status of BS threatened species, as well as their critical habitats
- Spatial distribution of benthic flora and fauna is inadequately studied, thus habitat mapping is not well advanced
- Gaps of adequate frequency and relevant data for indicators
- Lack of programmes to study invasive non-indigenous species
- Lack of targeted data for toxic phytoplankton species
- The available data are mostly limited to coastal waters and this data are furthermore scarce, disperse and heterogeneous
- Insufficient knowledge/data to address climate impacts on biodiversity
- Need to define scientifically sound baseline conditions for most of the indicators (taking into account the climate impacts)
- Gap in availability of pressure data to validate good indicators for state assessment (no integrated monitoring)
- Gaps in pressures addressed (marine litter, noise, synthetic and non-synthetic compounds)
- Lack of coherence between the different organizations at national level providing data (pressures/state variables)
- Lack of coordinated investigations at basin-wide scale (regional level)
- Lack of adequate equipment/ methodologies to generate comparative data sets
- Limited basin-wide applicability of indicators addressing Descriptor 6 (and not only) due to their relation only to regional specificities and mainly to coastal waters. The Black Sea should (due to its specificity) not be considered as one region (there are contrasting differences between NW and Eastern part, shelf and open sea which need specific approach)

Gaps in the Sea of Marmara

- No routine monitoring on any key species and/or habitats which are under impact of certain pressure(s) or which have pristine conditions
- Appropriately long and detailed time series data on phytoplankton and zooplankton are not available. Some discontinuous data sets for quite short periods are present thanks to the some discrete research projects which were carried out whether for academic purposes or environmental baseline and impact assessment studies specific to an impact source in a given area. Most are inaccessible or partly accessible
- Systematic and periodic biogeochemical observational studies with a carefully designed sampling strategy have to be programmed within the framework of international, multidisciplinary and multi-institutional research efforts
- Bio-monitoring studies for harmful and toxic species should be organized and continued routinely by responsible experts to prevent undesired effects on public health, tourism and aquacultural activities
- No appropriately designed comprehensive studies for monitoring and/or assessing the fishery stocks in Turkey have existed yet

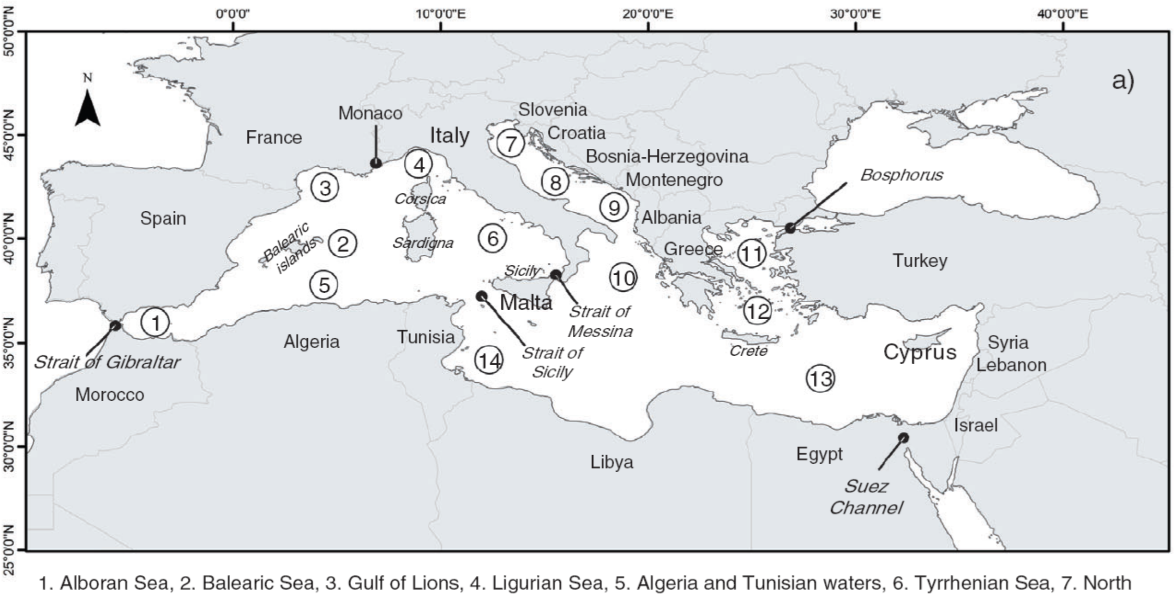
4.4. Mediterranean Sea

4.4.1. Ecosystem overview

This ecosystem overview aims to outline the main features of the Mediterranean Sea ecosystem from the point of view of biodiversity, habitats and impacts. The overview relies heavily on previous published work and reviews. This includes major regional resources (such as UNEP/MAP 2009, State of the environment and Development in the Mediterranean; UNEP/MAP-RAC/SPA 2010a, The Mediterranean Sea biodiversity: state of ecosystems, pressures, impacts and future priorities; UNEP/MAP-RAC-SPA 2010b, Fisheries conservation management and vulnerable ecosytems in the Mediterranean open seas including the deep sea; UNEP/MAP 2012a, State of the Mediterranean marine and Coastal Environment 2012; UNEP/MAP 2012b, Initial Assessment of the Mediterranean sea: fullfilling step 3 of the Ecosystem Approach Process UNEP(DEPI)MED IG.20/Inf.8), recent published biodiversity and impacts reviews (such as Coll *et al.* 2010; Danovaro *et al.* 2010; Coll *et al.* 2011; Micheli *et al.* 2013) as well as EU projects outputs (such as the DEVOTES Deliverable 4.1, Piroddi *et al.* 2013 on Available models for biodiversity and needs for development; the ODEMM Deliverable by Knights *et al.* 2011 on Sustainable use of European regional seas and the role of the Marine Strategy Framework Directive; the Perseus Deliverable by Laroche *et al*. (2013) on Identified gaps on MSFD assessment elements).

Key characteristics and habitats

The Mediterranean Sea extends from 30°N to 45°N and from 6°W to 36°E and constitutes the world's largest (2,969,000 km^2) and deepest (average 1,460 m, maximum 5,267 m) enclosed sea connected to the Atlantic Ocean by the Strait of Gibraltar in the west, to the Black Sea by the Bosphorus, and the Dardanelles in the north-east and to the Red Sea via the Suez Canal in the south-east (**Figure 50**, taken from Coll *et al*. 2010). Overall the basin is considered oligotrophic with some exceptions along coastal areas due mainly to river discharges (Barale and Gade 2008). Phosphorus, rather than nitrogen, is the limiting nutrient. Biological productivity decreases from north to south and west to east whilst an opposite trend is observed for temperature and salinity. In particular, the mean sea surface temperature varies between 14–16°C (west to east) in winter, and maximum of about 20–26°C (again, west to east), in summer (with the exception of the shallow Adriatic Sea where the range is between the 8–10°C of winter and the 26–28°C of summer) (Barale and Gade 2008). Evaporation greatly exceeds precipitation and river runoff and it increases from west to east, causing the water level to decrease and salinity to increase eastward (Coll *et al*. 2010). The surface waters have also high salinity values ranging between 39.1–39.3. In the upper part of the deeper layers (down to 700 m) less saline Atlantic waters, ranging between 36.5–38.6, are traceable before the winter convective mixing process prevails, nonetheless deeper layers always have lower salinity than surface waters (38.5–38.7) (Oguz ve Tugrul 1998). The Mediterranean Sea has a diverse continental shelf that varies from south (mainly narrow and steep) to north (wider areas); a few exceptions to this north- south rule are found, in the northern part, in few Turkish coasts, in the Aegean, Ligurian and northern Alboran Sea and, in the southern part, in Tunisia and near Nile Delta (Pinardi *et al*. 2006). Shelf waters represent 20 % of the total Mediterranean, the rest is open sea (Coll *et al*. 2010).



1. Alboran Sea, 2. Balearic Sea, 3. Gulf of Lions, 4. Ligurian Sea, 5. Algeria and Tunisian waters, 6. Tyrrhenian Sea, 7. North Adriatic Sea, 8. Central Adriatic Sea, 9. South Adriatic Sea, 10. Ionian Sea, 11. North Aegean Sea, 12. South Aegean Sea, 13. Levant Sea, 14. Gulf of Gabés.

Figure 50. Mediterranean biogeographic regions (from Coll *et al*. 2010).

The region is comprised of a wide array of habitats, including brackish water lagoons, estuaries, transitional areas, coastal plains, wetlands, rocky shores, seagrass meadows, coralligenous communities, upwellings, seamounts and pelagic systems (UNEP/MAP 2012a). Most of Mediterranean habitat research has been focusing on priority, endangered, threatened and in need of conservation marine habitats. The most typical such example is the *Posidonia* meadows, which is an Annex I Habitat Directive NATURA 2000 habitat, and a habitat under Annex II List of Endangered or Threatened Species of the SPA/BD Protocol under the Barcelona Convention. Posidonia is a EUNIS level-5 habitat (A5.535 Posidonia beds) while most of the recent habitat reviews/assessments recognize the lack of habitat data at grosser scales (e.g. EUNIS level 3) and at sea basin scales (Mangos *et al*. 2010). Mapping at EUNIS level 2 or 3 habitats as appearing in many MSFD related documents is mostly lacking for the Mediterranean and especially so for the Eastern and southern parts (but see EUSeaMap 2010 for significant progress made for the Western Mediterranean). Although UNEP 2002 and MESMA 2010 have very detailed descriptions for some of these biotopes at EUNIS level 3 or 4 or 5, the spatial aspects are often missing.

The Mediterranean is considered as being a hotspot of both terrestrial and marine biodiversity (Bianchi and Morri 2000; Meyers *et al*. 2000; Coll *et al*. 2010), hosting species of conservation priority, such as the bluefin tuna, *Thunnus thynnus*, and the Mediterranean monk seal, *Monachus monachus*, along with a high habitat diversity, such as the meadows of the endemic *Posidonia oceanica*. *Posidonia* is one of the leading Mediterranean ecosystems in terms of both biodiversity and as ecosystem goods and services provider including supporting a very number of marine species of the region as well as spawing and refuge habitat functions for commercial species, and water oxygenation and beach erosion protection services (UNEP/MAP 2009 and Mangos *et al*. 2010). *Posidonia* occurs in shallow waters (mostly up to 50 m depths but occasionally deeper too) in both soft and hard substrata and is found in most of the region although not everywhere (Giakoumi *et al*. 2013). *Posidonia* is considered a priority habitat under the EU habitats directive and the Barcelona Convention. The species and habitat is maybe the best studied and cited habitat in the region (UNEP/MAP 2009) while its distribution and extent is still not fully documented or known despite most recent mapping and modelling efforts (e.g. MESMA Project: MESMA 2010 and Salomidi *et al*. 2012; MEDISEH Project: MEDISEH 2013 and the NETMED Project: Giakoumi *et al*. 2013).

Coralline habitats harbour the most biologically rich communities in Europe (OCEANA 2006). In the Mediterranean corallogenic formations or reefs or concretions are built up through the accumulation of calcareous algae (mainly corallinales of the *Mesophyllum* and *Pseudolithophyllum* type), which are common throughout the basin with the exception of the Israeli and Lebanese coasts, at a depth of between 40 and 120 m, but also closer to the surface in caves, on the vertical walls and in poorly lit spots (Mangos *et al*. 2010). They provide a home for a vast range of sessile invertebrates (bryozoans, gorgonians, sponges) and comprise the second Mediterranean ecosystem in terms of biodiversity, with over 1,700 species, a high percentage of which are endemic. The species associated with the corallogenic reefs comprise 75 % invertebrates, 19 % macrophyte algae and numerous fish and small shark species. A large number of the species present are of commercial interest and their exploitation dates way back in history (e.g. sponges, red coral) (Mangos *et al*. 2010). Maërl beds, a type of corraline biogenic habitat, are comprised of unattached rhodolithes of coralline algae and the most important regional maërl-forming species are *Lithothamnion* corallioides and *Phymatolithon* calcareum (OCEANA 2006).

Recognizing their importance and the need for habitat restoration the COUNCIL REGULATION (21 1967/2006 EC) concerning management measures of the sustainable exploitation of fishery resources in the Mediterranean Sea, prohibits fishing with trawls and other towed gears above beds of *Posidonia oceanica* or other marine phanerogams, or above coralligenous habitats and mäerl beds. The regulation calls Member States to take appropriate steps to ensure the collection of scientific information with a view to the identification of habitats to be protected. However, knowledge and mapping gaps along with drive for growth prevent full implementation of this regulation.

While the Mediterranean Sea is one of the most intensively investigated areas of the world in both terrestrial and coastal marine biodiversity, it lags other regions of the world in studies of its deep-sea habitats and fauna (Danovaro *et al*. 2010). Beyond the 100 m isobath open seas in the Mediterranean cover a bit over 200,000 km^2 (Mangos *et al*. 2010) and a very significant part of its waters is characterised as deep sea (depths from over 200 m and stretching to over 5000 m) supporting a variety of habitats including open slopes, deep basins, canyons, cold seeps, seamounts, deep-water corals and deep-hypersaline anoxic basins. The Mediterranean deep sea hosts numerous sites of conservation interest as seen in recent proposals (UNEP/MAP-RAC-SPA 2010b; OCEANA 2011). A number of recent EU Projects sush as CoralFISH, HERMES and HERMIONE have contributed to the identification and mapping of vulnerable habitats such as deep sea cold water reefs and other deep sea biotopes in the Mediterranean.

Key biodiversity components

Currently approximately 17,000 species have been recorded in the Mediterranean Sea with a gradient of species richness that decreases from northwest to southeast (Bianchi and Morri 2000; Coll *et al*. 2010). Of these 17,000 species, at least 26 % are prokaryotic (Bacteria and Archaea) and eukaryotic (Protists) marine microbes. All of the biodiversity components, except Bacteria and Archaea, display a decreasing pattern with increasing water depth, but to a different extent for each component (Danovaro *et al*. 2010).

Phytoplankton is composed predominantly of Coccolithophores, Dinoflagellata and Bacillariophyaceae and includes more than 1,500 species (the majority of which comes from Dinoflagellata (45 %) and Bacillariophyaceae (49 %); macrophytes on the other hand are approximately 850 species with Rhodophyta constituting the most important taxonomic group (77 %) followed by Chlorophyta (22 %) and Magnoliophyta (1 %). Among microzooplankton, foraminifera is the main group with more than 600 species (Coll *et al*. 2010).

Generally, small phytoplankton taxa are the main phytoplankton biomass and production contributors in the eastern Mediterranean and in the north and south Aegean Sea (Polat 2006; Ignatiades *et al*. 2002; Siokou-Frangou *et al.* 2002). Usually, these ultra (or pico) phytoplankton are relatively numerous towards the bottom of the euphotic zone or in deep chlorophyll maxima (DCM). There is some evidence that they are adapted to low light in the green region of the spectrum (Glover *et al.* 1984). Heterotrophic microciliates may be important consumers of bacteria and ultra-phytoplankton.

Epipelagic mesozooplankton communities in the open Mediterranean Sea are highly diversified in terms of taxonomic composition, but copepods represent the major group both in terms of abundance and biomass. The dominance of small copepods (≤ 1 mm) in terms of both numbers and biomass represents the major feature of the structure of mesozooplankton communities at basin level. A few small-sized and species-rich genera of calanoids (*Clausocalanus* and *Calocalanus*, together with *Ctenocalanus vanus*) and cyclopoids (*Oithona*, oncaeids, corycaeids) account for the bulk of copepod abundance and biomass in epipelagic layers of the Mediterranean Sea (Seguin *et al*. 1994; Siokou-Frangou *et al*. 1997; Saiz *et al*.

1999; Andersen *et al*. 2001; Youssara and Gaudy 2001; Gaudy *et al*. 2003; Fernandez de Puelles *et al*. 2003; Mazzocchi *et al*. 2003; Riandey *et al*. 2005; Licandro and Icardi 2009). West-to-east differences in the percentage contribution of some important species to the whole copepod assemblage might reflect differences in species biogeography, but might also be indicative of different structural and functional features of these systems.

The majority of species (~11,500) are within the Animalia with the greatest contributions coming from the Crustacea (13.2 %) and Mollusca (12.4 %) followed by Annelida (6.6 %), Plathyhelminthes (5.9 %) and Cnidaria (4.5 %) (Coll *et al*. 2010). Annelida, mollusca and crustacea contribute to the Mediterranean fauna with approximately 5,500 species (Coll *et al*. 2010) while a total of 337 zoobenthic species within three main groups Polychaeta, Mollusca and Crustacea are reported along the Levantine coast of Turkey (Cinar *et al*. 2012). There are 650 marine species of fishes of which approximately 80 are elasmobranchs and the rest are mainly from the Actinopterygii class (86 %) (Coll *et al*. 2010). In the Eastern Mediterranean, due to the east-west gradient of both salinity and temperature, fish diversity decreases (Abdul Malak *et al*. 2011). There are 43 other vertebrate species comprising mammals, reptiles and birds. Nine species of marine mammals (five belong to the Delphinidae, and one each to the Ziphiidae, Physeteridae, Balaenopteridae, and Phocidae) and three species of sea turtles (the green *Chelonia mydas*, the loggerhead *Caretta caretta* and leatherback *Dermochelys coriacea* turtle) are encountered regularly in the Mediterranean Sea. Of these sea turtles, the green and loggerhead one also nest in the eastern part of the basin. Regarding seabirds only 15 species occur in the Mediterranean Sea, ten are gulls and terns (Charadriiformes), four are shearwaters and storm petrels (Procellariiformes), and one is shag (Pelecaniformes) (Coll *et al*. 2010).

Out of 5 biodiversity components (plankton, fish, marine mammals and reptiles, seabirds, and species listed under the Habitats Directive) marine mammals and reptiles and species listed under the Habitats Directive were scored as in high risk of failing to achieve GEnS in the Mediterranean Sea (**Figure 51**, Knights *et al*. 2011; Breen *et al*. 2012). A large number of species are characterised as under threat including the world's most endangered pinniped, the critically endangered Mediterranean monk seal along with a number of threatened species of sea turtles, whales, dolphins, skates, sharks and rays, several of these at critical risk of extinction (Cuttelod *et al*. 2009; UNEP/MAP 2009; Abdul Malak *et al.* 2011).

GES Descriptor	Problems	Areas of Concern	Risks to GES	Risk Confidence
1a. Plankton	Yes	Alterations in the dominance of plankton species are on-going, but no notable or maintained changes are occurring.	Moderate	Moderate
1b. Fish	Yes	30 species of cartilaginous fish in the Mediterranean Sea are current threatened with as many as 73% of bony fish outside safe biological limits. Trends indicate a decline in the abundance of many species	Moderate	Moderate
1c. Marine Mammals & reptiles	Yes	Several species of marine mammal and reptiles are currently threatened (IUCN criteria) with rates of decline in abundance and distributional range suggesting those species may be lost within the next 10 years	High	High
1d. Seabirds	Yes	60% of Annex II SPA-BD species (Barcelona Convention) are listed as threatened or endangered shown by reducing population (breeding) sizes, however, these species are not currently expected to be lost	Moderate	Moderate
1e. Predominant Habitats	Yes	Nearly all predominant habitat types in the Mediterranean are declining or exhibiting some degree of degradation with many in poor, endangered or unfavourable status	Moderate	Moderate
2. Non-indigenous species (NIS)*	Yes	There are a considerable number of invasive species in the Mediterranean that have resulted in widespread negative impacts on native species. Introductions continue to occur as a result of shipping, mariculture and entry via the Suez canal	High	High
3. Commercial fish and shellfish	Yes	More than 25% are exploited beyond sustainable levels, with most key pelagic and demersal species over-exploited and at high risk of stock collapse. Contributing factors include unregulated fishing practices, lack of enforcement, illegal gears and fishing and absence of management or protection measures	High	Moderate
4. Food webs	Yes	The prevalence of invasive jellyfish species and structure of top predators suggests that the Mediterranean food web is in an advanced state of degradation	High	Moderate
5. Eutrophication*	Yes	Algal blooms, hypoxia, eutrophication hot spots coupled with local oxygen deficiencies are of some concern, but due to low nutrient inputs and given the large area of the basin, eutrophication is a problem limited to sheltered marine waters such as harbours or bays and not expected to be of concern in the next two decades	Moderate	High
6. Seafloor Integrity*	Yes	Human activities such as agriculture, coastal infrastructure, fishing, navigational dredging, non-renewable energy (oil & gas), shipping, and tourism and recreation contribute widespread and persistent pressures that have detrimental effects on several aspects of the Mediterranean Sea ecosystem	High	Moderate
7. Hydrographic conditions*	Yes	Increases in sea surface and bottom temperatures indicate warming sea in conjunction with continued ocean acidification and increases in pCO_2	Not assessed	Not assessed
8. Contaminants	Yes	Heavy concentrations of some heavy metals are present in the region and concentrations continue to rise from transport introductions, however, other contaminants are declining e.g. Pb and PAHs.	Moderate	High
9. Fish and Shellfish Contamination	Yes	Concentrations of Mercury currently exceed benchmark dose limits (BMDL) and some heavy metals are high in concentration, but they occur from natural sources	Low	Moderate
10. Marine Litter*	Yes	More than 111 species of seabird and several species of marine mammals and reptiles have been reported to ingest marine debris. Although the amount of litter (number of items and mass) has reduced, shoreline and recreational activities continue to discard large volumes of litter in to the marine environment	High	High
11. Energy (Underwater noise)*	Yes	Trends indicate an increase in shipping activity leading to an increase in underwater noise throughout the region	High	Moderate
12. Habitats Directive Habitats	Yes	35% of habitats are in unfavourable status under at least one assessment criterion and over 40% declining in some aspect (e.g. range, area, structure and function, or future prospects). There is considerable uncertainty of the status of many habitats.	High	High
12. Habitats Directive Species	Yes	>50% of species are in unfavourable condition, with many species exhibiting declines across all assessment criteria (range, population size, habitat, and future prospects).	High	High

Figure 51. Areas of concern and risk to GEnS, from ODEMM (Knight et al. 2011). In RED as high risk: Mammals, NIS, D3, D4, D6, Marine litter, Underwater noise and Habitats Directive species and habitats.

