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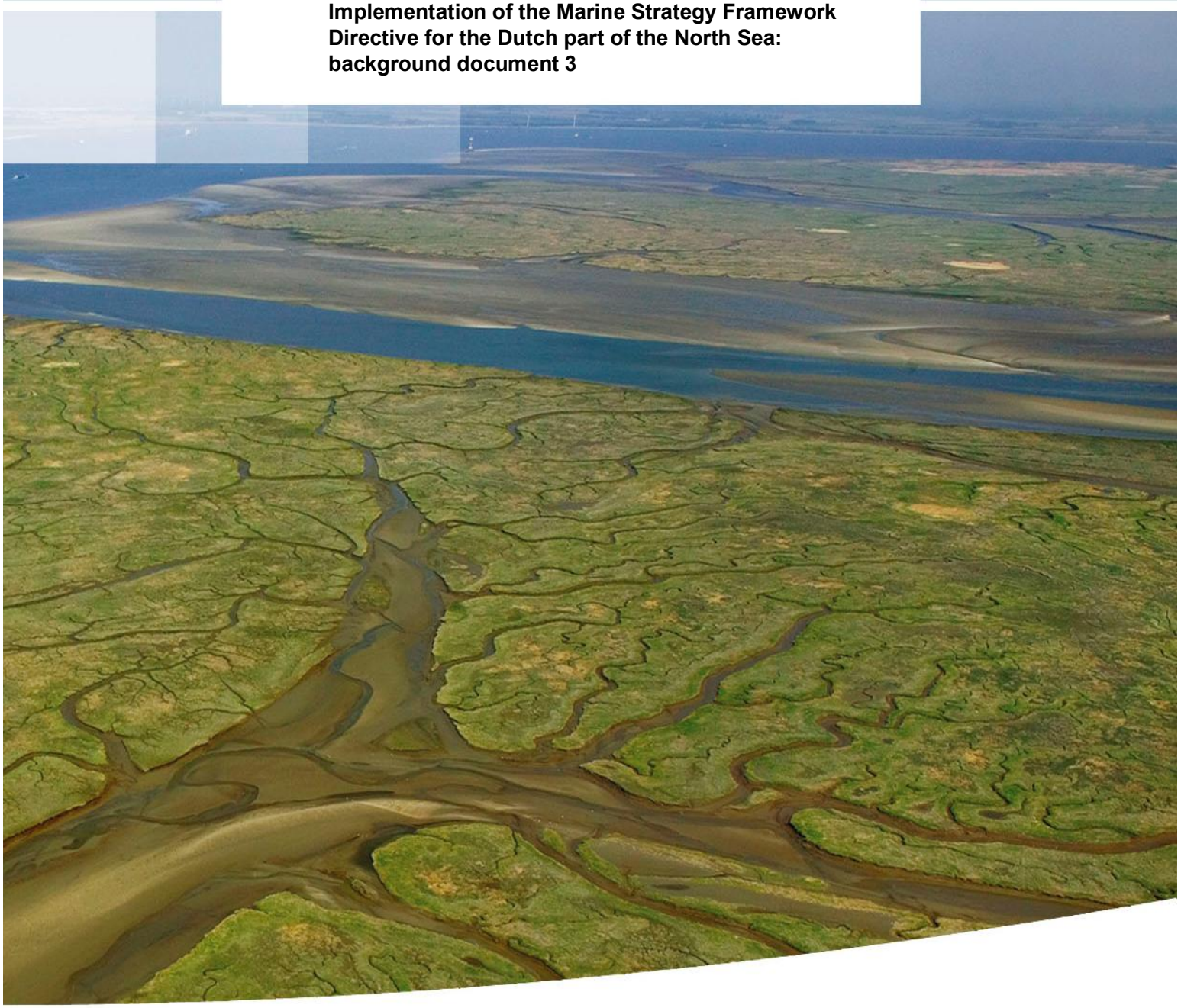
Environmental targets and associated indicators

Implementation of the Marine Strategy Framework Directive for the Dutch part of the North Sea: background document 3



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Implementation of the Marine Strategy Framework Directive for the Dutch part of the North Sea: background document 3

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Summary
This report is one in a series of three documents that provide the scientific background for the implementation of the Marine Strategy Framework Directive (MSFD) in the Netherlands. The MSFD requires the establishment of a set of environmental indicators and targets. This report proposes indicators and targets that are applicable in the Dutch part of the North Sea.

Version	Date	Author	Initials	Review	Initials	Approval	Initials
	Dec. 2010	dr. A.R. Boon dr. T.C. Prins		prof. R.W.P.M. Laane dr. G.J. Piet		ir. T. Schilperoort	
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Justification and status of the report
These advice reports should be regarded as scientific background reports, that serve as advisory documents in the preparation for the Marine Strategy, to be written by the Ministry of Infrastructure and Environment. The reports are based on currently available knowledge, laid down in reports, scientific literature, and unpublished material and on expert judgment.
Deltares and IMARES have been working on the three background documents between January 2010 en April 2011. March 15th, 2011 is taken as set date. Documents and proceedings of meetings available later than March 2011 could not be taken into account for this scientific background report. Between April and September 2011 a review process by the Ministry of Infrastructure and Environment and the Ministry of Economic Affairs, Agriculture and Innovation took place, after which the document was finalised in September 2011.
The implementation of the Marine Strategy Framework Directive entails an on-going process of workshops, meetings, guidance documents, and (draft) working documents provided by the EC, OSPAR, ICES, JRC and others in order to facilitate national implementation and regional coherence. The editors and the ministry are aware of the fact that after March 2011 additional information became available through documents and workshops, and this information might deviate from the contents in the advice reports.