Human activities and pressures on the marine environment

Historical and current pressures have caused major shifts in the Mediterranean marine ecosystems and the region has been characterised as a sea «under siege» (Galil 2000; Lotze *et al*. 2006; Coll *et al*. 2011; Micheli *et al*. 2013). With its densely populated and well visited coasts over the centuries this basin has been always subjected to human activities affecting/threatening its marine diversity. The most important threats in the region are habitat loss and degradation (through urbanization, industrialization, coastal infrastructure, shipping and tourism), pollution (including litter), harmful algal blooms, invasive species, overexploitation of marine resources, fisheries related impacts (unsustainable fishing practices, by-catches and discards, illegal fishing) as well as climate change (UNEP/MAP 2009; Coll *et al*. 2010; Costello *et al*. 2010).

Currently habitat degradation and loss is considered to be the most widespread threat due mainly to coastal development and pollution which are responsible for reducing the extent of marine habitats (e.g. seagrass meadows, oyster reefs and macroalgal beds) and a variety of dependent benthic organisms (such as bryozoans, sponges, echinoderms, benthic decapods) (Coll *et al*. 2010). At least one third of the habitats listed under the Habitats Directive are in unfavourable conservation status and predominant habitats exposed to a multitude of pressures are assessed as being at high and moderate risk of failure to achieving GEnS under the MSFD (Knights *et al*. 2011; Breen *et al*. 2012). The Mediterranean Sea is subject to pollution by sources either from land or from the sea; those related to land are relevant to agricultural, urban and industrial activities, while those related to the sea mostly concern maritime traffic activities. Chemical contamination of sediments and biota, along with the impact of marine litter concentrated especially in shallow areas and eutrophication, localized in semi-enclosed basins are regarded as issues of great concern across the Mediterranean due to their harmful impacts on the environment (UNEP/MAP 2012). Pollution affects and is of great concern not only for benthic organisms and their habitats but also for species at the top of the food-web (Borrell *et al*. 1997; Giangrande *et al*. 2005; Sanpera *et al*. 2007). In terms of eutrophication, although the Mediterranean is regarded as an oligotrophic basin, in coastal areas of large cities the impacts of nutrients and organic enrichment are more significant, especially in cases where waste waters are poorly treated. The North-western Mediterranean and the Adriatic Sea are considered as areas of high concern due to the impacts that organic contaminants in sediments have on benthic communities. Marine litter pollution is an emerging issue in the Mediterranean region, and most studies show that it is mostly accumulated in bays and coastal areas rather than the open sea (Galgani *et al*. 2010; Koutsodendris *et al*. 2008).

Exploitation of marine species is another important threat to marine biodiversity. In the Mediterranean Sea, several fish, macrophytes and a variety of invertebrates are highly exploited or overexploited (Papaconstantinou and Farrugio 2000; Lleonart and Maynou 2003). Additionally, unsustainable exploitation affects many of the commercially exploited fish stocks of the Mediterranean, causing shifts in species diversity, community structure and, thus affecting ecological processes. During the last half-century the mean trophic level of Mediterranean catches declined by about one trophic level, placing a great impact upon marine food-webs by reducing the abundance of large predator species (Pauly *et al*. 1998).

Bottom fishing and dredging have important impacts on the structure of benthic communities and sea-floor integrity, contributing to the degradation of the Mediterranean ecosystems (UNEP/MAP 2012). Deep water corals such as *Leptometra phalangium*, *Funiculina quadrangularis* and *Isidella elongata* are among the most vulnerable species to this kind of impacts in open seas (UNEP/MAP 2012). Fisheries also affect marine mammals, sea turtles and seabirds directly and indirectly through by-catch, direct killing and prey depletion (Tudela 2004). Several species of marine mammals and reptiles are currently threatened by IUCN criteria and suffering considerable abundance declines (Reeves and Notarbartolo di Sciara 2006; Cuttelod *et al*. 2009). Chondrichthyans (sharks, rays and chimeras) are at particular risk with at least 40 % of these classified as threatened by IUCN criteria (Cavanagh and Gibson 2007).

Bioinvasions and the increasing establishment of NIS is the most recently recognized pressure among the most important regional pressures (Coll *et al*. 201; UNEP/MAP 2012). To date, nearly 1,000 marine NIS have been introduced in the Mediterranean, of which more than half are considered to be established and spreading (Zenetos *et al*. 201; Zenetos *et al*. 2012). Marine NIS may become invasive and displace native species, cause the loss of native genotypes, modify habitats, change community structure, affect food-web properties and ecosystem processes, impede the provision of ecosystem services, impact human health, and cause substantial economic losses (Wallentinus and Nyberg 2007; Vilà *et al*. 2009). The 5 dominant groups among NIS are Mollusca (with 215 species), followed by Crustacea (159), Polychaeta (132), Macrophyta (128) and Fish (126). The majority of NIS occur in the eastern Mediterranean (775), whereas a lower number of species is present in the western and central parts of the basin (308 and 249 respectively), and even lower in the Adriatic Sea (190) (Zenetos *et al*. 2012). In terms of NIS richness there is a marked gradient from southeast to northwest. Very few NIS have been reported in offshore areas so far. More than half (54 %) of the marine NIS in the Mediterranean Sea were probably introduced by corridors (mainly Suez Canal). Shipping is the second most common pathway of introduction (49 %), followed by aquaculture (12 %) and the aquarium trade (2 %). The impact of invasive NIS in the Mediterranean has been severe and in some cases has greatly affected keystone species or entire ecosystem processes, while many NIS are considered habitat engineers and creators of novel habitats. For example several biotopes are affected by the coarse sea grape *Caulerpa racemosa* var. *cylindracea*, (Klein and Verlaque 2008; Katsanevakis *et al*. 2010).

The analysis of the spatial distribution and severity of these anthropogenic pressures shows the most severely impacted subregions or eco-regions by single stressors or cumulatively. The Levantine Sea is severely impacted by bioinvasions, and the Alboran and the Levantine regions have the highest average cumulative impacts (Coll *et al*. 2010, 2011; Micheli *et al*. 2013). Data on recent introductions of NIS (e.g. last decade) and trends since the 1950s in the temporal and spatial distribution of alien invasion in the Mediterranean clearly show the increased pressure for the Eastern Mediterranean MSFD subregion (Zenetos *et al.* 2012, **Figure 52**).

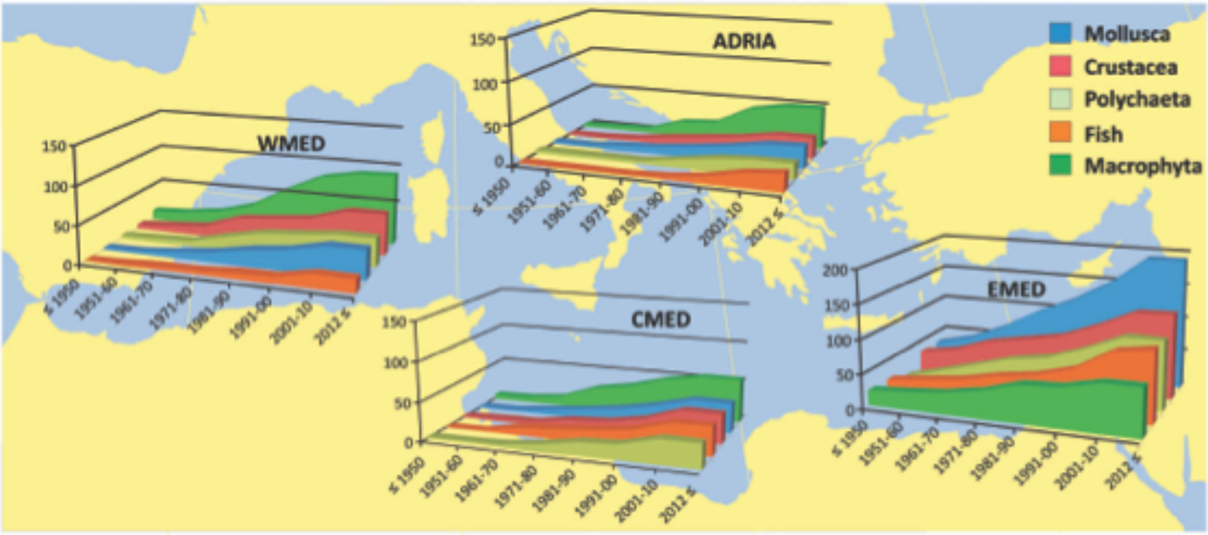


Figure 52. Non-indigenous species trends in the Mediterranean (from Zenetos *et al*. 2012).

Sea based activities result in higher scores in the western and southern regions, while land-based activities broadly affect coastal areas and large portions of the Adriatic (Micheli *et al*. 2013). Areas of potential high cumulative threats are widespread in both the western and eastern basins, with fewer areas located in the south-eastern region. A number of, spatially variable, high threat sector-pressure combinations have been identified in the region depending on their extent, frequency and severity of impacts along with resilience and persistence parameters (Knights *et al*. 2011, **Figure 53**). Spatial overlap of areas of both high biodiversity and high threats to various biodiversity components is seen in both the western and eastern basins (**Figure 54**) while climatic drivers have the greatest impact scores in the Eastern Mediterranean (Coll *et al*. 2011; Micheli *et al*. 2013).

High Threat Pressure Combinations following the Risk Assessment Criteria					
Criteria	**Extent**	**Frequency**	**Degree of Impact**	**Resilience**	**Persistence**
106 High Threat Pressure Combinations identified	1. Widespread 2. Widespread 3. Widespread	1. N/A 2.Persistent/Common/Occasional 3. Persistent/Common	1. Acute/Chronic 2. Acute 3. Chronic	N/A	1. Continuous/High 2. N/A 3. N/A
Summary of High Threat Sectors: • Aggregates • Agriculture • Aquaculture • Coastal Infrastructure • Fishing • Navigational dredging • Non-renewable energy (oil & gas) • Shipping • Tourism and Recreation	Sector-Pressure Ecological Characteristic Combinations with the categories defined above and taken from the Risk Assessment framework document. Combination 1: Sectors include Aquaculture, Coastal infrastructure; Fishing; Shipping; Non-renewable energy (oil & gas); and Tourism/Recreation. Pressures: Changes in wave exposure; Introduction of NIS; Introduction of synthetic compounds; Marine litter; Substrate loss; and Water flow rate changes. Combination 2: Sectors include Agriculture; Aquaculture, Coastal Infrastructure; Fishing, Navigational dredging; Non-renewable energy (oil & gas), and tourism/recreation. Pressures: Abrasion; Introduction of synthetic compounds; Marine litter; Selective extraction of non-living resources; Selective extraction of species; Smothering; and Substrate loss. Combination 3: Sectors include Aggregates; Agriculture; Aquaculture; Coastal infrastructure; Fishing; Non-renewable energy (oil & gas); Shipping; and Tourism/Recreation Pressures: Abrasion; Changes in wave exposure; Changes in siltation; Input of organic matter; Introduction of NIS; Introduction of synthetic compounds; Marine litter; Nitrogen & Phosphorus enrichment; Smothering; Thermal regime changes; and Water flow rate changes.				

Figure 53. Different High threat to GEnS sector-driver combinations in all predominant habitat types in the Mediterranean Sea (from ODEMM: Knight *et al*. 2011).

Figure 6 Global areas of conservation concern in the Mediterranean Sea where high biodiversity of invertebrates, fishes, marine mammals and turtles, and seabirds, and high threats overlap. The overlap index (*OI*) indicates areas where both species diversity and intensity of cumulative threats were: (a) ≥ 25% (OI_{25}), (b) ≥ 50% (OI_{50}) and (c) ≥ 75% (OI_{75}). 0 = no groups (of the four biodiversity groupings studied: invertebrates, fishes, marine mammals and turtles, and seabirds) show high diversity and high cumulative threats; 1 = only one group shows high diversity and high threats; 2 = two groups of the four show high diversity and high threats; 3 = three groups of the four show high diversity and high threats; and 4 = all groups show high diversity and high threats. Black circles indicate cells with data.

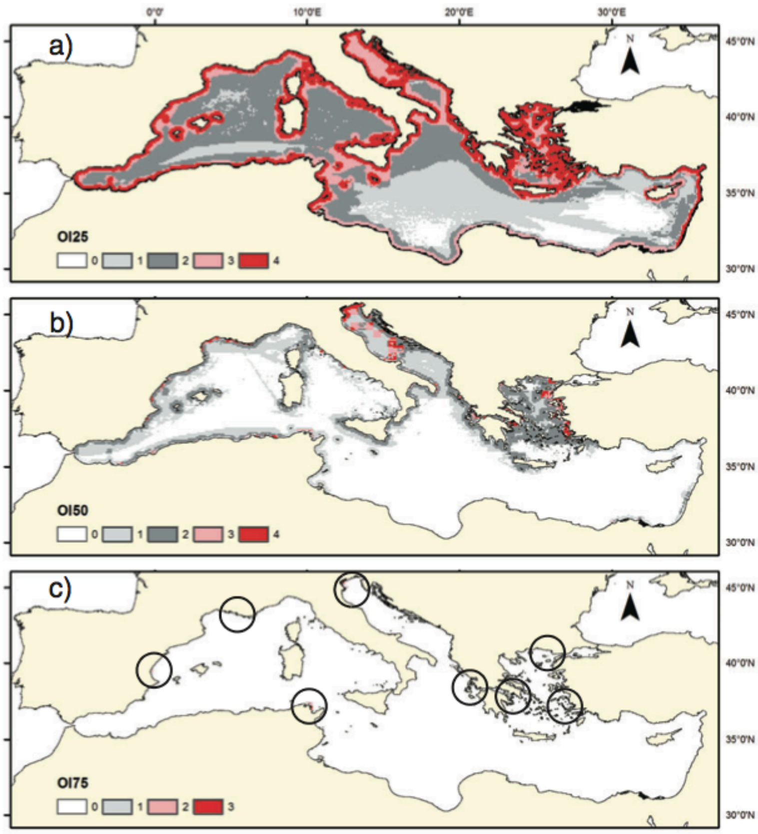


Figure 54. Areas of conservation concern where high biodiversity and high threats to biodiversity components overlap (from Coll *et al*. 2011).

However most of these anthopogenic pressures are expected to increase (Coll *et al*. 2010), it is therefore expected that future monitoring will shed more light on their impacts and allow for robust conclusions.

4.4.2. Indicators availability and capability

In order to assess the indicators availability and capability, we explored the DEVOTES Catalogue of Indicators. Two types of structured analyses were performed.

The DEVOTES database and tool was first used to provide an overview of what is available in terms of indicators in the Mediterranean region and what is their status (e.g. operational vs. conceptual) and capability to link up with pressures (how many pressures can be potentially addressed or are missing).

As part of an in depth analysis focussing on the operational indicators, the indicators for the MSFD subregion Eastern Mediterranean Sea (Aegean and Levantine Sea) were selected from the corresponding indicator catalogue database and have been analyzed in a structured way according to specific relevant criteria, based on their associated metadata and status.

Mediterranean Sea overall analysis

Descriptors and criteria

Based on the analysis that was carried out, 137 indicators are seen for the overall Mediterranean Sea, of which less than 10 are marked as under development or at a conceptual level (**Figure 55**). The majority of the indicators were found to be connected with issues concerning biodiversity followed by issues concerning seafloor integrity and marine food-webs, while there were only a few indicators targeting matters of non-indigenous species (108 indicators for D1, 42 indicators for D6, 18 indicators for D4, 3 indicators for D2) (**Figure 56**).

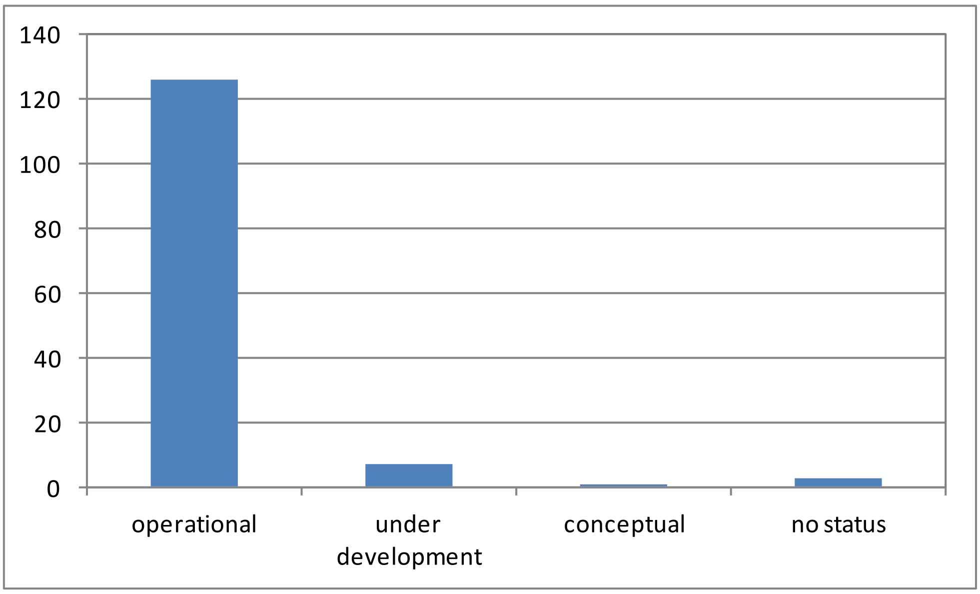


Figure 55. Indicators availability and their status. Data for D1, D2, D4 and D6 for the Mediterranean region based on WP3 indicator catalogue.

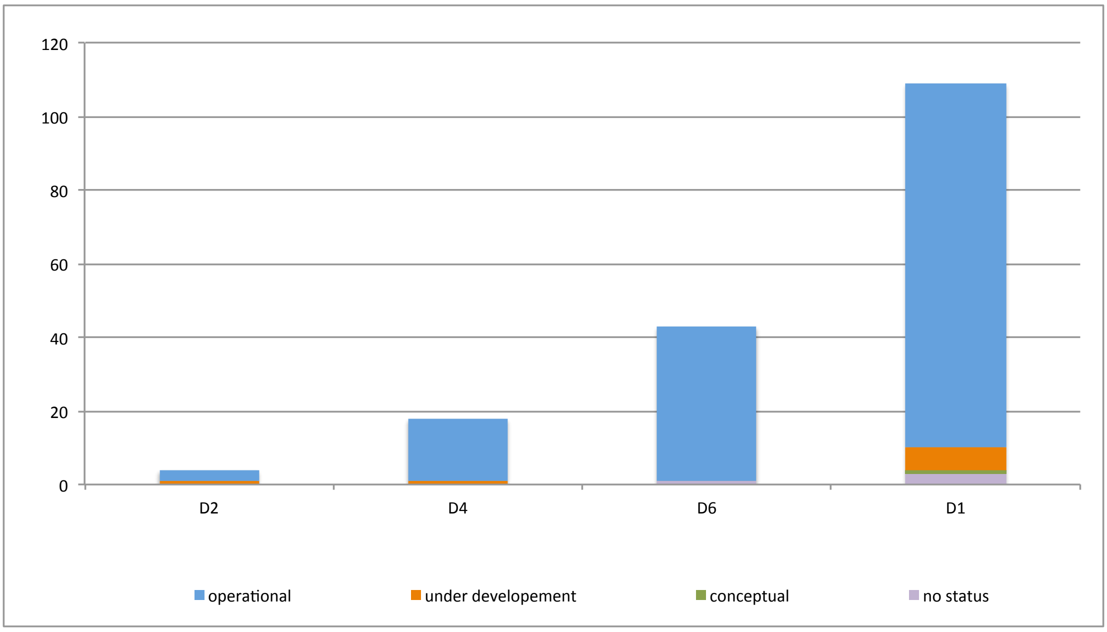


Figure 56. Number of indicators per descriptor in ascending order with indicator status.

Descriptor 1 criteria

Figure 57 illustrates the distribution of indicators included in the DEVOTES catalogue, based on the eight different EU criteria of Descriptor 1. Most indicators covered "Habitat condition" (40) followed by "Habitat distribution" (23), "Species distribution" (22) and "Ecosystem structure" (20). MSFD criterion 1.8 "Ecosystem processes and functions" was not represented in the analysis. In all the respective criteria the majority of indicators were operational, while there were quite a few indicators under development and a conceptual one.

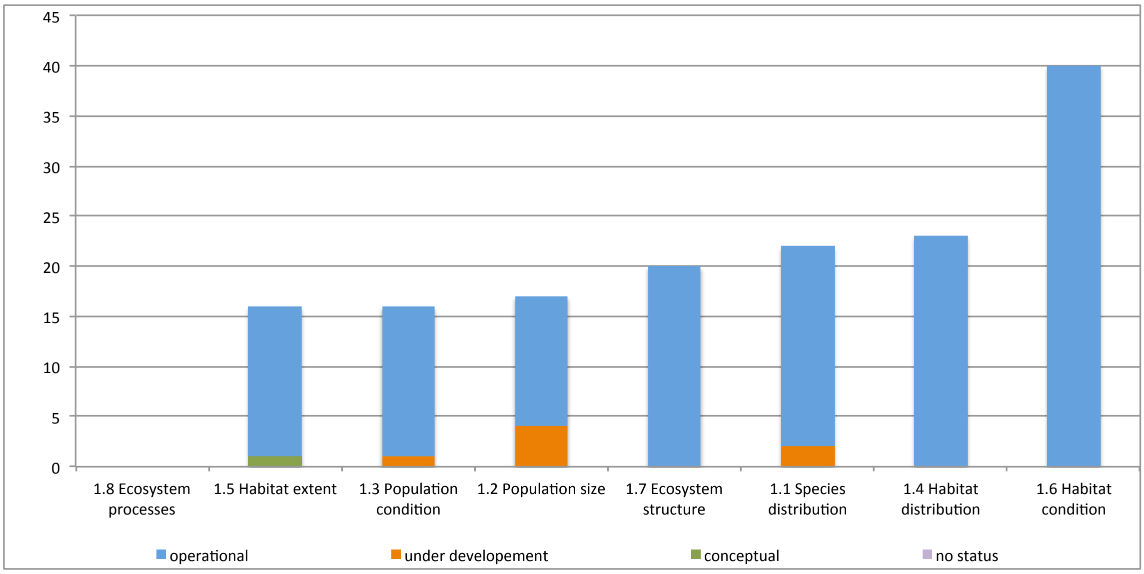


Figure 57. Number of indicators per D1 criteria in ascending order with indicator status.

Descriptor 2 crieria

Concerning Descriptor 2, the results of the analysis showed that 3 of the available indicators (2 operational and 1 under development) were assigned to criterion 2.1 ”Abundance and state…”, while only one indicator under development was assigned to criterion 2.2. No indicator having a conceptual status was found in the analysis.

As far as Descriptor 4 is concerned (**Figure 58**), the majority of the listed indicators were found to apply to criterion 4.3 “Abundance/distribution of key trophic groups/ species” (19), most of which were operational and 1 under development. Likewise, 2 operational indicators were related to criterion 4.1 “Productivity of key species or trophic groups” and 3 to criterion 4.3 “Proportion of selected species ...” respectively. The criterion “Other” was introduced by the DEVOTES project, focusing on breeding success, bottom-up and top-down effects in marine size spectra, trophic pyramids of richness and on competition avoidance through niche packing and, in the overall basin, 1 operational indicators was found to be related to it. None conceptual indicator was found in the analysis.

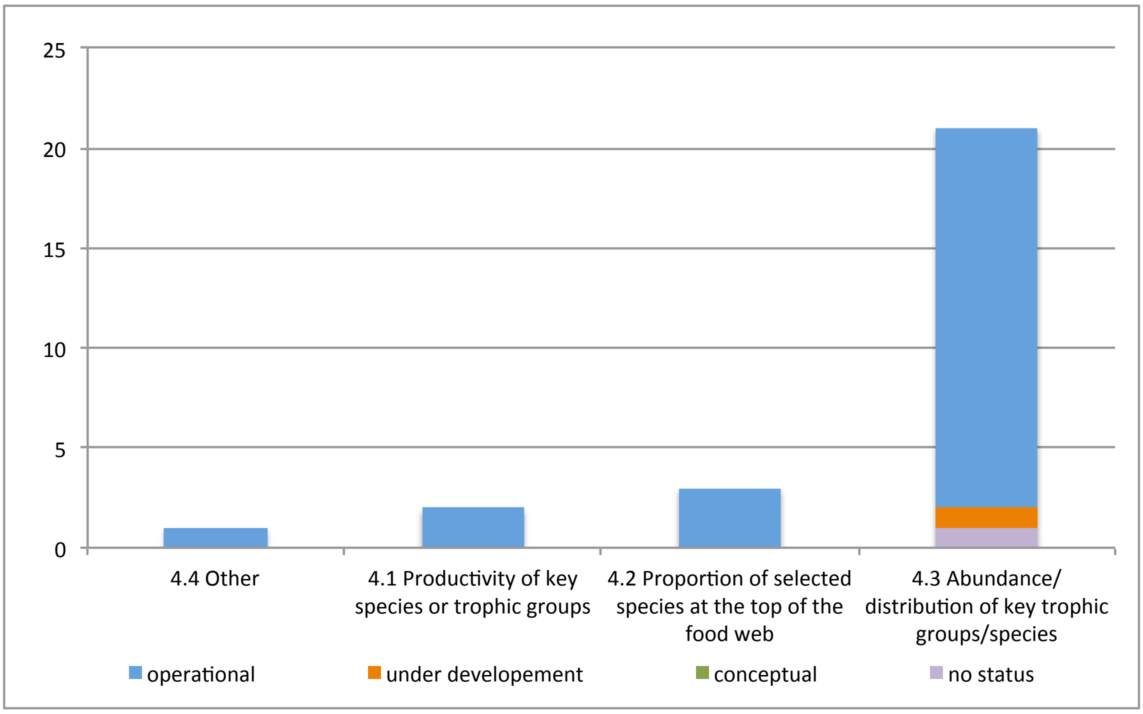


Figure 58. Number of indicators per D4 criteria in ascending order with indicator status.

Descriptor 6 criteria

For Descriptor 6, 25 operational indicators presented (**Figure 59**) connection with EU criterion 6.1 “Substrate characteristics”, and accordingly 26 operational indicators with criterion 6.2 “Condition of benthic community”. None indicator regarding conceptual or under development status were found in the current analysis.

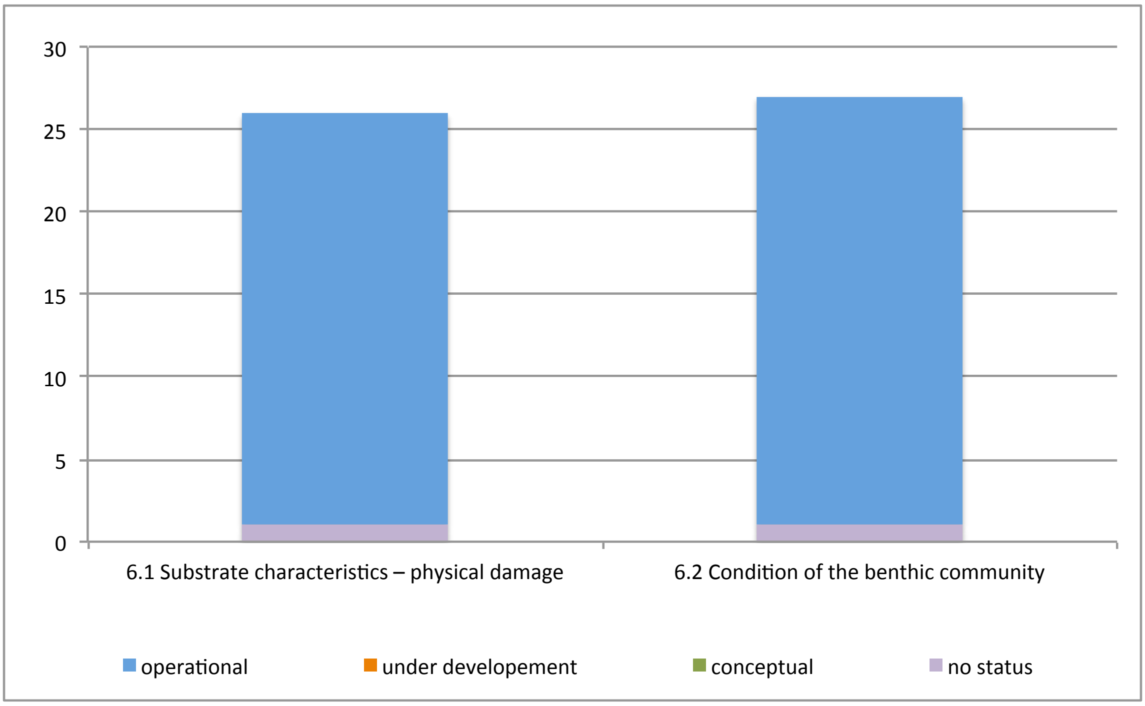


Figure 59. Number of indicators per D6 criteria in ascending order with indicator status.

Biodiversity components

The analysis of the number of indicators per biodiversity components for the Mediterranean Sea can be found in **Table 38** and **Figure 60**. A quarter of the indicators (irrespectively of their status or descriptor focus) addressed the biodiversity component fish. Over 70 % of the indicators addressed 4 biodiversity components: fish, benthic Invertebrates, angiosperms and macroalgae (72 % of the total and and 80 % of the operational indicators). The highest number of indicators addressing exclusively one biodiversity component were for "Fish" (22), "Angiosperms" (18) and "Benthic Invertebrates" (15), concerning mostly operational indicators. None of the available indicators addressed the components: "Microbes" and "Pelagic invertebrates", while for "Phytoplankton" (2), "Zooplankton" (2) and "Birds" (1) the number of related indicators was quite low. It should be stated that no indicator marked as conceptual was connected to any of the listed components.

Table 38. Number of indicators per biodiversity component, divided into indicators specifically addressing one component and indicators addressing further components in addition [sum (operational/under development/conceptual/no status)].

Biodiversity component	one component	several components
Microbes	0	0
Phytoplankton	2(0/1/0/1)	7 (5/1/0/1)
Zooplankton	2(2/0/0/0)	7 (7/0/0/0)

Biodiversity component	one component	several components
Angiosperms	18(16/0/0/2)	23 (21/0/0/2)
Macroalgae	8(8/0/0/0)	15 (14/1/0/0)
Benthic invertebrates	15(15/0/0/0)	23 (22/1/0/0)
Pelagic invertebrates	0	0
Fish	22(22/0/0/0)	31 (28/3/0/0)
Cephalopods	0	5 (3/2/0/0)
Marine mammals	6(3/3/0/0)	7 (4/3/0/0)
Reptiles	6(6/0/0/0)	7 (7/0/0/0)
Birds	1(1/0/0/0)	1 (1/0/0/0)

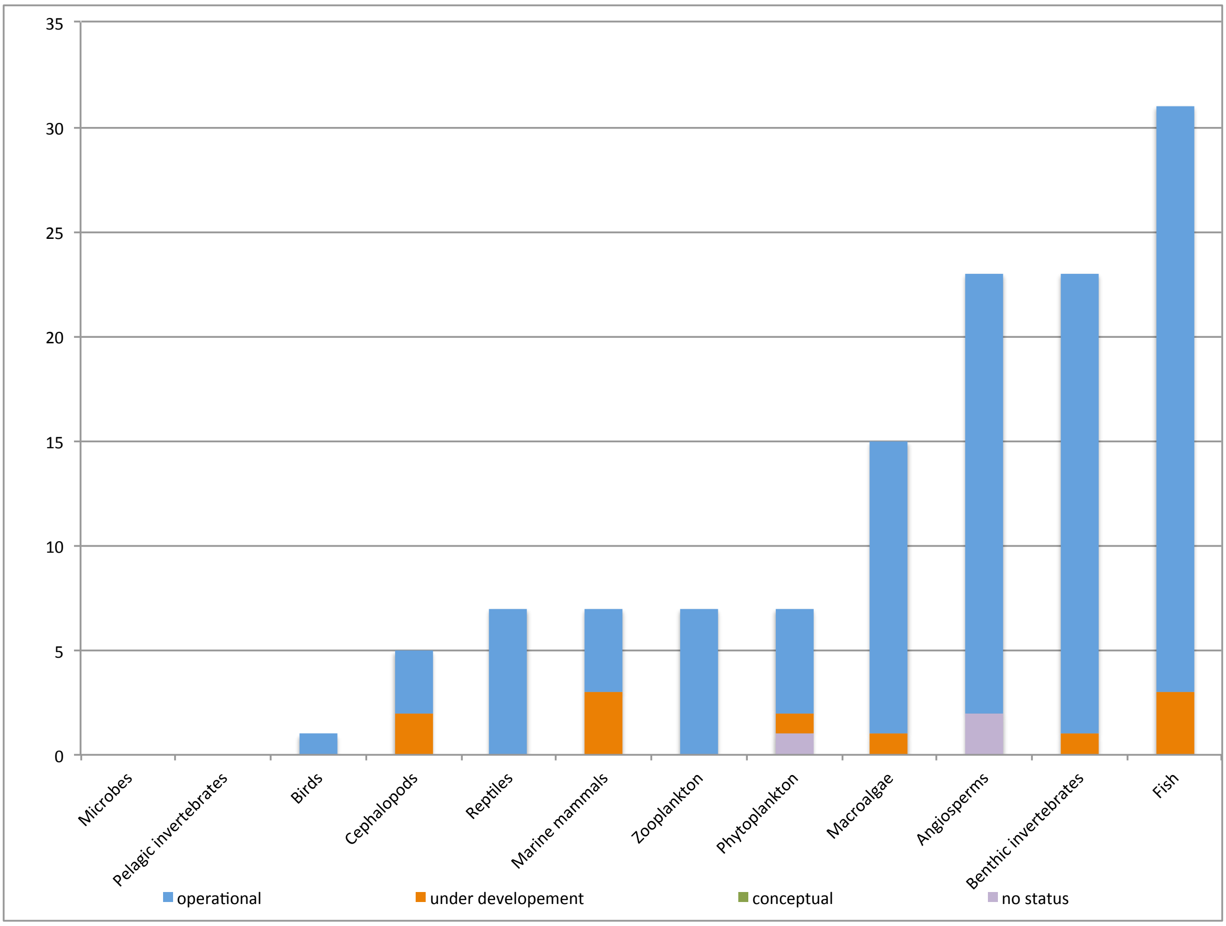


Figure 60. Number of indicators per biodiversity component in ascending order with indicator status.

Habitat types

Results regarding the number of indicators *per* habitat type are presented in **Table 39** and **Figure 61** respectively. There were 75 indicators were related to seabed habitats exclusively, 14 to water column habitats (most of which were operational in both cases) and none to ice habitats. Overlapping of indicators was expected, since indicators related to both seabed and water column exist.

Table 39. Number of indicators per habitat type, divided into indicators specifically addressing one habitat type and indicators addressing further habitat types in addition [sum (operational/under development/conceptual/no status)].

Habitat type	one habitat type	several habitat types
Seabed	75(71/1/1/2)	79(75/1/1/2)
Water column	14(7/6/0/1)	18(11/6/0/1)
Ice habitat	0	0

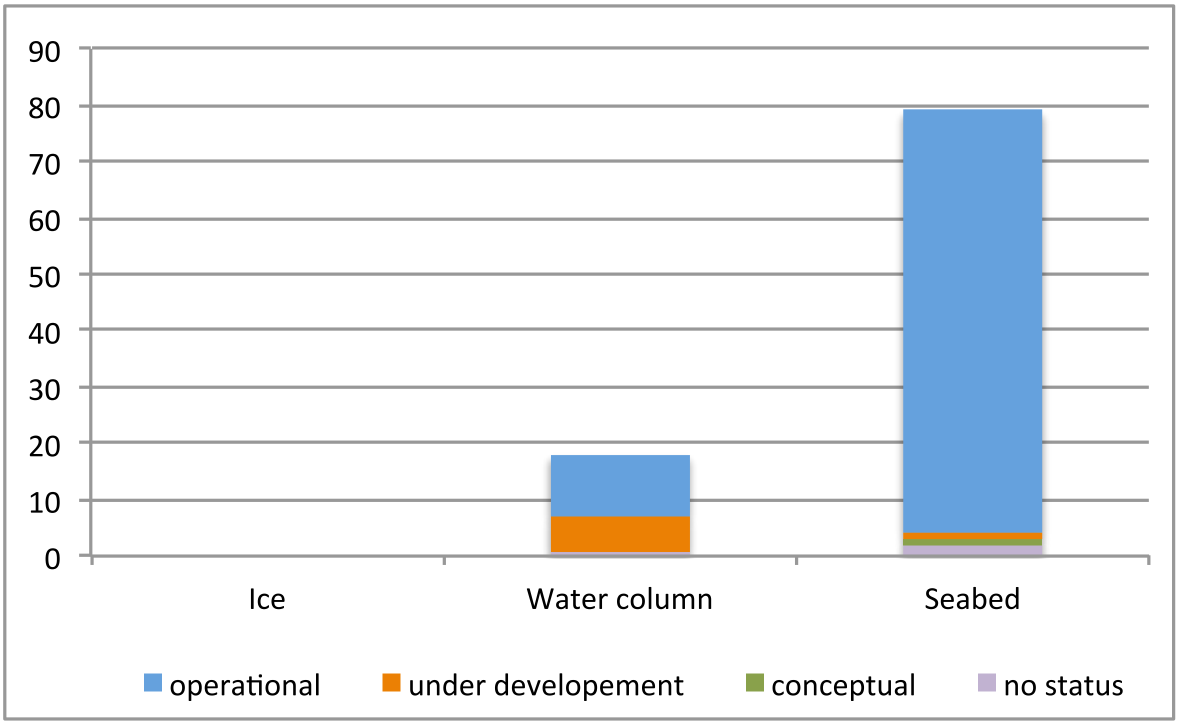


Figure 61. Number of indicators per habitat type in ascending order with indicator status.

Pressures

The number of indicators *per* pressure are listed in **Table 40** and illustrated in **Figure 62.** Most of the indicators were operational, while none conceptual was included. Most of the indicators were not addressing any pressure (98 out of 126 operational indicators), while 17 % of them were addressing more than one pressure (22 out of 126 operational indicators). The highest number of indicators addressing pressures was related to "Nutrient and organic matter enrichment" (22), "Physical damage to habitats" (17), "Physical loss" (16), "Interference with hydrological processes" (15) and "Others", pressures related to climate change (12). Lowest numbers of related indicators occurred for "Marine acidification" (1), "Underwater noise" (3), "Marine litter" (3), "Introduction of microbial pathogens" (3), while categories of pressures such as: “Extraction of species: seaweed harvesting” and “Extraction of species: maerl” were not represented at all.

By analysing indicators addressing exclusively only one pressure, results indicated that none of the available indicators was related to the major listed pressures, among which were: “Physical loss”, “Marine litter” and “Marine acidification”. What is more, the number of indicators directly related to the pressures: “Physical damage to habitats”, “Nutrient and organic matter enrichment”, “Extraction of species: fish and shellfish (catch)”, “Extraction of species: fish and shellfish (by-catch)” and “Other” was rather low.

Table 40. Number of indicators per pressure, divided into indicators specifically addressing one pressure and indicators addressing further pressures in addition [sum (operational/under development/conceptual/no status)].

Pressure	one pressure	several pressures
Physical loss	0	16 (15/0/0/1)
Physical damage to habitats	3(3/0/0/0)	20 (19/0/0/1)
Underwater noise	0	3 (1/2/0/0)
Marine litter	0	3(1/2/0/0)
Interference with hydrological processes	0	15(14/0/0/1)
Contamination by synthetic compounds	0	9(7/2/0/0)
Contamination by non-synthetic substances and compounds	0	11(9/2/0/0)
Contamination by radionuclides	0	3(3/0/0/0)
Acute pollution events	0	9(7/2/0/0)
Nutrient and organic matter enrichment	1 (1/0/0/0)	23(21/1/0/1)
Introduction of microbial pathogens	0	3(1/2/0/0)
Non-indigenous species	0	6(5/1/0/0)
Extraction of species: fish and shellfish (catch)	1(1/0/0/0)	5(3/2/0/0)
Extraction of species: fish and shellfish (by-catch)	1 (0/1/0/0)	8(3/5/0/0)
Extraction of species: fish and shellfish (discard)	0	4(2/2/0/0)
Extraction of species: maerl	0	0
Extraction of species: seaweed harvesting	0	0
Extraction of species: other	0	2(2/0/0/0)
Marine acidification	0	1(1/0/0/0)
Other	2 (1/1/0/0)	14(9/5/0/0)

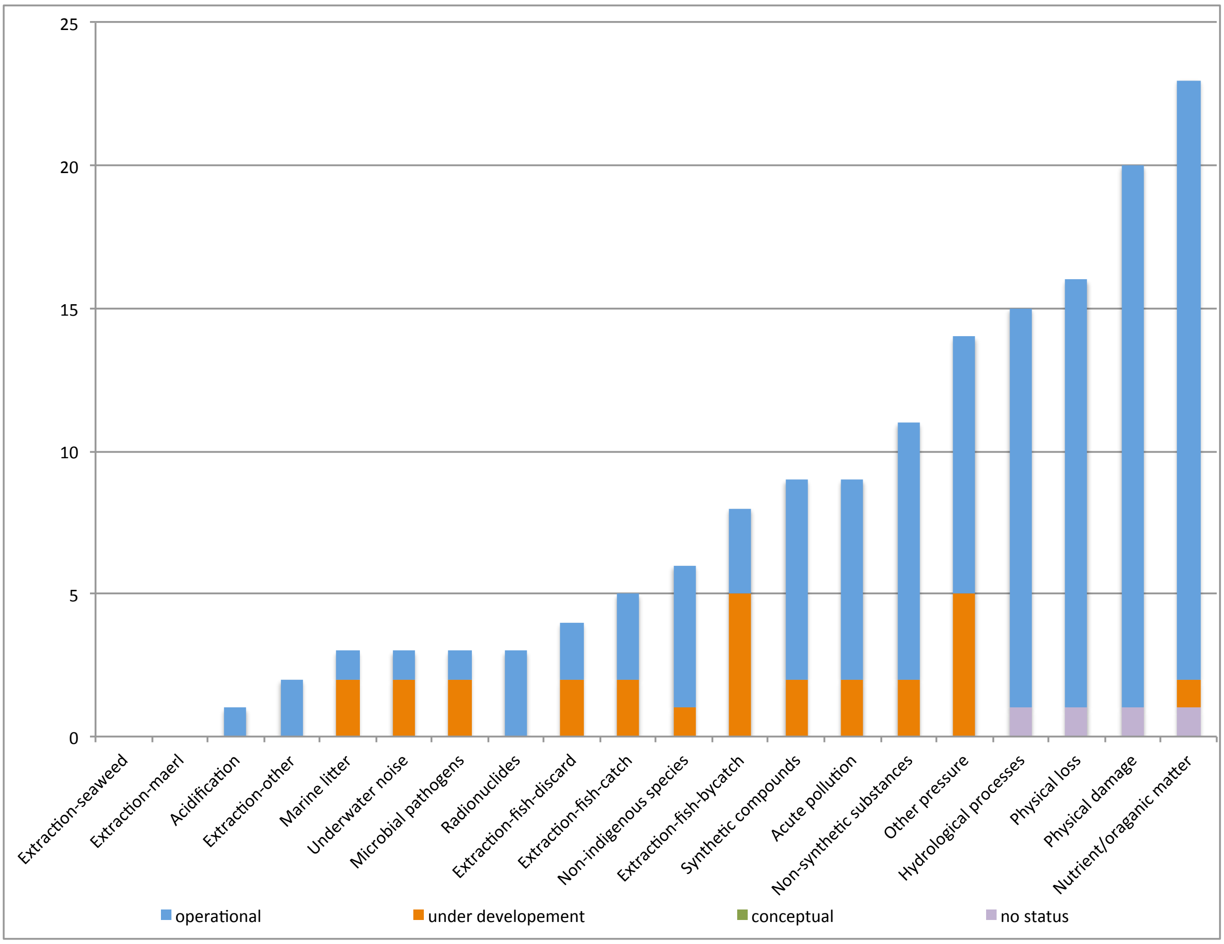


Figure 62. Number of indicators per pressure in ascending order with indicator status.

Eastern Mediterranean subregion analysis

In total 35 indicators have been identified for the Eastern subregion of the Mediterranean Sea out of the 137 corresponding to overall basin, related to biodiversity, non-indigenous species, marine food-webs and seafloor integrity, mainly contributed by HCMR. From these 34 were operational, while the indicator: Ratio of non-indigenous/native species is still under development. These indicators along with their metadata information correspond to the Initial Assessments carried out by Greece and Cyprus in the framework of the MSFD (Articles 8, 9 and 10), based on a review analysis carried out by HCMR.

The results (**Table 41** to **Table 49**) revealed that 12 (operational) indicators of the 34 were coupled with specific identified pressures in the subregion mainly regarding physical loss, physical damage, pollution by non-synthetic substances and compounds, eutrophication, hydrological processes, non-indigenous species and extraction of species. What is more, the indicators: “Total cover of macroalgae”, “Shannon Index for benthic invertebrates”, “Ecological Evaluation Index” and “BENTIX” were suggested to tackle issues regarding MSFD Descriptors 1, 4 and 6 (biodiversity, marine food-webs and seafloor integrity) (**Table 52**).

According to the analysis, 23 (operational) indicators were linked with MSFD Descriptor 1 Biological Diversity (**Table 41**), and were mainly connected to the seabed type of habitats (shelf and shallow sublittoral sediments), and very few to the water column type, and more specifically to coastal areas. Only BENTIX and 2 other indicators were linked to both seabed and water column habitats. The biodiversity components, with which the provided indicators were linked, mainly corresponded to angiosperms, macroalgae, benthic invertebrates and fish, with Pielou's Evenness being the cost commonly used on various biological components including phytoplankton and zooplankton. The above indicators conveyed information for different types of pressures, such as physical loss, physical damage, pollution by non-synthetic substances and compounds and finally eutrophication (**Table 42**). Pielou's Evenness of selected biological components, species richness of fish and BENTIX presented connections with most of the above-mentioned pressures. Finally, the indicators: Pielou's Evenness of selected biological components, Shannon index for benthic invertebrates, species richness of fish, Ecological Evaluation Index and BENTIX were connected to a broader array of the corresponding MSFD D1 indicators than the rest (**Table 43**).

Table 41. Operational indicators for the Eastern Mediterranean subregion under D1 and links with MSFD criteria under D1 (EU indicators 1.1.1 to 1.8.2).

No	Indicators names	1.1.1	1.1.2	1.1.3	1.2.1	1.3.1	1.3.2	1.4.1	1.4.2	1.5.1	1.5.2	1.6.1	1.6.2	1.6.3	1.7.1	1.7.2	1.8.1	1.8.2
1	Macroalgae-diversity indices	X																
2	Zoobenthos-diversity indices		X															
3	Fish-diversity index (Shannon)			X														
4	Areal extent of marine angiosperms									X								
5	Abundance of seaturtle spawning population				X													
6	Survival rate of Posidonia oceanica					X												
7	CymoSkew											X						
8	PREI - Posidonia oceanica Rapid Easy Index														X	X		
9	Abundance of benthic invertebrates												X					
10	Abundance of fish				X													
11	Areal extent of maerl-type biogenic sediments									X								
12	Evenness (Pielou) of selected biological components	X						X				X			X	X		
13	Abundance of macroalgae (total cover)								X	X			X					
14	Species diversity (Shannon index) of benthic invertebrates		X									X	X		X	X		
15	Species richness of fish	X	X	X											X			
16	Species richness of macroalgae														X			
17	Species diversity (Shannon index) of macroalgae											X			X			
18	Species diversity (Shannon index) of fish											X						
19	Species richness of benthic invertebrates		X															
20	Abundance of seals	X	X	X	X													

No	Indicators names	1.1.1	1.1.2	1.1.3	1.2.1	1.3.1	1.3.2	1.4.1	1.4.2	1.5.1	1.5.2	1.6.1	1.6.2	1.6.3	1.7.1	1.7.2	1.8.1	1.8.2
21	Areal extent of Posidonia oceanica meadows									X								
22	EEI - Ecological Evaluation Index			X	X					X		X			X	X		
23	BENTIX				X							X	X		X	X		

Table 42. Operational indicators for the Eastern Mediterranean subregion under D1 and links with Pressures.

No	Indicators names	Physical Loss	Physical damage to marine habitats	Underwater noise	Marine Litter	Intereference with hydrological processes	Contamination by synthetic compounds	synthetic substances & compounds	Contamination by radionuclides	Acute pollution events	Nutrient and organic matter enrichment	Non-indigenous species	Extraction of species: fish and shellfish (catch)	Extraction of species: fish and shellfish (by-catch)	Extraction of species: fish and shellfish (discards)	Extraction of species: maerl	Extraction of species: seaweed harvesting	Extraction of species: other	Marine acidification	Other
1	Macroalgae-diversity indices																			
2	Zoobenthos-diversity indices																			
3	Fish-diversity index (Shannon)																			
4	Areal extent of marine angiosperms																			
5	Abundance of seaturtle spawning population																			
6	Survival rate of Posidonia oceanica																			
7	CymoSkew	X	X								X									
8	PREI - Posidonia oceanica Rapid Easy Index																			
9	Abundance of benthic invertebrates																			
10	Abundance of fish																			
11	Areal extent of maerl-type biogenic sediments																			
12	Evenness (Pielou) of selected biological components					X	X	X	X	X	X									X
13	Abundance of macroalgae (total cover)	X	X								X									
14	Species diversity (Shannon index) of benthic invertebrates	X	X								X	X								
15	Species richness of fish	X	X		X			X			X							X		X
16	Species richness of macroalgae																			
17	Species diversity (Shannon index) of macroalgae		X								X									
18	Species diversity (Shannon index) of fish												X							
19	Species richness of benthic invertebrates																			
20	Abundance of seals			X		X	X	X						X				X		
21	Areal extent of Posidonia oceanica meadows																			
22	EEI - Ecological Evaluation Index	X	X			X					X									
23	BENTIX	X	X			X		X		X	X	X								

Table 43. Operational indicators for the Eastern Mediterranean subregion under D1 and links with Biodiversity components.

No	Indicators names	Microbes	Phytoplankton	Zooplankton	Angiosperms	Macroalgae	Benthic inverterbrates	Pelagic invertebrates	Fish	Cephalopods	Marine mammals	Reptiles	Birds
1	Macroalgae-diversity indices					X							
2	Zoobenthos-diversity indices												
3	Fish-diversity index (Shannon)								X				
4	Areal extent of marine angiosperms				X								
5	Abundance of seaturtle spawning population											X	
6	Survival rate of Posidonia oceanica				X								
7	CymoSkew				X								
8	PREI - Posidonia oceanica Rapid Easy Index				X								
9	Abundance of benthic invertebrates						X						
10	Abundance of fish								X				
11	Areal extent of maerl-type biogenic sediments				X								
12	Evenness (Pielou) of selected biological components		X	X		X	X		X				
13	Abundance of macroalgae (total cover)					X							
14	Species diversity (Shannon index) of benthic invertebrates												
15	Species richness of fish								X				
16	Species richness of macroalgae					X							
17	Species diversity (Shannon index) of macroalgae					X							
18	Species diversity (Shannon index) of fish								X				
19	Species richness of benthic invertebrates						X						
20	Abundance of seals										X		
21	Areal extent of Posidonia oceanica meadows				X								
22	EEI - Ecological Evaluation Index					X							
23	BENTIX						X						

Only 2 operational indicators (Spatial distribution of non-indigenous species, Trends in arrival of new non-indigenous species per pathway) were included in the DEVOTES catalogue concerning non-indigenous species for the Eastern Mediterranean Sea (which are actually the only ones provided for the overall basin), and both were found to be linked with the corresponding MSFD indicator 2.1.1, targeting both seabed and water column habitats and a wide range of biodiversity components (phytoplankton, zooplankton, angiosperms, macroalgae, benthic invertebrates, fish and cephalopods) (**Table 44** and **Table 45**). The main pressures addressed by these indicators refer to non-indigenous species and activities related to invasions such as shipping, aquaculture and aquarium trade. Non-indigenous species constitute an acute threat for the Eastern Mediterranean and an important pressure identified for the whole Mediterranean Sea. These results highlight that further development (in terms of monitoring programmes, data availability and solid methodological approaches) is required in order to establish quantified operational indicators to address it. At the moment, the low availability of data along with the lack of legislative frameworks are two major issues that do not allow thorough assessments.

Table 44. Operational indicators for the Eastern Mediterranean subregion under D2 and links with MSFD criteria and Pressures.

	Indicators names	Links with MSFD criteria			Links with Pressures
		2.1.1	2.2.1	2.2.2	Others
1	Spatial distribution of non-indigenous species	X			
2	Trends in arrival of new non-indigenous species per pathway	X			X

Table 45. Operational indicators for the Eastern Mediterranean subregion under D2 and links wcith Biodiversity components.

No	Indicators names	Phytoplankton	Zooplankton	Angiosperms	Macroalgae	Benthic inverterbrates	Fish	Cephalopods
1	Spatial distribution of non-indigenous species	X	X	X	X	X	X	X
2	Trends in arrival of new non-indigenous species per pathway	X	X	X	X	X	X	X

Likewise, 9 operational indicators of Eastern Mediterranean Sea were found to be linked to MSFD Descriptor 4 (**Table 46**): Marine food-webs mainly connected to seabed type of habitats (shelf and sublittoral sediments).

Table 46. Operational indicators for the Eastern Mediterranean subregion under D4 and links with MSFD criteria under D4.

No	Indicators names	4.1.1	4.1.2	4.2.2	4.3.1	4.4
1	Biomass ratio of demersal fish (at higher trophic levels in the total catch)			X		
2	Trends in populations of large pelagic fish		X			
3	Eveness (Pielou) of selected biological components				X	
4	Abundance of macroalgae (total cover)				X	

No	Indicators names	4.1.1	4.1.2	4.2.2	4.3.1	4.4
5	Species diversity (Shannon index) of benthic invertebrates				X	X
6	Species richness of fish				X	
7	Abundance of seals	X				
8	EEI - Ecological Evaluation Index				X	
9	BENTIX				X	

The biological components used to quantify these indicators were fish, benthic invertebrates and macroalgae (**Table 47**).

Table 47. Operational indicators for the Eastern Mediterranean subregion under D4 and links with Biodiversity components.

No	Indicators names	Microbes	Phytoplankton	Zooplankton	Angiosperms	Macroalgae	Benthic invertebrates	Pelagic invertebrates	Fish	Cephalopods	Marine mammals	Reptiles	Birds
1	Biomass ratio of demersal fish (at higher trophic levels in the total catch)								X				
2	Trends in populations of large pelagic fish								X				
3	Eveness (Pielou) of selected biological components		X	X		X	X		X				
4	Abundance of macroalgae (total cover)					X							
5	Species diversity (Shannon index) of benthic invertebrates						X						
6	Species richness of fish								X				
7	Abundance of seals										X		
8	EEI - Ecological Evaluation Index					X							
9	BENTIX						X						

Among the available pressures, physical loss, physical damage, pollution by non-synthetic substances and compounds and finally eutrophication were the main pressures linked with the available indicators (**Table 48**). Pielou's Eveness of selected biological components, Species richness of fish, Ecological Evaluation Index and BENTIX revealed connections with most of the above mentioned pressures. Finally, the indicators: Pielou's Eveness of selected biological components, Shannon Index for benthic invertebrates was found to be connected to a broader array of the corresponding MSFD D4 indicators than the rest.

Table 48. Operational indicators for the Eastern Mediterranean subregion under D4 and links with Pressures.

No	Indicators names	Physical Loss	Physical damage to marine habitats	Underwater noise	Marine Litter	Intereference with hydrological processes	Contamination by synthetic compounds	Contamination by non-synthetic substances & compounds	Contamination by radionuclides	Acute pollution events	Nutrient and organic matter enrichment	Non-indigenous species	Extraction of species: fish and shellfish (by-catch)	Extraction of species: other	Other
1	Biomass ratio of demersal fish (at higher trophic levels in the total catch)														
2	Trends in populations of large pelagic fish														
3	Eveness (Pielou) of selected biological components					X	X	X	X	X	X				X
4	Abundance of macroalgae (total cover)	X	X								X				
5	Species diversity (Shannon index) of benthic invertebrates	X	X								X	X			
6	Species richness of fish	X	X		X			X			X			X	X
7	Abundance of seals			X		X	X	X					X	X	
8	EEI - Ecological Evaluation Index	X	X			X					X				
9	BENTIX	X	X			X		X		X	X	X			

Results indicated that 15 operational indicators were included in the DEVOTES catalogue addressing seafloor integrity issues, mainly linked to seabed habitat types (shelf and sublittoral sediments). These indicators were quantified using different biological components such as angiosperms, macroalgae and benthic invertebrates (**Table 49**), and they were connected with the following pressures: physical loss, physical damage and eutrophication (**Table 50**). CymoSkew, Total cover of macroalgae, Shannon index of benthic invertebrates, Species richness of benthic invertebrates, Ecological Evaluation Index and

BENTIX presented links with more than one of the corresponding MSFD D6 indicators (**Table 51**). Accordingly, Shannon index of benthic invertebrates, Ecological Evaluation Index and BENTIX were also found to be connected with more than one of the above-mentioned pressures.

Table 49. Operational indicators for the Eastern Mediterranean subregion under D6 and links with Biodiversity components.

No	Indicators names	Microbes	Phytoplankton	Zooplankton	Angiosperms	Macroalgae	Benthic inverterbrates	Pelagic invertebrates	Fish	Cephalopods	Marine mammals	Reptiles	Birds
1	Areal extent of marine angiosperms				X								
2	Abundance of perennial seaweeds					X							
3	Presence of particularly sensitive and/or tolerant species												
4	CymoSkew				X								
5	Areal extent of maerl-type biogenic sediments				X								
6	Abundance ratio of benthic invertebrates above specified length						X						
7	Abundance of macroalgae (total cover)					X							
8	Species diversity (Shannon index) of benthic invertebrates						X						
9	Species diversity (Shannon index) of macroalgae					X							
10	Species richness of benthic invertebrates						X						
11	Areal extent of Posidonia oceanica meadows				X								
12	Abundance of shade-adapted, slow growing calcareous species					X							
13	Abundance of opportunistic macroalgae					X							
14	EEI - Ecological Evaluation Index					X							
15	BENTIX						X						

Table 50. Operational indicators for the Eastern Mediterranean subregion under D6 and links with Pressure.

No	Indicators names	Physical Loss	Physical damage to marine habitats	Underwater noise	Marine Litter	Intereference with hydrological processes	Contamination by synthetic compounds	Contamination by non-synthetic substances & compounds	Contamination by radionuclides	Acute pollution events	Nutrient and organic matter enrichment	Introduction of microbial pathogens	Non-indigenous species
1	Areal extent of marine angiosperms												
2	Abundance of perennial seaweeds												
3	Presence of particularly sensitive and/or tolerant species												
4	CymoSkew	X	X								X		
5	Areal extent of maerl-type biogenic sediments												
6	Abundance ratio of benthic invertebrates above specified length												
7	Abundance of macroalgae (total cover)	X	X								X		
8	Species diversity (Shannon index) of benthic invertebrates	X	X								X		X
9	Species diversity (Shannon index) of macroalgae		X								X		
10	Species richness of benthic invertebrates												
11	Areal extent of Posidonia oceanica meadows												
12	Abundance of shade-adapted, slow growing calcareous species												
13	Abundance of opportunistic macroalgae												
14	EEI - Ecological Evaluation Index	X	X			X					X		
15	BENTIX	X	X			X		X		X	X		X

Table 51. Operational indicators for the Eastern Mediterranean subregion under D6 and links with MSFD criteria under D6.

No	Indicators names	6.1.1	6.1.2	6.2.1	6.2.2	6.2.3	6.2.4
1	Areal extent of marine angiosperms	X					
2	Abundance of perennial seaweeds				X		
3	Presence of particularly sensitive and/or tolerant species			X			
4	CymoSkew	X		X		X	
5	Areal extent of maerl-type biogenic sediments	X					
6	Abundance ratio of benthic invertebrates above specified length						X
7	Abundance of macroalgae (total cover)	X		X			
8	Species diversity (Shannon index) of benthic invertebrates		X		X		
9	Species diversity (Shannon index) of macroalgae				X		
10	Species richness of benthic invertebrates			X	X		
11	Areal extent of Posidonia oceanica meadows	X					
12	Abundance of shade-adapted, slow growing calcareous species				X		
13	Abundance of opportunistic macroalgae				X		
14	EEI - Ecological Evaluation Index	X		X	X		
15	BENTIX			X	X		

The analysis resulted in interesting findings concerning the indicators' availability and capability for the Eastern Mediterranean Sea in terms of their status, their links with the corresponding MSFD indicators, the spectrum of pressures that they address, the array of biodiversity components that they represent and finally the types of habitats with which they are connected. However, results should not be misinterpreted as highlighting good or promising indicators, since they are based on metadata information coming from the Initial Assessments of the EU MS of the subregion. This kind of information (selection of indicators) requires further analyses and the acquirement of both existing and new data, in order to reach more accurate conclusions. Such analyses and the selection of indicators will be carried out during further activities in the framework of DEVOTES future activities.

Table 52. Operational indicators for the Eastern Mediterranean subregion, common indicators between D1 and D4 in red, between D1, D4 and D6 in red bold, additional common indicators between D1 and D6 in green and remaining indicators in black font.

No	Indicators names	D2	D4	D6
D1	Macroalgae-diversity indices			
D1	Zoobenthos-diversity indices			
D1	Fish-diversity index (Shannon)			
D1	Areal extent of marine angiosperms			X
D1	Abundance of seaturtle spawning population			

No	Indicators names	D2	D4	D6
D1	Survival rate of Posidonia oceanica			
D1	CymoSkew			X
D1	PREI - Posidonia oceanica Rapid Easy Index			
D1	Abundance of benthic invertebrates			
D1	Abundance of fish			
D1	Areal extent of maerl-type biogenic sediments			X
D1	Eveness (Pielou) of selected biological components		X	
D1	**Abundance of macroalgae (total cover)**		X	X
D1	**Species diversity (Shannon index) of benthic invertebrates**		X	X
D1	Species richness of fish		X	
D1	Species richness of macroalgae			
D1	Species diversity (Shannon index) of macroalgae			X
D1	Species diversity (Shannon index) of fish			
D1	Species richness of benthic invertebrates			X
D1	Abundance of seals		X	
D1	Areal extent of Posidonia oceanica meadows			X
D1	**EEI - Ecological Evaluation Index**		X	X
D1	**BENTIX**		X	X
D2	Spatial distribution of non-indigenous species			
D2	Trends in arrival of new non-indigenous species per pathway			
D4	Biomass ratio of demersal fish (at higher trophic levels in the total catch)			
D4	Trends in populations of large pelagic fish			
D6	Abundance of perennial seaweeds			
D6	Presence of particularly sensitive and/or tolerant species			
D6	Abundance ratio of benthic invertebrates above specified length			
D6	Abundance of shade-adapted, slow growing calcareous species			
D6	Abundance of opportunistic macroalgae			

4.4.3. Gaps in the Mediterranean Sea

Based on the database contents and expert opinion, gaps for the several Mediterranean marine subregions were identified (Eastern Aegean Turkish coast, Adriatic Sea, and a few considerations on the NW Mediterranean), along with more general remarks.

Descriptors

Biological diversity (D1) indicators currently included in the catalogue revealed some weaknesses with respect to their linkage to major pressures.

Four indicators are related to fish in the **Eastern Mediterranean** under biodiversity D1 and two additional ones under D4 Food-webs. No comprehensive studies of overfishing in Turkey exist. Greece and Cyprus are following the EU DCF regulation for effort and stock monitoring. Fishing bans are observed and for larger vessels are enforced through the VMS system.

Non-indigenous species (D2) are currently monitored in the Italian territory including the **Adriatic** (and also in the **NW Mediterranean**). Specific selection of stations is random and any decision is taken individually by each partner that contributes to the monitoring programme. A total of 8 groups/taxa have been proposed so far for the monitoring programme: Plants, Cnidaria, Decapoda, Bryozoa, Ascidia, Fish, Mollusca, and Polychaeta. From all the indicators linked to the MSFD Descriptor 2, the only operational indicator used to assess pressure is the trend on arrival of new species. Spatial distribution is operational but there are no GIS maps available yet. Species Abundance is operational but limited to the 8 taxa monitored. Ballast waters and fouling are the main drivers for invasions (28 %) followed by aquaculture (18 %). Gaps are related to the limited number of taxa monitored and the limited number of data collected. The Ratio of non-indigenous species to native species indicator could be assessed only for Bryozoa.

Biodiversity components

The biodiversity components least covered by the indicators in the catalogue in the **Eastern Mediterranean Sea** subregion are microbes, phytoplankton, zooplankton, pelagic invertebrates, cephalopods, marine mammals, reptiles and birds.

Indicators of **microbes** are currently non-existent in the catalogue and this includes both operational and under development. In DEVOTES WP5 several partners are working with the objective to i) evaluate (and standardize) some molecular approaches that can be used to determine and quantify microbial (bio)diversity and ii) use these values in monitoring of plankton marine ecosystems. In particular, there are plans to evaluate the usefulness of the currently most-used high-throughput sequencing tools (i.e. 454 Roche and Illumina technologies) applied to the amplification, sequencing and estimation of relative abundance of the 16S rRNA gene with primers for Bacteria and Archaea (thus targeting bacterial and archaeal diversity) and to the amplification, sequencing and quantification of the 18S rRNA gene with primers for Eukaryotes in the size fractions 0.2-3 µm (picoplankton) and 3-20 µm (nanoplankton).

Studies on phytoplankton species distribution across inshore and offshore waters of the **Mediterranean Sea** are scattered both in space and time and provide rather heterogeneous information in terms of methodology, sampling scales and organisms addressed. Therefore, it is impossible to trace large scale patterns or seasonal cycles that can parallel those depicted in the previous section for biomass and production.

Phytoplankton and zooplankton abundance and composition studies to assess the impact of diminished river outflow on the ecosystem of the **Southeastern Mediterranean** region, are needed to document the geographic and seasonal variations in the distribution and abundance of phytoplankton and zooplankton populations, which include fish eggs and larvae. In the **Adriatic**, the pelagic habitat and the biodiversity components phytoplankton, zooplankton and bacteria have the most data and most monitoring programmes. There are other operational inicators available for zooplankton in the **Mediterranean** although this is being addressed by indicators under development for phytoplankton.

Indicators of pelagic invertebrates are currently non-existent in the catalogue and this includes both operational and under development.

A large number of indicators (25) is related to fish in the **Adriatic Sea** but a limited number is currently operational in Italy. In the Adriatic Sea, the abundance/biomass ratio is only for functional groups of demersal fishes and not at the species level. The most relevant regional Pressures are affecting the breeding potential of fish stocks, body length of fish (multiple Indicators in the catalogue) and include a strong pressure by fishing. Gaps include the very limited number of species targeted for data collection.

Mammals are one of the most threatened biodiversity components in the **Mediterranean**. They are in decline in the **Eastern Aegean** due to extensive poaching and lack of environmental law enforcement. Limited information is available on their conservation, ecology or management (Can and Togan, 2009). Many small mammal species are either data deficient and/or are threatened by habitat lost (Sekercioglu *et al*. 2011). The catalogue shows one indicator (abundance of seals) as operational. However it is questionable if this is truly operational i.e. linked to reference levels and targets (as seen by the lack of these in some MS Initial assessments).

The only indicator related to Birds in the **Mediterranean Sea** in the catalogue is the “Distributional range of birds”. This indicator seems to be the only one currently and only partially adopted in the **Northern Adriatic Sea**. Pressures for this biodiversity component in the region are related to direct catch during fishing and anthropogenic impact in tourist areas due to fast boat traffic. Gaps are abundant and primarily due to lack of institutes and local research centres with monitoring programmes in place. Also, there are no specific indicators based on key species.

Habitat types

The majority of the indicators address seabed habitats and most are operational. The majority of indicators address Descriptor 1 and the criterion habitat condition (followed by habitat distribution and extent).

There are no (international) basin-wide monitoring programmes for neritic and oceanic habitats and thus no applied indicators.

There are very scarce data and information on deep sea ecosystems and as seen in the **Eastern Mediterranean** analysis, relevant habitat indicators and links are missing. A number of other habitats are also either not addressed by indicators and/or these indicators are not truly operational (i.e. with corresponding reference levels and targets). This includes, for example, maerl and biogenic habitats, i.e. habitats listed or protected under EU and regional regulation. A number of these habitats are also understudied and uncharted while mapping efforts show large spatial regional variations.

For the **Eastern Mediterranean Sea subregion**, based on a structured analysis of the DEVOTES Catalogue of Indicators and their accompanying metadata, it is apparent that habitat types concerning the water column (shelf, reduced salinity water, estuarine water, coastal, open sea) are not targeted by current indices approaches and therefore constituting a gap.

Likewise, **Eastern Mediterranean** seabed habitats types such as littoral, lower bathyal, upper bathyal, abyssal rock and biogenic reefs/sediments are also not covered by the reported indicators.

Pressures

A number of very important regional pressures are not addressed by the existing operational indicators. This includes marine litter, underwater noise, introduction of pathogens and acidification.

A few indicators included in the database under **Central and Western Mediterranean** do not have a demonstrated pressure-impact relationship. For example phytoplankton indicators tested under WISER for WFD have not demonstrated links with pressures and therefore should not be suitable for MSFD biodiversity assessment. The DEVOTES project (through some of his partners) will closely follow tasks that are ongoing and related to the 3rd phase of the WFD intercalibration process and, when this phase will be finished, DEVOTES can revise its database and check whether new selected indicators should be included in the DEVOTES list. Besides, the DEVOTES project also follows tasks that are ongoing and performed by MSFD working groups, both at national and international levels.

For the **Eastern Mediterranean,** pressures such as underwater noise, marine litter, contamination by synthetic compounds/radionuclides, acute pollution events, introduction of microbial pathogens and extraction of species, were identified as important in the subregion, but are not addressed in the scope of the indicators compiled or could be better addressed by other types of indicators.

5. Overall GAP analysis

This section summarizes the findings about gaps in the indicator coverage as observed through the catalogue compilation and analysis process.

5.1. Gaps in relation to MSFD descriptors, criteria and indicators

All of the EU MSFD descriptors, criteria and indicators (those listed in the Commission Decision) are covered in the catalogue.

While the Biological diversity Descriptor (D1) generally is well-covered in all regional seas, indicators for the criterion “Ecosystem structure, processes and functions” are still relatively scarce. Only 7 ecosystem processes and function related indicators are reported, all of them for the North-Eastern Atlantic. The number of indicators between population and habitat level criteria is unbalanced with a concentration on the population level and a comparable low indicator number for criteria habitat distribution and extent. **There is considerable need for the development of biodiversity indicators that work on ecosystem level. In addition, there is a gap regarding indicators for the genetic structure of population. Indicators for habitat distribution and extent need some adjustment to ensure that the indicator set covers all relevant habitat types.**

It is noteworthy that the environmental impact of invasive non-indigenous species (Descriptor 2, criterion 2.2) does not have any operational indicators. Five are under development and one at a conceptual state. **A gap exists regarding indicators that assess the effects of invasive non-indigenous species on all regional seas.**

The Food-web descriptor (D4) has a much lower number of indicators than does biodiversity, but the existing indicators cover all of the indicators of the Commission Decision. Most of the D4 indicators are related to Criterion 4.3 “Abundance/distribution of key trophic groups/species”, and are simultaneously D1 indicators. This implies an ambiguity between D1 and D4, and on the other hand reflects the fact that biodiversity and food-web structure are both tightly related to the ecosystem functioning and to each other. The DEVOTES Catalogue of Model Derived-indicators (Piroddi *et al*. 2013) showed that these indicators are better addressed by modelling approaches and therefore the gap identified here might be overcome by considering them. In any case the same trend regarding D4 criteria fulfilment was also observed in that catalogue (Piroddi *et al*. 2013). **Indicators related to criteria 4.1 and 4.2 should be further developed, in criterion 4.1 especially focusing on primary and secondary producers.**

It was noticed that **some ambiguity exists about the relationship between indicators of different descriptors**, such as the 1.4 habitat distribution, 1.5 habitat extent, 6.1 substrate characteristics, and 4.3.1.3 habitat-defining groups/species. These indicators have potentially a high overlap, and this issue should be clarified to increase consistency between Member States and regional seas. This ambiguity makes it difficult to analyse the gaps related to seafloor integrity (D6). However, in general, the seafloor integrity seems to be covered by indicators relatively well in all regional seas.

5.2. Gaps in relation to biodiversity components and habitats

The biodiversity components least well covered by indicators in all regional seas are **microbes, pelagic invertebrates, and reptiles**, and **indicators for those groups should be further developed** for all regional seas. In addition, **ice-associated species/communities** may be underrepresented by the indicator set. In general, fish and benthic invertebrates are generally well covered. However, the focus of indicator development has clearly been different in the different regional seas: For example, in the North-East Atlantic and the Baltic Sea, several bird indicators exist or are being developed, while in the Mediterranean and in the Black Sea, these are nearly lacking. Mardedly fewer indicators compared to all other regional seas cover the water column components phytoplankton and zooplankton in the Mediterranean Sea. On the other hand, in the Mediterranean Sea a higher number of angiosperm indicators exist compared to the other regional seas. These findings reflect partly the differences in the ecosystem structure of the regional seas but also highlight the potential to exchange indicators between the regional seas. Several species-specific indicators exist for each regional sea. At the moment a gap analysis for key stone species is not possible as the task for defining key stone species for each regional sea is ongoing (DEVOTES task 6.1.3).

Abyssal and **bathyal zones** are not present in all regional seas resulting in a low overall number of indicators covering those depth zones; no indicators specifically address those zones. Indicators should be further or newly developed for the respective geographical area.

There are indicators operating on several time scales in the compiled set of indicators. Indicators related to the life cycle of long-lived species may take years to show an effect and again years to return to good state, while some other indicators may give a relatively quick response. Many of the phytoplankton and zooplankton indicators are likely to function as **early warning indicators**, i.e. indicators that respond quickly to changes in the environment and give swift feedback about changes happening in the food-web and ecosystem. Some benthic flora and fauna indicators may also serve as such. For example, the growth depth limit of macroalgae may relatively quickly indicate negative changes in the water transparency since a lack of light immediately affects plant growth and distribution capabilities. The recovery after water transparency is back to a pre-impact state may however be slow because it depends on other factors than only light availability (e.g. substrate type and exposure or species-specific regeneration and reproduction abilities). Macroinvertebrates indicate oxygen conditions in the seafloor, dying when oxygen depletion event occur, but regeneration again also depends on other factors and may be much slower. This is a complication of the otherwise clear and direct pressure-impact relationship. Other benthic indicators may indicate pressures that already fully took place, such as seafloor habitat destruction. When the changes are observed in the indicators, the damage has been done and there is no early warning as such. There are relatively many phytoplankton and benthic indicators reported in the catalogue. However, analysing whether they would serve as early warning indicators requires specific expertise and is not extractable from the catalogue. Furthermore, the link between biotic components with fast response and the pressures is not strainghtforward and needs more scientific research. For example, phytoplankton communities have a rapid response to changes in environmental conditions. However, they do not integrate over time but react to environmental fluctuations by starting a quick succession. The diversity of a single sample mainly depends on the succession status at the moment of the sampling. Diversity is difficult to interpret if it is defined as species richness within a specific space and during a specific time lapse. The same diversity values could be achieved by different environmental fluctuations or succession status, and therefore the link to pressures may be difficult to interpret. Pressure-diversity-function relationships are not well known and conclusions regarding these kinds of indicators are difficult to achieve, as well as those involving GEnS.

5.3. Gaps in relation to the most important pressures

Indicators are present in the catalogue responding to the most important pressures: eutrophication (Black Sea and Baltic Sea) and habitat loss and effects of selective extraction of species (Mediterranean and North-Eastern Atlantic). However**, the reliability of these indicators in indicating the changes caused by these pressures is yet to be demonstrated** in many cases, a task that will be taken by DEVOTES Specific Objective 3.2.

5.4. Gaps in the status of development of the indicators

Many of the **operational indicators did not report any quantitative or qualitative targets** or even the existence of those. This might have been due to a misinterpretation of the objectives of this survey, and therefore contributors might have refrained from indicating the targets previously used. In any case, an indicator output must be easily interpreted within a good-bad continuum. In a legal and regulatory context, such as the MSFD, it is also crucial to pair indicators with thresholds, although deriving them can often be more challenging than developing the indicators themselves. However, these thresholds are fundamental to observe the accomplishment of legally imposed targets.

The majority of the **indicators lack any measure of confidence or uncertainty associated with their assessment results**. These measures are of utmost importance to ensure robust GEnS assessments, especially if we consider that 56 indicators are outlined in the MSFD Commission Decision to be addressed and integrated while reporting on the status of marine regions.

Within DEVOTES, ongoing tasks will attempt to overcome both these gaps by developing methodologies for setting reference and target values for biodiversity related indicators where possible and by developing a framework for quality checking indicators.

5.5. Gaps in the coverage of the Indicator catalogue

As shown in Chapter 2.2, **some EU member states' indicators are so far missing** from the catalogue (**Figure 2**) due to unavailability of the indicators or experts. **Barcelona Convention UNEP/MED** at the time of this report was also still agreeing on their common indicators for the MFSD, and therefore no information was available for that RSC. This may cause some distortion to the statistics regarding the indicators set, since in different countries the traditional focus on research, and hence the focus of the indicator development, may vary. However, this effect is unlikely to change the overall results, since the major gaps in the indicator set are stemming from major knowledge gaps in general. Nevertheless, the gaps in the country and regional coverage will be filled to the extent possible in the future.

The catalogue does not cover extensively **indicators proposed in the scientific literature**. While there may be such indicators, it is difficult to find them from the vast expanse of scientific literature and identify which of them might have relevance for the MSFD. At this stage these indicators were not the primary target of the survey but may also be added to the catalogue as they are identified during the DEVOTES project.

In addition**, indicators in conceptual stage are probably underrepresented** since scientists may be hesitant to talk about work that is not close to ready and since it may be difficult to fill in the various entries of the catalogue if the indicator is still at a conceptual stage. Therefore, it may be that new indicators emerge faster than could be anticipated based on this catalogue alone.

6. Molecular tools in synergy to emerging indicators: reviewing the potential application

Currently, no indicator has been fully or even partially integrated with existing molecular tools for assessing the quality of marine waters. However, the use of molecular techniques could provide a substantial improvement targeting specific key and rare organisms in support to different descriptors such as (biodiversity, alien species, food-webs and seafloor integrity). Moreover, the integration of new methodologies, which are capable of increasing the level of sensitivity and specificity, might offer the opportunity to develop emerging indicators measuring variables that could not be measured without the existence of these techniques for example to describe microbial communities that are not taxonomically characterized by other techniques. In particular, the definition of functional groups could lead to the assessment of biodiversity components. Descriptors and indicators that would directly benefit from the integration with molecular techniques are described in the following **Table 53**.

Table 53. Descriptors and indicators that would directly benefit from the integration with molecular techniques.

Descriptor	Indicator
D1 Biological diversity	Population genetic structure
D2 Non-indigenous species	Trends in abundance, temporal occurrence and spatial distribution
D4 All elements of the marine food-webs	Abundance trends of functionally important selected groups/species
D6 Seafloor integrity	Presence of particularly sensitive and/or tolerant species

Recently, the potential of molecular tools applied to marine monitoring programmes as part of a view point to implement the MSFD was described in details in Bourlat *et al*. (2013). The authors have considered the most promising molecular techniques that could have the potential to be applied to the assessment of the environmental status, including DNA barcoding-metabarcoding, metagenomics, microarrays, quantitative PCR, single nucleotide polymorphisms (SNPs) and transcriptomics. These approaches with their advantages and disadvantages have been evaluated on the base of cost-efficiency issues and their potential to be integrated in monitoring programmes. One of the most promising molecular tools that would provide support to D1 is DNA metabarcoding, which could emerge as an alternative approach to visual techniques for taxonomic identification. Therefore, this technique could be applied to all indicators requiring taxonomic identification of the species present in a sample, ranging from bacteria to macroinvertebrates (e.g. EU indicators 1.1.1 Distributional range; 2.1.1 Trends in abundance, temporal occurrence and spatial distribution of non-indigenous species; 4.3.1 Abundance trends of functionally important selected groups/species; 6.2.1 Presence of particularly sensitive and/or tolerant species).

Although proof of concept of genomic approaches has been demonstrated, several steps (often requiring several years) are required to develop robust validated tools of known cost. In particular, there is a need for focused research on practical applications including setting up laboratory protocols and developing bioinformatics data analysis pipelines.

Within DEVOTES project (WP5, tasks 5.1.2 and 5.2.1) ongoing activities directly deal with the application of molecular tools as innovative monitoring techniques for assessing marine environmental status. The target species groups include bacteria, microbial eukaryotes, toxic algae, meiofauna and macrofauna. In particular, investigating the validation of developed techniques since standardization and reproducibility are required in monitoring programmes universally accepted. Microbiological quality of marine waters dedicated to bathing and aquaculture activities is currently estimated by determination of faecal indicator bacteria. On routine base, regional laboratories as part of national monitoring programmes assessing the marine environment status carry out conventional microbiological analyses using culturing techniques. Unfortunately, less than 1 % of the actual abundance of prokaryotes can grow on plate. Within DEVOTES, it will be studied the presence of *E. coli* and fecal *Enterococchi* in water samples, and *E. coli*, fecal *Enterococchi* and *Salmonella* in sediment samples comparing both traditional and molecular tools (qPCR and DNA barcoding). In addition to fecal and enterococci pathogens, *S. aureus* (MRSA) offers a good example on how novel molecular techniques targeting new pathogenic organisms could provide additional information to existing indicators (Enns 2012).

In general, and as concluded in the “Marine Genomics For Users” Workshop in Dublin (28th June, 2013), these genomic methods have high potential and provide capability not provided by current approaches. However, the shortage of standardized methodologies may still represent a limitation to the use of these methods.

7. Selecting indicators from the Catalogue

Throughout this report it has been shown that many and very different purposes can drive the search and selection of indicators from the DEVOTES Catalogue of Indicators. The **DEVOTool** software allows performing analyses for extracting subsets of indicators, according to their relevance for specific goals or end-uses. For practical advice on how to extract this kind of information, see the guidance in Annex 2 of this report.

However, in order to provide additional functionalities for exploring the catalogue, the software offers also the possibility for ranking such indicators providing support on the selection of most promising indicators for different purposes, e.g. to refine, ready to use, to develop new indicators. This functionality allows furthermore evaluating the strengths and weakness of catalogued biodiversity (D1), food-web (D4), and seafloor integrity (D6) indicators; since the weaknesses and strengths of the indicators will come out as consequence of the rankings under main “thematic questions”. Those with lower rankings will have more loose points to be solved and are probably weaker. Those higher ranked will have more strength to address the main goals of specific end-uses and users.

Such thematic questions, not yet implemented in the current version of the software, will be found under the Analyses form of the **DEVOTool** (see details in section 7.1).

The rankings are based on predefined criteria which are scored in relation to the final purpose of using the indicators. In the present version of the **DEVOTool**, the criteria available for selecting indicators are solely based on the fields initially available in the database that contained relevant metadata on the indicators (see section 7.2 for details on the available criteria). This is expected to be further developed in future tasks of the DEVOTES project.

7.1. Main questions driving selection of indicators

Selecting the most promising indicators depends on the final goal of the end-user. Most promising in this context refers to the basic capabilities and potential of an indicator and we use the metadata in the catalogue to build the criteria for selecting and supporting the extraction of such indicators according to your end goals or main questions.

So it might be useful to clarify that at this stage we are not referring to the process of quality checking the indicator assessment results. Future tasks in the DEVOTES project will work specifically on developing a framework for quality check of the indicators performance.

So far, in function of the information in our databse we could implement criteria for selecting indicators adequate for the main questions in **Table 54**.

Table 54. Main thematic questions driving indicators selection for which there are criteria available in the DEVOTES catalogue database. Beneficiaires or potentially interested parties are indicated for each main theme.

Main thematic questions	Beneficiaries or interested parties
Q1. Most promising operational indicators to be used in environmental assessment programmes	*Member States, RSC, stakeholders* and *managers*
Q2. Most promising indicators for further development	*Research groups, R&D funding agencies*
Q3. Most promising indicators for large scale Marine Policies	*Wide scale conservation policies/strategies*

Other questions would also be of relevance, but further work is needed to check how the data in the catalogue can be used to adequately address them. Below there is an example of another question that is related but sufficiently different from the first two. In the first question we ask about the present ecological status (quality assessment) of the sea – that question is useful to evaluate present management (if the indicator is good). In the second question we ask which indicator is most promising to devote R&D effort. We could also formulate a fourth question as to the vulnerability/resilience of an ecosystem, in view of activity planning. If one can deduce from an indicator of state that at present the ecosystem is in good condition, it may still be of interest to know how much it could change if a different management is going to be applied. Some ecosystems (e.g. maerl) will be much more vulnerable than others (e.g. dynamic sand beds).

Upon extraction of an initial list some subsequent judgement is still required to assess whether the indicators are actually applicable, powerful and relevant to the required area. At this stage we aim at providing a good and as useful as possible tool to help in a first screening of available indicators.

7.2. Scoring of criteria and ranking of indicators

The criteria implemented at this stage in the **DEVOTool** software are constrained by the metadata available in the catalogue that allow scoring or classifying the indicators in relation to those criteria. The 7 criteria for selecting most promising indicators so far available are outlined in **Table 55**. Fundamentally, each of the selection criteria must be reflected in the indicator catalogue in an indicator parameter or a combination of parameters (i.e. specific information of the indicator entered into the catalogue). This means that certain data fields in the catalogue (that define some property of the indicator) act as anchor points for the above criteria in order to execute the actual query. Some definitions in the context of this work were proposed for each criterion as outlined below.

Operationality

The indicator should ideally be fully developed, meaning that it has been validated and tested and is directly applicable. Indicators that are still under development or in a conceptual stage, although valuable, will need further research and investment, and thus do not warrant yet a reliable ecological assessment.

Data availability

The indicator should be easy to monitor and analyse (using established gears and instruments, whenever possible, with standardized protocols). The indicator should be compatible with existing monitoring so it does not require completely new monitoring strategies. For example, a new indicator that is based on existing time series and is compatible with on going data collection is preferable to indicator requiring different or additional data collection.

Geographic applicability

The indicator should ideally be used in many geographical regions or it should be easy to transfer to another region. If an indicator is specific to a narrow geographical area (e.g. a subdivision of the Baltic Sea) it might be difficult to adapt and calibrate it for other regions, since it may depend on some fundamental characteristics unique to that narrow area. A wide applicability is also a valuable asset in the pan European context of the MSFD since it enhances the potential of comparability among assessment results.

Possibility to define a target

The indicator should have target values or it should be possible to define target values or at least have a defined baseline and exhibit temporal trends; making it possible to interpret it within a good-bad continuum. It is also crucial to pair indicators with thresholds since these thresholds are fundamental to observe the accomplishment of legally imposed targets, and ultimately follow policy effects.

Relevance to major pressures

The indicator should have at least a conceptual relevance to major pressures. It should be responsive to one or more pressures in order to inform on the activities that need to be managed for minimizing the pressure.

Cost-efficiency

The data requirements and processing should be such that the ratio of deliverd benefit to the cost of data collection is as high as possible.

Simplicity

The indicator should ideally be easy to calculate (e.g. simple algorithm or not requiring great expertise) and to communicate to the target groups (e.g. policy-makers, stakeholders, Member States). At the same time, it should nonetheless be robust and allow for a reliable assessment.

Other relevant criteria are under discussion at the moment, e.g. “Responsiveness to management/governance changes” or “Ecosystem relevance” which could be related for instance with the context of the MSFD. In the catalogue we have fields such as the number of descriptors or the number of criteria and indicators within descriptors that each indicator could inform on, which could be used to address these criteria. However the best way to extract such information from the catalogue has yet to be defined.

To exemplify the rationale for this in **Table 55** the criteria were allocated under two of our main thematic questions (Q1 and Q2) for which they could support the selection of indicators. It also shows in which fields of the database (surrogate fields) the criteria can get information on the indicators currently in the catalogue. Then you can also find information on the modality score for the criteria (also constrained by the nature of the metadata gathered during the survey). One criterion can be used in two different ways and scored differently depending if it is favourable or not for the end-goal, e.g. the criterion “Status of development of an indicator” and see how it scores differently under Q1 and Q2.

As seen in the table, the use of some of the criteria is still under discussion, e.g. how to use the "Relevance to major pressures" criterion using the information in the catalogue? Would matching a large number on pressures be a sign of a promising indicator? Depending on the answer, the end-user might want to score it taking the "number of pressures covered" or just "sensitive to selected pressures". In order to allow build tailored queries the user is allowed to use this functionality independently of the main questions or of the criteria that could be suggested under each, by building his own set of criteria more adapted to specific questions.

In a near future, in the DEVOTES works compatibility with other criteria used in other frames, e.g. the recently adopted ICES criteria (ICES 2013) or the EPA guidelines in the USA (Jackson *et al*. 2000) will be checked. It is of best interest to increase coherence and try to have them as standardized as possible across different initiatives already in place.

Table 55. Table of criteria for selecting most promising indicators from the DEVOTES Catalogue of indicators, using DEVOTool software database.

Query criterion	Possible surrogate fields in the Catalogue (Annexes 1 and 2)	Modality (levels)	Score Q1 Environmental management perspective *	Score Q2 Further research perspective *
1. Operationality	1.1 Status of development	operational	3	1
		under development	2	2
		conceptual	1	3
	1.2 Confidence/ Uncertainty	Yes/No	1/0	0/1
2. Data Availability	2.1 Data requirement/ collection method	*<yet to interpret from catalogue's metadata>*	*<not yet usable>*	Not a relevant criterion
	2.2 Existing related monitoring	<numeric>	<number of monitoring programmes associated>	Not a relevant criterion
	2.3 Data series	*<yet to interpret from catalogue's metadata>* *E.g. of possible scoring scheme:* Data available and easily accessible (e.g. public web page, open access resources) (3); Data in process to be obtained (e.g. ongoing monitoring networks), but needing processing (2); Need to undertake ex-novo monitoring networks (1))>	*<not yet usable>*	*<not yet usable>*
3. Geographic applicability	3.1 Geographical subdivisions	<numeric>	<number of subdivisions>	<number of subdivisions> OR <applicable to the area of interest> OR <not relevant>
4. Possibility to define targets	4.1 Target or reference value	Yes/No	1/0	0/1
5. Relevance to major pressures	5.1 Pressures	<numeric>	<number of pressures covered>	<number of pressures covered> OR <sensitive to selected pressures>
6. Cost-efficiency	6.1 Data requirements/ data used	*<yet to interpret from catalogue's metadata>*	*<not yet usable; possible scoring scheme:* high cost (1), moderate cost (2) and low cost (3)>	Not a relevant criterion
	6.2 Data requirements/ collection method	*<yet to interpret from catalogue's metadata>*		Not a relevant criterion
7. Simplicity	7.1 Bibliographic sources / Indicator description / coupled with expert judgement	*<info not always directly in the catalogue>* *E.g. of possible schemes:* a) easy/difficult b) several categories: direct measure/simple aritmethics/fancy statistics/modeling (to allow future integration of WP4 model derived indicators)	*<not yet usable>*	Not a relevant criterion (??)

8. Relevance for future DEVOTES outputs

Table 56. Main links of the results presented in the current Deliverable (D3-1) with future DEVOTES activities (by Work Package). Further information on each WP activities can be consulted on the project website (http://www.devotes-project.eu/work-packages/).

Work Package	Links of the results presented in this Deliverable 3.1 with future DEVOTES activities
WP1. Human Pressures and Climate Change	Specific objectives of WP1 link directly to this WP3 and will form the basis of much of our understanding of the links between pressures and impacts for which indicators are required. The production of pressure-impact matrices for regional seas is ongoing. They will indicate the spatial distribution of pressure types and impacts which will link to the analysis of the geographical distribution of indicators. That is, do we have an indicator for a specific pressure and is it operational in the regions where that pressure has been identified? Secondly, it is simultaneously being built a monitoring catalogue, identifying monitoring programmes of direct relevance to the MSFD throughout Europe and their geographical distribution. Furthermore, this catalogue identifies the GEnS descriptors, pressures and habitat types targeted by each monitoring programme, together with details of monitoring frequency, longevity (availability of time-series data), quality assurance and supporting data as an indication of the adequacy of the monitoring. The gap analyses in WP's 1 and 3 (Monitoring and Indicator catalogues, respectively) will enable us to assess where monitoring is lacking and where indicators to support the monitoring are lacking. Finally, it will be evaluated the adequacy of pressure-impact links as means to indicate status and changes of key processes and will use the information contained in the catalogue of indicators that relates the available indicators with the main pressures they respond to.
WP2. Social-economic implications for achieving GES	Under WP2, indicators in the catalogue will be assessed for cost effectiveness, in a socio-economic context: 1) identify criteria to determine the cost-effectiveness of different suites of monitoring and assessment systems used and developed for MSFD, 2) assess the cost-effectiveness of different suites of monitoring and assessment systems used and developed for MSFD. This information will then feed back to WP3 in our assessment of indicator quality/feasibility.

Work Package	Links of the results presented in this Deliverable 3.1 with future DEVOTES activities
WP3. Indicator testing and development	The indicator catalogue will form the basis of WP3 activities. The analysis of indicators will rely on lists of indicators extracted from the catalogue as their starting point as well as possible additional indicators. Activities will involve tests/analyses of a selection of promising indicators contributing to identify pressure-response relationships for these indicators, reduce uncertainty/increase robustness of the assessments provided by the indicators and establish links between indicators and ecosystem services.Later tasks will develop frameworks for establishing targets for indicators.
WP4. Innovative modelling tools	WP3 and WP4 Catalogues of Indicators and Model-derived Indicators will be checked for complementarity. Many descriptors within the MSFD are better described by modelling approaches, only by comparing the two catalogues we can provide a real overview of how well the MSFD requirements are covered by the currently available assessment tools or approaches.
WP5. Innovative monitoring techniques	Monitoring in the context of MSFD is tightly linked to the indicators by which the environmental status is assessed; hence development of monitoring methods and indicators are tightly linked. The catalogue can be used to evaluate, which indicators would the most benefit from improved monitoring methods. During the project life our aim is to update the catalogue of indicators with these new developments to increase their public awareness, make them available for use and be able to compare them with the pool of currently available assessment tools. Ongoing activities directly deal with the application of molecular tools as innovative monitoring techniques for assessing marine environmental status.
WP6. Integrative assessment of biodiversity	Most of the results of WP3 will be utilized in the integrative assessment of WP6. WP6 will also test different weighting and scoring schemes for the overall ecological assessment and these schemes can also be used for the kind of queries done here.

Work Package	Links of the results presented in this Deliverable 3.1 with future DEVOTES activities
WP7. Outreach, stakeholder engagement and product dissemination	The tools developed in WP3 will also be part of the basis for end-user applications developed in WP7. Updates and news about the progress of WP3 will be spread through the DEVOTES dissemination channels.The results of WP3 will be presented in several meeting and conferences. The outputs of this WP will be reported in manuscripts and will be utilized for the production of the DEVOTES final book. The tools developed in WP3 will be tested as part of a capacity building (doctoral level) research programme. The tools developed in WP3 will also be part of the basis for end-user applications developed in WP6 and WP7.

9. References

2010/477/EU: Commission Decision of 1 September 2010 on criteria and methodological standards on good environmental status of marine waters. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:232:0014:0024:EN:PDF

Abdul Malak D., S R Livingstone, D Pollard, B A Polidoro, A Cuttelod, M Bariche, M Bilecenoglu, K E. Carpenter, B B. Collette, P Francour, M Goren, M Hichem Kara, E Massutí, C Papaconstantinou and L Tunesi (2011) Overview of the Conservation Status of the Marine Fishes of the Mediterranean Sea. Gland, Switzerland and Malaga, Spain: IUCN. vii + 61pp.

Acara A.and Nalbandoğlu U., 1960. Preliminary report on the red tide outbreak in the Gulf of Izmir . Rapp. p.-V. reun. Com: Int. Explor. Scient. Mer. Mediterr., 15(3): 33-38.

ACCOBAMS, 2012. Black Sea Workshop on ACCOBAMS implementation (ACCOBAMS Report), Istanbul, Turkey, June, 2012.

Aktan, Y. 2005. Toxic and harmful algal species in the Izmit Bay, Marmara Sea. UNESCO, HAN, No: 28, August.

Alexandrov B.G. , L. M. Teren'ko, D. A. Nesterova, 2012. The First Case of a Bloom of Nodularia spumigena Mert. ex Born. et Flah. (Cyanophyta) in the Black Sea. International Journal on Algae, Volume 14, 2012 Issue 1: 31-43.

Alheit J, Möllmann C, Dutz J, Kornilovs G, Löwe P, Mohrholz V, Wasmund N (2005) Synchronous ecological regime shifts in the central Baltic and the North Sea in the late 1980s. ICES Journal of Marine Science, 62:1205-1215.

Andersen V, Gubanova A, Nival P, Ruellet T (2001) Zooplankton community during the transition from spring bloom to oligotrophy in the open NW Mediterranean and effects of wind events. 2. Vertical distributions and migrations. J. Plankton Res. 23, 243–261.

Aysel V, Guner H (1979). Qualitative and quantitative studies of the algaepopulation in the Aegean and Marmara Seas. 3. Cracilariaverrucosa (Huds.) Papenf. population. EU Fac Sci Ser B 3: 111-118.

Aysel V, Guner H (1980). Qualitative and quantitative studies of the algaepopulation in the Aegean and Marmara Seas.4. Gelidiumcapillaceum (Gmel.) K.tz. Population. EU Fac Sci. Ser B 4: 141-153.

Aysel V, Guner H (1982). Qualitative and quantitative studies of the algaepopulation in the Aegean and Marmara Seas. 6. Laurencia obtusa(Huds.) Lam. var. Obtusa population (Rhodomelaceae, Ceramiales,Rhodophyta). Doga 6(3): 97-103.

Bakır, K. (2012). Contributions to the knowledge of crustaceans on soft bottoms in the Sea of Marmara, with a checklist. Crustaceana, 85(2), 219–236.

Barale V, Gade M (2008) Remote sensing of the European seas, Vol. Springer

Bargu S., Tufan Koray, Nina Lundholm, 2002. First Report of Pseudo-nitzschia calliantha Lundholm, Moestrup and Hasle 2003, a New Potentially Toxic Species from Turkish Coasts.//E.U. Journal of Fisheries and Aquatic Sciences, Volume 19(3-4): 479 – 483

Bat, L., Sezgin, M., Satılmış, H.H., Şahin, F., Üstün, F., Özdemir Birinci, Z., Gökkurt Baki, O., 2011. Biological Diversity of the Turkish Black Sea Coast, Turkish Journal of Fisheries and Aquatic Sciences 11: 533–542

Baxter, J.M., Boyd, I.L., Cox, M., Donald, A.E., Malcolm, S.J., Miles, H., Miller, B. and Moffat, C.F., (Editors), 2011. Scotland's Marine Atlas: Information for the national marine plan. Marine Scotland, Edinburgh. pp. 191

Besiktepe, S.T., Sur, H.I., Ozsoy, E., Latif, M.A. Oguz, T., and Ünlüata, Ü.1994. The Circulation and Hydrography of the Marmara Sea", Progress in Oceanography, 34, 285-334

Bianchi C, Morri C (2000) Marine biodiversity of the Mediterranean Sea: situation, problems and prospects for future research. Marine Pollution Bulletin 40:367-376

Birk, S., Bonne, W., Borja, A., Brucet, S., Courrat, A., Poikane, S., Solimini, A., van de Bund, W., Zampoukas, N. & Hering, D., 2012. Three hundred ways to assess Europe’s surface waters: An almost complete overview of biological methods to implement the Water Framework Directive. Ecological Indicators 18, 31-41.

Birk, S., Strackbein, J. and Hering, D., 2010. WISER methods database. Version: March 2011. Available at http://www.wiser.eu/results/method-database/.

Bizsel, K.C., Bizsel, N., 2002. New records of toxic algae Heter¬osigma cf. akashiwo and Gymnodinium cf. mikimotoi in the hypereutrophic Izmir Bay (Aegean Sea): coupling between organisms and water quality parameters. Israel Journal of Plant Sciences, 50, 33-44.

Bizsel, N. 1988. Dynamics of phosphate and nitrate in the Sea of Marmara. Master Thesis, Middle East Technical University, pp.:226.

Bodeanu N and M Usurelu. 1979. Dinoflagellate blooms in Romanian Black Sea coastal waters. In: Taylor D L and H H Seliger (eds), Toxic Dinoflagellate Blooms. Elsevier/North Holland, Inc., New York:151-154.

Borrell A, Aguilar A, Pastor T (1997) Organochlorine pollutant levels in Mediterranean monk seals from the western Mediterranean and the Sahara coast. Marine Pollution Bulletin 34:505-510

Bourlat SJ, Borja A, Gilbert J, Taylor MI, Davies N, et al. (2013) Genomics in marine monitoring: New opportunities for assessing marine health status. Marine Pollution Bulletin. 74 :19-31

Breen P, Robinson L, Rogers S, Knights A, Piet G, Churilova T, Margonski P, Papadopoulou N, Akoglu E, Eriksson A (2012) An environmental assessment of risk in achieving good environmental status to support regional prioritisation of management in Europe. Marine Policy 36:1033-1043

BSC, 2007. Black Sea Transboundary Diagnostic Analysis. The Commission on the Protection of the Black Sea Against Pollution (BSC), Istanbul, Turkey.

BSC, 2008. State of the Environment of the Black Sea (2001-2006/7). The Commission on the Protection of the Black Sea Against Pollution (BSC), Istanbul, Turkey.

BSC, 2010 . 'Diagnostic Report' to guide improvements to the regular reporting process on the state of the Black Sea environment (BSC), Istanbul, Turkey.

Butchart SHM, Walpole M, Collen B, van Strien A, Scharlemann JPW, Almond REA, Baillie JEM, Bomhard B, Brown C. & Bruno J (2010) Global biodiversity: indicators of recent declines. Science, 328, 1164–1168.

Can E, Togan I (2009) Camera trapping of large mammals in Yenice Forest, Turkey: local information versus camera traps. Oryx 43, 427–430.

Carletti A, Heiskanen AS (2009) Water Framework Directive intercalibration technical report. Part III Coastal and Transitional Waters. JRC Scientific and Technical Reports.

Casini M, Cardinale M, Arrhenius F (2004) Feeding preferences of herring (Clupea harengus) and sprat (Sprattus sprattus) in the southern Baltic Sea ICES Journal of Marine Science 61:1267-1277.

Casini M, Cardinale M, Hjlem J (2006) Inter-annual variation in herring, Clupea harengus, and sprat, Sprattus sprattus, condition in the central Baltic Sea: what gives the tune? Oikos 112:638-650.

Cavanagh RD, Gibson C (2007) Overview of the conservation status of cartilaginous fishes (Chondrichthyans) in the Mediterranean Sea, Vol 3. IUCN, Gland, Switzerland and Malaga, Spain

Cinar ME, Gönlügür-Demirci G (2005) Polychaete assemblage on shallow-water benthic habitats along the Sinop Peninsula (Black Sea, Turkey). Cah. Biol. Mar. 46: 253-263

Cinar ME, Katagan T, Öztürk B, Dagli E, Açik S, Bitlis B, Bakir K, Dogan A (2012) Spatio-temporal distributions of zoobenthos in Mersin Bay (Levantine Sea, eastern Mediterranean) and the importance of alien species in benthic communities. Marine Biology Research, 8: 954-968.

Çınar, M. E. 2009. Alien polychaete species (Annelida: Polychaeta) on the southern coast of Turkey (Levantine Sea, eastern Mediterranean), with 13 new records for the Mediterranean Sea. Journal of Natural History, Volume 43, Issue 37-38.

Çınar, M. E., Bilecenoğlu, M., Öztürk, B., Katagan, T., Aysel, V., 2005. Alien species on the coasts of Turkey. Mediterranean Marine Science, 6/2, 119-146.

Çoban-Yildiz, Y., Tugrul, S., Polat, S.Ç., Ediger, D., Yilmaz, A. 2000. A comparative study on the abundance and elemental composition of POM in three interconnected basins: the Black, the Marmara and the Mediterranean Seas. Med. Mar. Sc., 1(1), 51. "Mediterranean Marine Scinces Journal ", 1, p.51-63.

Cochrane SKJ, Connor DW, Nilsson P, Mitchell I, Reker J, Franco J, Valavanis V, Moncheva S, Ekebom J, Nygaard K, Serrão Santos R, Narberhaus I, Packeiser T, van de Bund W, Cardoso AC (2010) Marine Strategy Framework Directive – Task Group 1 Report Biological diversity. EUR 24337 EN – Joint Research Centre.

Coll M, Piroddi C, Albouy C, Ben Rais Lasram F, Cheung WWL, et al. (2011) The Mediterranean Sea under siege: spatial overlap between marine biodiversity, cumulative threats and marine reserves. Global Ecology and Biogeography 21(4): 465–480.

Coll M, Piroddi C, Steenbeek J, Kaschner K, Lasram FBR, Aguzzi J, Ballesteros E, Bianchi CN, Corbera J, Dailianis T et al (2010) The biodiversity of the Mediterranean Sea: estimates, patterns, and threats. PloS one 5:e11842, doi:10.1371/journal.pone.0011842.

Costello MJ, Coll M, Danovaro R, Halpin P, Ojaveer H, Miloslavich P (2010) A census of marine biodiversity knowledge, resources, and future challenges. PloS one 5:e12110

Cuttelod A, García N, Malak DA, Temple HJ, Katariya V (2009) The Mediterranean: a biodiversity hotspot under threat. In: Vié J-C, Hilton-Taylor C, Stuart SN (eds) Wildlife in a Changing World–An Analysis of the 2008 IUCN Red List of Threatened Species, Book 89, Gland, Switzerland

Danovaro R, Company JB, Corinaldesi C, D'Onghia G, Galil B, et al. (2010) Deep-Sea Biodiversity in the Mediterranean Sea: The Known, the Unknown, and the Unknowable. PLoS ONE 5(8): e11832. doi:10.1371/journal.pone.0011832.

Dumont, H., T. Shiganova and U. Niermann - The Ctenophore Mnemiopsis leidyi in the Black, Caspian and Mediterranean Seas and other aquatic invasions - NATO ASI Series, 2. Environment-. Kluwer Academic Publishers: 33-70.

Dural B., Aysel V., 2007. Role of Benthic Algae and the Seagrasses in the Biodiversity of the Turkish Aegean and Mediterranean Seas. Acta Pharmaceutica Sciencia 49: 85-118.

Ediger D. and A. Yılmaz. 1996. Variability of light transparency in physically and biochemically different water masses: Turkish seas. "Fresenius Environmental Bulletin" 5: 133-140

Elmgren R (2001) Understanding human impact on the Baltic ecosystem: Changing views in recent decades. Ambio 30: 222-231.

Enns, A. A., Vogel, L. J., Abdelzaher, A. M., Solo-Gabriele, H. M., Plano, L. R. W., Gidley, M. L., et al. (2012). Spatial and temporal variation in indicator microbe sampling is influential in beach management decisions. Water Research, 46(7), 2237–2246. doi:10.1016/j.watres.2012.01.040

EUSeaMap 2010. Preparatory Action for development and assessment of a European broad-scale seabed habitat map EC contract no. MARE/2008/07, Final Report

Fenske C., Zaiko A., Wozniczka A., Dahlke A., Orlova M.I. (2013) Variation in length–frequency distributions of zebra mussels (Dreissena polymorpha) within and between three Baltic Sea subregions Szczecin Lagoon, Curonian Lagoon, and Gulf of Finland. Chapter 49 In: Nalepa, T., Schlosser, D. (Eds.), Quagga and zebra mussels: Biology, Impacts and Control. Second Edition, 725-739

Fernández de Puelles ML, Pinot JM., Valencia J (2003) Seasonal and interannual variability of zooplankton community in waters off Mallorca Island: 1994–1999. Oceanologica Acta 2003;26:673-686.

Fevzioğlu, M. A., Boran, M., Sivri, N. (2000): The effects of environmental factors on the winter bloom of Scripsiella trochoidea (Dinophyceae) in the bay of Surmene. (in Turkish). 1. Ulusal Deniz Bilimleri Konferansı, Bildiriler ve Poster Özetleri, Z. UYSAL. ve I. SALIHOGLU (eds.), 121-125.

Fevzioğlu, M., Boran, M. (1997): A study on Pyramimonas orientalis (Butcher, 1959) (Chlorophyta: Chlorodendrales) bloom at vicinity of Çamburnu. (in turkish). Tr. J. of Biology, 21:49-54.

Finenko, 2008. "Biodiversity and bioproductivity". The Black Sea Environment. The hand book of environmental chemistry. Vol. 5/Q. Springer. P. 351 – 374.

Flinkman J, Aro E, Vuorinen I, Viitasalo M. (1998) Changes in the northern Baltic zooplankton and herring nutrition from 1980s to 1990s: top-down and bottom-up processes at work. Marine Ecology Progress Series 163:127-136.

Friligos, N. and Gotsis-Skretas, O. 1989 Eutrophication and red tide in Aegean coastal waters. Toxicological and Environmental Chemistry 24, 171–180.

Galgani F, Fleet D, Van Franeker J, Katsanevakis S, Maes T, Mouat J et al (2010). MSFD, Task Group 10 Report, Marine litter. Office of Official Publications of the European Communities, Luxembourg. http://www.ices.dk/projects/MSFD/TG10final. pdf

Galil, BS (2000) A sea under siege – alien species in the Mediterranean. Biol. Inv. 2: 77–186

Gaudy R, Youssara F, Diaz F, Raimbault P (2003) Biomass, metabolism and nutrition of zooplankton in the Gulf of Lions (NW Mediterranean). Oceanol Acta 26: 357−372.

Giakoumi S, Sini M, Gerovasileiou V, Mazor T, Beher J, et al. (2013) Ecoregion-Based Conservation Planning in the Mediterranean: Dealing with Large- Scale Heterogeneity. PLoS ONE 8(10): e76449. doi:10.1371/journal.pone.0076449

Giangrande A, Licciano M, Musco L (2005) Polychaetes as environmental indicators revisited. Marine Pollution Bulletin 50:1153-1162

Glover H E, Phinney D A, Yentsch C S (1984) Photosynthetic characteristics of picoplankton compared with those of large phytoplankton populations in various water masses in the Gulf of Maine. Biol. Oceanogr, 3, 223-248.

Gönlügür- Demirci G , Katağan T (2004) Qualitative and Quantitative Investigations on *Ulva rigida* Facies from the Upper Infralittoral Zone Along Sinop Coast, Middle Black Sea 161-171 . Öztürk, B., Mokievsky, V.O. And Topaloğlu, B. (Eds) International Workshop on Black Sea Benthos. Published by Turkish Marine Research Foundation Turkey

Gönlügür G, Katağan T, Sezgin M, Kirkim F (2004) Contributions to the Knowledge On Benthic Crustaceans From Turkish Black Sea Coast. Middle Black Sea In: Öztürk B, Mokievsky VO, Topaloğlu B (ed) International Workshop On Black Sea Benthos. Turkish Marine Research Foundation, Istanbul, Turkey

Gonlugur-Demirci G and Karakan I (2006) Sinop Kıyılarında (Orta Karadeniz) Deniz Cayırlarının Dağılımı. Fırat Univ. Fen ve Muh. Bil. Dergisi, 18 (3):331-337

Gorokhova E, Lehtiniemi M, Viitasalo-Frosen S (2009) Molecular evidence for the occurrence of Mertensia ovum in the northern Baltic Sea and implications for the status of Mnemiopsis leidyi invasion. Limnol Oceanogr 54: 2025–2033

Gorokhova E, Lehtiniemi M, Lesutiene J, Strake S, Uusitalo L, Demereckiene N, Amid C (2013) Zooplankton mean size and total abundance. HELCOM Core Indicator Report. Online. Viewed 30 December 2013. http://www.helcom.fi/Core%20Indicators/HELCOM-CoreIndicator-Zooplankton_mean_size_and_total_abundance.pdf

Güneralp B, Tezer AI, Albayrak T (2013) Local Assessment of İstanbul: Biodiversity and Ecosystem Services. Chapter 16, pp. 291-311. In: Elmqvist et al. (eds.), Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities: A Global Assessment

Hall-Spencer JM, Stehfest KM (2009) Assessment of *Lophelia pertusa* reefs in the OSPAR area. Marin Institute, University of Plymouth report to Joint Nature Conservation Committee.

Harvey CJ, Cox CP, Essington TE, Hansson S, Kitchell JF (2003) An ecosystem model of food-web and fisheries interactions in the Baltic Sea. ICES Journal of Marine Science 60:939–50.

HELCOM (2010) Ecosystem health of the Baltic Sea 2003-2007: HELCOM Initial Holistic Assessment. Baltic Sea Environment Proceedings No 122.

ICES (2013) Report of the Working Group on Biodiversity Science (WGBIODIV), 18-22 February 2013, ICES headquarters, Copenhagen, Denmark. ICES CM 2013/SSGEF:02. 61 pp.

Ignatiades L, Psarra S, Zervakis V, Pagou K, Souvermezoglou E, Assimakopoulou G, Gotsis-Skretas O (2002) Phytoplankton size-based dynamics in the Aegean Sea (Eastern Mediterranean). J. Mar. Syst., 36, 11–28.

Ignatiades, L., Psarra, S., Zervakis, V., Pagou, K., Souvermezoglou, E., Assimakopoulou, G., Gotsis-Skretas, O., 2002. Phytoplankton size-based dynamics in the Aegean Sea Aegean Sea (Eastern Mediterranean). J. Marine Syst. 36, 11-28.

Ignatov E.I. (2008) Coastal and BottomTopography // Hdb Env Chem Vol. 5, Part Q Springer-Verlag Berlin Heidelberg, P. 47–62

Ivanov, L. I., Samodurov, A. S., 2001. The role of lateral fluxes in ventilation of the Black Sea. Journal of Marine Systems, 31, 159-174.

Jackson L E, Kurtz J, Fisher W S (2000) *Evaluation guidelines for ecological indicators*. EPA/620/R-99/005 Environmental Protection Agency, Office of Research and Development.

JNCC Coasts and Seas of the United Kingdom http://jncc.defra.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00000318#

Kamburska L., W. Schrimpf, S. Djavidnia, T. Shiganova, K. Stefanova, 2006. Addressing the ecological issue of the invasive species, Special focus on the ctenophore Mnemiopsis leidyi (Agassiz, 1865) in the Black Sea. EUR 22310 EN, JRC-EC Publication office, 59

Katsanevakis S, Issaris Y, Poursanidis D, Thessalou-Legaki M (2010) Vulnerability of marine habitats to the invasive green alga Caulerpa racemosa var. cylindracea within a marine protected area. Marine environmental research 70:210-218

Kazumi M. and Yasuwo F. 2000. Technical Giude for Modern Dinoflagellate Cyst Study. WESTPAC-HAB/WESTPAC/IOC, 29 pp.

Kideys, A E., Yüksek, A and Sur H I. 2013. Abrupt Changes in the Marmara Pelagic Ecosystem during the recent jellyfish Liriope tetraphylla invasion and mucilage events. Geophysical Research.Vol. 15, EGU-10084.

Kiseleva M.I.,1979. Zoobentos. In: Greze VN (ed) Bases of biological productivity of the Black sea. Naukova Dumka, Kiev, p 208 (in Russian)

Kiseleva, 1979. Zoobentos. In: Greze VN (ed) Bases of biological productivity of the Black sea. Naukova Dumka, Kiev, p 208 (in Russian)

Klein J, Verlaque M (2008) The Caulerpa racemosa invasion: A critical review. Marine Pollution Bulletin 56:205-225

Knight et al., 2011. “Sustainable use of European regional seas and the role of the Marine Strategy Framework Directive”. Deliverable 1, EC FP7 Project (244273) ‘Options for Delivering Ecosystem-based Marine Management’. University of Liverpool. ISBN: 978-0-906370-63-6: 165 pp.

Knights AM, Koss RS, Papadopoulou N, Cooper LH, Robinson LA (2011) Sustainable use of European regional seas and the role of the Marine Strategy Framework Directive. In: Deliverable 1, EC FP7 Project (244273) ‘Options for Delivering Ecosystem-based Marine Management’, University of Liverpool. ISBN: 978-0-906370-63-6: 165 pp.

Koivisto ME (2011) Blue mussel beds as biodiversity hotspots on the rocky shores of the northern Baltic Sea. PhD Thesis, University of Helsinki. http://urn.fi/URN:ISBN:978-952-10-7121-8

Konsulova Ts, Tasev V, Todorova V, Konsulov A (2003) The effect of bottom trawling on mussel beds along the Bulgarian Black Sea coast. Proceedings of the “Second international conference Oceanography of the Eastern Mediterranean and Black Sea: Similarities and Differences of Two Interconnected Basins", 14-18 October 2002, Ankara, Turkey, 888-896.

Koray, T. (1990): Planktonik protista associated with "color-tides" in Izmir Bay (Aegean Sea). Rapp. Comm. int. Mer Medit.,32, 1, 212.

Koray, T. (1992): Noxious blooms in the Bay of Izmir, Aegean Sea, UNESCO, IOC Newsletter on Toxic Algae and Algal Blooms, Suppl. to ims Newsletter, No.63, 2, 1-2.

Koray, T., Büyükışık, B., Parlak, H., Gökpınar,S. (1996): Eutrophication processes and algal blooms (red-tides) in Izmir Bay. UNEP. MAP Technical Reports Series No. 104. 1-26.

Korotaev, G., Oguz, T., Riser, S., 2006. Intermediate and deep currents of the Black Sea obtained from autonomous profiling floats. Deep-Sea Research II 53 1901–1910.

Korotaev, G.K., T. Oguz, A. Nikiforov, C. J. Koblinsky, 2003. Seasonal, interannual and mesoscale variability of the Black Sea upper layer circulation derived from altimeter data. J. Geophys. Res., 108(C4), 3122

Köster FW, Möllmann C, Neuenfeldt S, Vinther M, St. John MA, Tomkiewicz J, Voss R, Hinrichsen HH, MacKenzie B, Kraus G, Schnack D (2003) Fish stock development in the central Baltic Sea (1974–1999) in relation to variability in the environment. ICES Marine Science Symposium 219:294–306.

Koutsodendris, A., Papatheodorou, A., Kougiourouki, O. and Georgiadis, M. (2008). Benthic marine litter in four Gulfs in Greece, Eastern Mediterranean; abundance, composition and source identification. Est. Coast. Shelf Sci. 77, 501-512.

Kucuk A and Aytekin E H, 2011. Seasonal variations of microplankton composition in İzmit Bay (Sea of Marmara J of the Black Sea/Mediterranean Env. Vol:17 Issue 3 p 216.

Kurt Şahin G, Çınar ME (2012) A Check-list of Polychaete Species (Annelida: Polychaeta) from the Black Sea, J. Black Sea/Mediterranean Environment, 18 (1): 10-48

Laine, AO (2003) Distribution of soft-bottom macrofauna in the deep open Baltic Sea in relation to environmental variability. Estuarine Coastal and Shelf Science 57:87–97.

Laroche S, Andral B, Cadiou J-F, Pantazi M, Gonzalez Fernandez D, Vasile D, Vasilopoulou V et al, 2013. Identified gaps on MSFD assessment elements. Perseus Deliverable D.5.2. PERSEUS Project. ISBN 978-960-9798-01-3

Licandro P, Icardi P (2009) Basin scale distribution of zooplankton in the Ligurian Sea (north-western Mediterranean) in late autumn, Hydrobiologia, 617, 17–40.

Lleonart J, Maynou F (2003) Fish stock assessments in the Mediterranean: state of the art. Scientia marina 67:37-49

Llope M., Daskalov G., Rouyer T., Mihneva V., Chan K - S. , Grishin A., Stenseth N., 2011. Overfishing of top predators eroded the resilience of the Black Sea system regardless of the of the climate and anthropogenic conditions. Global Change Biology 17: 1251-1265

Lotze HK, Lenihan HS, Borque BJ, Bradbury RH, Cooke RG, et al. (2006) Depletion, Degradation, and Recovery Potential of Estuaries and Coastal Seas. Science 312: 1806–1809.

Ludwig W., E. Dumont, M. Meybeck, and S. Heussner. 2009. River discharges of water and nutrients to the Mediterranean and Black Sea: Major drivers for ecosystem changes during past and future decades? Progress in Oceanography 80:199-217.

Mangos A, Bassino J-P, Sauzade D (2010) The economic value of sustainable benefits rendered by the Mediterranean marine ecosystems. UNEP/MAP Plan Bleu, Valbonne. Blue Plan Papers 8.

Mazzocchi MG, Nervegna D, D'Elia G, Di Capua I, Aguzzi L, Boldrin A (2003) Spring mesozooplankton communities in the epipelagic Ionian Sea in relation to the Eastern Mediterranean Transient, J. Geophys. Res., 108, 8114

MEDISEH 2013. Mediterranean Sensitive Habitats (2013). Edited by Giannoulaki M., A. Belluscio, F. Colloca, S. Fraschetti, M. Scardi, C. Smith, P. Panayotidis, V. Valavanis, M.T. Spedicato. DG MARE Specific Contract SI2.600741, Final Report, 557 p.

Mee, 1992. "The Black Sea in crisis: A need for concerted international action". Ambio 21:278-286.

Meinesz, A., Cirik, S., Akcali, B., Javel, F., Migliaccio, M., Thibaut, T., Yüksek, A., Procaccini, G., 2009. Posidonia oceanica in the Marmara Sea. Aquat. Bot. 90, 18–22.

MESMA 2010. Deliverable 1.2 Catalogue of European seabed biotopes, Coordinator: Partner 5, HCMR, Greece, M. Salomidi.

MESMA, 2010 Monitoring and Evaluation of Spatially Managed Areas // Deliverable 1.2 Catalogue of European seabed biotopes (FP7/2007-2013) under grant agreement n° 226661.

MG4U Workshop Report. The potential of genomics for marine monitoring and biodiversity mapping: from concept to realization. (http://www.mg4u.eu/images/mg4u/News/mg4u%20_dublin_workshop_report_v2.pdf)

Mikaelyan, A.S., Silkin, V.A., Pautova, L.A., 2011. Coccolithophorids in the Black Sea: their interannual and long-term changes. Oceanology 51, 39–48.

Milchakova N.A., 2007. The regional aspects of the phytodiversity of Black Sea macrophyte flora. Morskoy ecologicheskiy zhurnal, 1(1), 44-54 (in Russian).

MMO spatial planning Portal (www.planningportal.narinemanagement.org.uk)

Möllmann C, Kornilovs G, Fetter M, Köster FW (2004) Feeding ecology of central Baltic Sea herring and sprat. Journal of Fish Biology 65:1563–1581.

Möllmann C, Kornilovs G, Fetter M, Köster FW (2005) Climate, zooplankton and pelagic fish growth in the Central Baltic Sea. ICES Journal of Marine Science 62:1270–1280.

Möllmann C, Kornilovs G, Sidrevics L (2000) Long-term dynamics of main mesozooplankton species in the central Baltic Sea. Journal of Plankton Research 22:2015-2038.

Möllmann C, Köster FW (1999) Food consumption by clupeids in the Central Baltic: evidence for topdown control? ICES Journal of Marine Science 56(suppl.): 100–113.

Möllmann C, Köster FW (2002) Population dynamics of calanoid copepods and the implications of their predation by clupeid fish in the Central Baltic Sea. Journal of Plankton Research 24:959–977.

Möllmann C, Köster FW, Kornilovs G, Sidrevics L (2003) Interannual variability in population dynamics of calanoid copepods in the central Baltic Sea. ICES Marine Science Symposium 219:220–230.

Molnar JL, Gamboa RL, Revenga C, Spalding MD (2008) Assessing the global threat of invasive species to marine biodiversity. Frontiers in Ecology and the Environment 6:485-492

Moncheva, S., Stefanova, K., Doncheva, V., Slabakova, N. Mavrodieva, R., 2012. Plankton features for assessment of western Black Sea ecosystem. Proceedings of eleventh international conference on marine science and technologies. "Black Sea' 2012", October 4th-6th, Varna, Bulgaria, 74-81. ISSN 1314-0957.

Nankinov D.N., 1996. Coastal parks and reserves along the Black Sea and their importance for seabirds. Marine Ornithology 24: 29–34.

Norkko J, Reed DC, Timmermann K, Norkko A, Gustafsson BG, Bonsdorff E, Slomp CP, Carstensen J, Conley DJ (2012) A welcome can of worms? Hypoxia mitigation by an invasive species. Global Change Biology 18:422-434.

Numann W., 1955. ˙Izmir Körfezi'nde "Balık kırılması"hadisesi. Hidrob. Mec., Ser. A, 3(2): 90-93.

OCEANA 2006. Habitats in danger. http://eu.oceana.org http://eu.oceana.org/en/eu/media-reports/publications?page=2

Oceana 2011. MedNet, MPA Network Proposal for the Mediterranean Sea. Report. 96pp. From: http://eu.oceana.org/sites/default/files/reports/OCEANA_MEDNet_report_16092011_ING.pdf

Oguz T, Salihoglu B, Moncheva S, Abaza V. 2012b, Regional peculiarities of community-wide trophic cascades in strongly degraded Black Sea food-web. J. Plankton Res., 34: 338-343.

Oguz T, Tugrul S (1998) Denizlerimizin genel oşinografik özelliklerine toplu bir bakış. Türkiye denizlerinin ve Çevre alanlarının Jeolojisi. (Editör:N Görür) s. 1-21, İstanbul.

Oguz T., Dippner, J.W. and Kaymaz, Z., 2006 Climatic regulation of the Black Sea hydrometeorological and ecological properties at interannual-to-decadal time scales. J. Mar. Syst., 60, 235-254.

Ojaveer E, Lumberg A, Ojaveer H (1998) Highlights of zooplankton dynamics in Estonian waters (Baltic Sea). ICES Journal of Marine Science 55:748–755

Ojaveer H, Jaanus A, MacKenzie BR, Martin G, Olenin S, Telesh I, Zettler M, Zaiko A (2010) Status of Biodiversity in the Baltic Sea. PLoS ONE Collection: Marine Biodiversity and Biogeography Regional Comparisons of Global Issues, 5(9): e12467.

OSPAR Quality Status Report 2000 (Regional QSR IV). http://qsr2010.ospar.org/en/index.html

Özbilgin, H., Tosunoglu, Z., Bilecenoglu, M and A. Tokaç. 2004. Population parameters of Mullus barbatus in Izmir Bay (Aegean Sea), using length frequency analysis. Journal of Applied Ichthyology Volume 20, Issue 3, pages 231–233.

Palaz, M., Colakoglu, S., & Yildiz, H. (2010). Distribution of macrozoobenthic invertebrates in the South Marmara Sea. Journal of Animal and Veterinary Advances, 9(3), 471–473.

Papaconstantinou C, Farrugio H (2000) Fisheries in the Mediterranean. Mediterranean Marine Science 1:5-18

Patrício J, Little S, Mazik K, Thomson S, Zampoukas N, Teixeira H, Uyarra MC, Solaun O, Papadopoulou N, Kaboglu G, Bucas M, Churilova T, Kryvenko O, Moncheva S, Borja A, Alvarez M, Zenetos A, Smith C, Zaico A, Stefanova K, Danovaro R, Carugati L, Elliott M (2014) Report on SWOT analysis of monitoring (DEVOTES Deliverable 1.4) DEVOTES, FP7 Project

Pauly, D., Christensen, V., Dalsgaard, J., Froese, R., Torres Jr., F., 1998. Fishing down marine food-webs. Science 279, 860-863.

Pekey, H. 2006. Heavy metal pollution assessment in sediments of the Izmit Bay, Turkey. Environmental Monitoring and Assessment, 123, 219-231.

Pekey, H., Karakaş, D., Ayberk, S., Tolun, L and M Bakoğlu. 2004. Ecological risk assessment by trace elements in the surface sediments of Izmit Bay (Northeastern Marmara Sea) Turkey. Marine Pollution Bulletin, 48(9-10), 946-953.

Pinardi N, Arneri E, Crise A, Ravaioli M, Zavatarelli M (2006) The physical, sedimentary and ecological structure and variability of shelf areas in the Mediterranean sea (27). In: Robinson AR, Brink KH (eds) The Sea: The Global Coastal Ocean Interdisciplinary Regional Studies and Syntheses Book 14. President and Fellows of Harvard College

Piroddi C, C Lynam, H Teixeira, C Smith, M Alvarez, K Mazik , E Andonegi, T Churilova, L Tedesco, M Chifflet, C Guillem-Chust, I Galparsoro, AC Garcia, M Kämäri, O Kryvenko, G Lassalle , S Neville, N Niquil, N Papadopoulou, A Rossberg, S Suslin, MC Uyarra (2013) Available models for biodiversity and needs for development. (DEVOTES Deliverable 4.1) DEVOTES, FP7 Project

Polat S (2006) Size fractionated distribution of the phytoplankton biomass in the İskenderun Bay, northeastern Mediterranean Sea. Fres. Env. Bull. 15: 417-423.

Polat, S., Sarıhan, E. ve Koray, T., (2000). Seasonal changes in the phytoplankton of the northeastern Mediterranean (Bay of İskenderun). Turkish Journal of Botany, 24: 1-12.

Polat, S.C, Tugrul, S., Coban, Y., Basturk, O., and Salihoglu, I., 1998. Elemental Composition of Seston and Nutrient Dynamics in the Sea of Marmara, Hydrobiologia, 363, 157-167.

Reeves R, Notarbartolo di Sciara G (2006) The status and distribution of cetaceans in the Black Sea and Mediterranean Sea. In: IUCN Centre for Mediterranean Cooperation, Malaga, Spain

Riandey V, Champalbert G, Carlotti F, Taupier-Letage I, Thibault-Botha D (2005) Zooplankton distribution related to the hydrodynamic features in the Algerian Basin (western Mediterranean Sea) in summer 1997, Deep-Sea Res. Pt I, 52, 2029–2048.

Ritt, B., Duperron, S., Lorion, J., Sara Lazar, C., and Sarrazin, J. (2012). Integrative study of a new cold-seep mussel (Mollusca: Bivalvia) associated with chemosynthetic symbionts in the Marmara Sea. Deep-Sea Research Part I: Oceanographic Research Papers, 67, 121–132. Retrieved from http://www.scopus.com/inward/record.url?eid=2-s2.0-84865337280&partnerID=40&md5=e38d4005754f998fb6578c7a7973240d

Ritt, B., Sarrazin, J., Caprais, J.-C., Noël, P., Gauthier, O., Pierre, C.,Desbruyères, D. (2010). First insights into the structure and environmental setting of cold-seep communities in the Marmara Sea. Deep-Sea Research Part I: Oceanographic Research Papers, 57(9), 1120–1136. Retrieved from http://www.scopus.com/inward/record.url?eid=2-s2.0-77955711782&partnerID=40&md5=66a529b9020b502501ef251ed13a3148

Rönkkönen S, Ojaveer E, Raid T, Viitasalo M (2004) Long-term changes in Baltic herring (Clupea harengus membras) growth in the Gulf of Finland. Canadian Journal of Fisheries and Aquatic Sciences 61: 219-229.

Routti H, Nyman M, Bäckman C, Koistinen J, Helle E (2005) Accumulation of dietary organochlorines and vitamins in Baltic seals. Marine Environmental Research 60: 267–287.

Ryabushko L. I., S. Besiktepe, D. Ediger, D. Yilmaz, A. Zenginer, V.I. Ryabushko, R.I. Lee, 2008. Toxic diatom of Pseudo-nitzschia calliantha Lundholm, Moestrup et Hasle from the Black Sea: morphology, taxonomy, ecology. Marine ecological journal, Vol. 7(3): 51 – 60

Saiz E, Calbet A, Irigoien X, Alcaraz M (1999) Copepod egg production in the western Mediterranean: response to food availability in oligotrophic environments. Mar Ecol Prog Ser 187:179–189

Salomidi M, S Katsanevakis, Á Borja, U Braeckman, D Damalas, I Galparsoro, R Mifsud, S Mirto, M Pascual, C Pipitone, M Rabaut, V Todorova, V Vassilopoulou and T Vega Fernández (2012) Assessment of goods and services, vulnerability, and conservation status of European seabed biotopes: a stepping stone towards ecosystem based marine spatial management. Mediterranean Marine Science 13(1): 49-88.

Sanpera C, Moreno R, Ruiz X, Jover L (2007) Audouin's gull chicks as bioindicators of mercury pollution at different breeding locations in the western Mediterranean. Marine Pollution Bulletin 54:691-696

SAP, 2009 Strategic Action Plan for the Environmental Protection and Rehabilitation of the Black Sea (SAP, 2009) http://www.boblme.org/eventDocs/Black%20Sea%20SAP.pdf

Schmidt J, Möllmann C, Temming A, Herrmann JP, Floeter J, Sell A, St. John MA (2003). Unusual water mass advection affected central Baltic key species 2: Pseudocalanus and the winter inflow. GLOBEC International Newsletter, 9: 28-29.

Scottish Government. 2013. FEAST – Feature Assessment Sensitivity Tool. http://www.marine.scotland.gov.uk/FEAST/Index.aspx Accessed 20/10/2013

Seguin G, Errhif A, Dallot S (1994) Diversity and structure of pelagic copepod populations in the frontal zone of the eastern Alboran Sea. Hydrobiologia, 292/293, 369-377.

Sekercioğlu CH, Anderson S, Akay E, Bilgin, R Emre Can Ö, Semiz, G Tavsanoğlu C , Yokes BM, Soyumert A, Ipekdal K, Ismail K. Sağlam K, Yücel M, Nüzhet Dalfes H (2011) Turkey's globally important biodiversity in crisis. Biological Conservation 144: 2752–2769.

Shiganova T., Musaeva E., Araskievich E., Kamburska L., Stefanova K., Michneva V., Polishchuk L., Timofte F., Ustun F., Oguz T., Khalvashi M. 2008. The State of Zooplankton. In: BSC, 2008. State of the Environment of the Black Sea (2001-2006/7). Edited by Temel Oguz. Publications of the Commission on the Protection of the Black Sea Against Pollution (BSC) 2008-3, Istanbul, Turkey, 448 pp (201-246).

Shiganova T.,Öztürk B., 2009. Trend on increasing Mediterranean species arrival into the Black Sea. In: Climate Forcing and Its Impacts on the Black Sea Marine Biota. CIESM Workshop Monographs no 39, pp75-91.

Shiganova T.A., Dumont H. J. D, Mikaelyan A. , Glazov D. M., Y. V. Bulgakova, E. I. Musaeva, P. Y Sorokin, .L A. Pautova, Z. A. Mirzoyan and E I. Studenikina. 2004. Interaction between the Invading Ctenophores Mnemiopsis leidyi (A. Agassiz) and Beroe ovata Mayer 1912, and their Influence on the Pelagic Ecosystem of the Northeastern Black Sea Edc.

Shiganova, T.A., 1998. Invasion of the Black Sea by the Ctenophore Mnemiopsis leidyi and Recent Changes in Pelagic Community Structure, Fisheries Oceanography-GLOBEC Special Issue, Coombs, S., Ed.: 305-310.

Siokou-Frangou I, Bianchi M, Christaki U, Christou ED, Giannakourou A, Gotsis O, Ignatiades L, Pagou K, Pitta P, Psarra S, Souvermezoglou E, Van Wambeke F (2002) Carbon flow in the planktonic food-web along a gradient of oligotrophy in the Aegean Sea (Mediterranean Sea), J. Mar. Syst., 33–34, 335–353.

Siokou-Frangou I, Christou ED, Fragopoulu N, Mazzocchi,MG (1997) Mesozooplankton distribution from Sicily to Cyprus (Eastern Mediterranean): II Copepod assemblages. Oceanol. Acta, 20, 537-548.

Suuronen P, Lehtonen E (2012) The role of salmonids in the diet of grey and ringed seals in the Bothnian Bay, northern Baltic Sea. Fisheries Research 125-126:283–288.

Szypula J, Ostrowski J, Margonski P, Krajewska-Sołtys A (1997) Food of Baltic herring and sprat in the years 1995/1996 in light of the availability of components. Bulletin of the Sea Fisheries Institute 141: 19-31.

Tolun, L G., Ergenekon, S., Hocaoglu, S M., Donertas, A S., Cokacar, T., Husrevoglu, S., Polat Beken, C and A, Baban. 2012. Socioeconomic Response to Water Quality: a First Experience in Science and Policy Integration for the Izmit Bay Coastal System. Ecology and Society 17(3): 40. http://dx.doi.org/10.5751/ES-04984-170340

Tudela S (2004) Ecosystem effects of fishing in the Mediterranean: an analysis of the major threats of fishing gear and practices to biodiversity and marine habitats. Studies and Reviews. General Fisheries Commission for the Mediterranean. No. 74. Rome, FAO. 2004. 44p.

Tüfekçi, V., Balkış, N., . Polat Beken, Ç , Ediger, D. and Mantıkcı, M. 2010. Phytoplankton composition and environmental conditions of a mucilage event in the Sea of Marmara. Turk J Biol 34:199-210 doi:10.3906/biy-0812-1.

Tugrul, S., Coban-Yildiz, Y., Ediger, D., ve Yılmaz, A., 2000. Karadeniz, Marmara ve Akdenizde Partikul Organik Madde Dagılımı ve Kompozisyonu, I. Ulusal Deniz Bilimleri Konferansı, 30 Mayıs-2 Haziran, Kultur ve Kongre Merkezi, ODTU Ankara, Bildiri ¨Özetleri Kitapcıgı, Uysal, Z., (ed.), 19.

UKSeaMap 2010 Interactive map http://jncc.defra.gov.uk/page-5534

UNEP (2002). Action Plan for the Mediterranean Regional Activity Centre for Specially Protected Areas Handbook for interpreting types of marine habitat for the selection of sites to be included in the national inventories of natural sites of conservation interest. UNEP/MAP RAC-SPA.

UNEP/MAP (2009) State of the Environment and Development in the Mediterranean. UNEP/MAP Plan Bleu, Athens

UNEP/MAP (2012) State of the Mediterranean Marine and Coastal Environment, UNEP/MAP – Barcelona Convention, Athens, 2012.

Uras, A.2006. Kıyı ve Denizler. In: Eken, G., Bozdoğan, M., Isfendiyaroğlu, S., Kılı., D.T., Lise, Y. (Eds.), Türkiye'nin nemli Doğa Alanları. Doğa Derneği, Ankara, Turkey, pp:44-46 (in Turkish).

Uusitalo L, Hällfors H, Peltonen H, Kiljunen M, Jounela P, Aro E (2013) Indicators of the Good Environmental Status of food-webs in the Baltic Sea. Report of the GES-REG project. Viewed 30 December 2013.

Uzars D (1994) Feeding of cod (Gadus morhua callarias L.) in the central Baltic in relation to environmental changes. ICES Marine Science Symposium, 198: 612–623.

Vershinin, A.O., A. A. Moruchkov, T. Leighfield, I.N. Sukhanova, S.L. Pan'kov, S.L. Morton, and J. S. Ramsdell, 2005. Potentially toxic algae in the coastal phytoplankton of the northeast Black Sea in 2001-2002. Journal Oceanology, 45 (2): 224-232

Viitasalo M, Flinkman J, Viherluoto M (2001) Zooplanktivory in the Baltic Sea: a comparison of prey selectivity by Clupea harengus and Mysis mixta, with reference to prey escape reactions. Marine Ecology Progress Series 216: 191–200.

Viitasalo M, Vuorinen I, Saesmaa S (1995) Mesozooplankton dynamics in the northern Baltic Sea: implications of variations in hydrography and climate. Journal of Plankton Research 17:1857–1878.

Vilà M, Basnou C, Pyšek P, Josefsson M, Genovesi P, Gollasch S, Nentwig W, Olenin S, Roques A, Roy D (2009) How well do we understand the impacts of alien species on ecosystem services? A pan-European, cross-taxa assessment. Frontiers in Ecology and the Environment 8:135-144

Vinogradov, M.E., Shushkina, E.A., Musaeva, E.I., and Sorokin, P. Y., 1989.New Settler in the Black Sea-Comb Jelly Mnemiopsis leidyi (Agassiz), Okeanologiya, vol. 29, no. 2: 293--299.

Vuorinen I, Hänninen J, Viitasalo M, Helminen U, Kuosa H (1998) Proportion of copepod biomass declines together with decreasing salinity in the Baltic Sea. ICES Journal of Marine Science, 55: 767-774.

Wallentinus I, Nyberg CD (2007) Introduced marine organisms as habitat modifiers. Marine Pollution Bulletin 55:323-332

Yokes B and B S Galil. 2006. New records of alien decapods (Crustacea) from the Mediterranean coast of Turkey, with a description of a new palaemonid species. Zoosystema 28(3):747-755.

Yokes M.B., 2009 Additions to the knowlegde of opisthobranchia from Turkey. Triton, 20:5-19.

Youssara F, Gaudy R (2001) Variations of zooplankton in the frontal area of the Alboran Sea (Mediterranean sea) in winter 1997, Oceanol. Acta, 24, 361–376.

Yuksek, A., Okus¸ , E., 2004. Investigations on Magnioliophyta at the south Marmara group Islands. J. Black Sea/Mediterranean Environ. 10, 103–111.

Zaiko A, Olenin S, Daunys D, Nalepa T (2007) Vulnerability of benthic habitats to the aquatic invasive species. Biological Invasions 9: 703-714

Zaitsev Y. and Öztürk B. (Eds). 2001. Exotic Species In the Aegean, Marmara, Black, Azov and Caspian Seas. Turkish Marine Research Foundation, Istanbul, Turkey, 267 pp.

Zaitsev Yu. (2008) An introduction to the Black Sea ecology. Odessa: Smil Edition and Publishing Agency ltd. 2008. — 228 p

Zampoukas N, Piha H, Bigagli E, Hoepffner N, Hanke G, Cardoso AC (2012) Monitoring for the Marine Strategy Framework Directive:Requirements and Options. EU COM DG Joint Research Center EUR 25187 EN

Zenetos A, Gofas S, Verlaque M, Cinar M, Raso JG, Bianchi C, Morri C, Azzurro E, Bilecenoglu M, Froglia C (2010) Alien species in the Mediterranean Sea by 2010. A contribution to the application of European Union's

Marine Strategy Framework Directive (MSFD). Part I. Spatial distribution. Mediterranean Marine Science 11:381

Zenetos A, Gofas S, Morri C, Rosso A, Violanti D, Raso JG, Hinar M, Almogi-Labin A, Ates A, Azzurro E (2012) Alien species in the Mediterranean Sea by 2012. A contribution to the application of European Union's Marine Strategy Framework Directive (MSFD). Part 2. Introduction trends and pathways. Mediterranean Marine Science 13:328-352

Zenetos, A., E. Meriç¸, M. Verlaque, P. Galli, C. F. Boudouresque, A. Giangrande, M. E. Cinar and M. Bilecenoglu. 2008. Additions to the annotated list of marine alien biota in the Mediterranean with special emphasis on foraminifera and parasites. Mediterr. Mar. Sci. 9: 119–165.

Zervakis, V. and Georgopoulos, D., 2002. Hydrology and circulation in the North Aegean (eastern Mediterranean) throughout 1997 and 1998. Medit. Mar. Sci., Vol.3/1, 2002, 05-19.

Zervoudaki, S., E.D. Christou, G. Assimakopoulou, H. Örek, A.C. Gucu, A. Giannakourou, P. Pitta, T. Terbiyik, N. Y cel, T. Moutsopoulos, K. Pagou, S. Psarra, E. Özsoy and E. Papathanassiou (2011). Copepod communities, production and grazing in the Turkish Straits System and the adjacent northern Aegean Sea during spring. Journal of Marine Systems 86 (3-4), 45-56.

MSFD Management Group Report and Task Group Reports (D1, D2, D4, D6)

MSFD Management Group Report:

Cardoso AC, Cochrane S, Doerner H, Ferreira JG, F Galgani, Hagebro C, Hanke G, Hoepffner N, Keizer PD, Law R, Olenin S, Piet GJ, Rice J, Rogers SI, Swartenbroux F, Tasker ML, van de Bund W (2010) Scientific support to the European Commission on the Marine Strategy Framework Directive. Management Group Report. EUR 24336 EN - 2010.

http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/13626/1/management%20group%20report_final_vii.pdf

MSFD Task Group 1 Report:

S.K.J. Cochrane, D.W. Connor, P. Nilsson, I. Mitchell, J. Reker, J. Franco, V. Valavanis, S. Moncheva, J. Ekebom, K. Nygaard, R. Serrão Santos, I. Narberhaus, T. Packeiser, W. van de Bund & A.C. Cardoso, 2010. Marine Strategy Framework Directive Task Group 1 Report Biological diversity EUR 24337 EN – 2010.

http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/13642/1/tg1final.pdf

MSFD Task Group 2 Report:

S. Olenin, F. Alemany, A. C. Cardoso, S. Gollasch, P. Goulletquer, M. Lehtiniemi, T. McCollin, D. Minchin, L. Miossec, A. Occhipinti Ambrogi, H. Ojaveer, K. Rose Jensen, M. Stankiewicz, I. Wallentinus & B. Aleksandrov, 2010. Marine Strategy Framework Directive Task Group 2 Report Non-indigenous species. EUR 24342 EN – 2010.

http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/13628/1/tg2%20report_final_vii.pdf

MSFD Task Group 4 Report:

S. Rogers, M. Casini, P. Cury, M. Heath, X. Irigoien, H. Kuosa, M. Scheidat, H. Skov, K. Stergiou, V. Trenkel, J. Wikner & O. Yunev. 2010. Marine Strategy Framework Directive Task Group 4 Food-webs EUR 24343 EN – 2010.

http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/13627/1/tg4%20report_final_vii.pdf

MSFD Task Group 6 Report:

J. Rice, C. Arvanitidis, A. Borja, C. Frid , J. Hiddink , J. Krause, P. Lorance, S. Á. Ragnarsson, M. Sköld and B. Trabucco, 2010. Marine Strategy Framework Directive Task Group 6 Report Seafloor integrity. EUR 24334 EN – 2010.

http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/13631/1/tg6%20report%20final_vii%20%282%29.pdf

Websites links

DEVOTES link to project website: http://www.devotes-project.eu/

MEECE link to project website: http://www.meece.eu/

MEECE Atlas link to website: http://www.meeceatlas.eu/Menu/

WISER link to Methods database: http://www.wiser.eu/results/method-database/

Eionet Central Data Repository: http://cdr.eionet.europa.eu/recent_etc?RA_ID=608

10. List of annexes

Annex 1 – D3-1 Annex1 DEVOTES catalogue-Indicators_software.zip (software)

Annex 1 contains both the Windows and Mac version of the software and the indicator catalogue itself.

Annex 2 – D3-1 Annex2 DEVOTES catalogue-Indicators_instructions.pdf (manual)

Annex 2 contains the software installation and usage manual and the license conditions for the use of the software.