Contents

Executive summary

Introduction

This report is one in a series of three documents that provide the scientific background for the implementation of the Marine Strategy Framework Directive (MSFD) in the Netherlands. The other two reports deal with the Initial Assessment, describing environmental conditions, human activities and current environmental status in the Dutch part of the North Sea, and with the determination of good environmental status.

This report presents a proposal for environmental indicators and targets, as required by Article 10 of the MSFD. These indicators and targets are tools to follow the progress towards achieving good environmental status (GES). The proposal is based on the criteria and indicators listed in the Commission Decision on criteria and methodological standards on GES of marine waters, on the definition of good environmental status and on a consideration of potential indicators in terms of suitability, quality and practicability. The indicators and targets can be used to translate the definition of good environmental status into more specific, qualitative or quantitative environmental requirements that must be met to achieve GES.

Development of indicators and targets

Environmental indicators are used to describe environmental conditions, in a quantitative or qualitative sense, and can be used to follow changes in the environment under the influence of human activities. The DPSIR framework describes the chain of causal links starting with 'Driving forces' (economic sectors, human activities), that through 'Pressures' (for example emissions, waste) influence the physical, chemical and biological 'State' of the environment, resulting in 'Impacts' on society, human health and ecosystem services, eventually leading to political 'Responses'. Within this framework, environmental indicators are generally linked to Pressures, States or Impacts.

In the process of development of indicators and targets for this report, several expert meetings have been organized. With the criteria and indicators from the Commission Decision as a starting point, a number of indicators have been proposed that come close to the intentions of the Commission Decision. Where possible, indicators were selected that already exist and are used in the framework of other EU policies or international agreements (Water Framework Directive, Bird and Habitat Directives, Common Fisheries Policy, OSPAR, etc.). In those cases, the proposed targets for the MSFD application are similar to the targets that are already defined. Where new indicators and targets are proposed, a pragmatic approach was taken. Ideally, it should be possible to link indicators to quantitative cause-effect chains in the DPSIR framework, making indicators sensitive, specific and accurate indicators of the effects of human activities on the environment. Indicators should also be based on scientific understanding, easy to measure and preferably data should already be available. And finally, indicators should be understandable by a non-scientific public. At this point in the development process, it was not possible to identify indicators that fulfil all of these criteria. However, these criteria have been used in this report to evaluate the proposed indicators. Quantitative targets for the indicators were defined, where possible. However, in many cases only directional targets (for example, "increase" or "decrease") could be proposed.

The table below gives an overview of the proposed indicators and targets.

Overview of the criteria and indicators in the Commission Decision (EC, 2010) and the proposed indicators and targets. Numbers refer to the numbering in EC (2010). S indicates status: red: no indicator; orange: indicator needs some elaboration; green: existing indicator; hatching: indicator partly covers EC (2010).

Criteria and indicators (EC, 2010)	S	Proposed indicator	Proposed target
1. Biological diversity			
Species distribution (1.1) *Distributional range (1.1.1)*		Benthos: • number/biomass of long-lived/vulnerable species • proportion of long-lived/vulnerable species in benthic community Fish: • number of species with a long-term negative trend • Threat indicator Birds: • Vulnerable species Marine mammals: • Number of grey seal, harbour seal, harbour porpoise	Increase in number/biomass Increase in proportion Zero Reduction in the rate of increase No decline No decline
Species distribution (1.1) *Distributional pattern within the latter, where appropriate (1.1.2)*			
Species distribution (1.1) *Area covered by the species (for sessile/benthic species) (1.1.3)*			
Population size (1.2) *Population abundance and/or biomass, as appropriate (1.2.1)*			
Population condition (1.3) *Population demographic characteristics (e.g. body size or age class structure, sex ratio, fecundity rates, survival/mortality rates) (1.3.1)*		Fish: • OSPAR EcoQO proportion of large fish in the fish community • Size diversity index Marine mammals: • OSPAR EcoQO on healthy seal populations	More than 30% of fish should be longer than 40 cm in the IBTS Increase towards a value of 1 No decline of >10% in grey seal pup populations or harbour seal populations over a five-year running mean
Population condition (1.3) *Population genetic structure, where appropriate (1.3.2).*		Not applicable yet	
Habitat distribution (1.4) *Distributional range (1.4.1)*		Distribution and pattern of habitats at EUNIS level 3	No decline in distributional range
Habitat distribution (1.4) *Distributional pattern (1.4.2)*			
Habitat extent (1.5) *Habitat area (1.5.1)*			
Habitat extent (1.5) *Habitat volume, where relevant (1.5.2)*			
Habitat condition (1.6) *Condition of the typical species and communities (1.6.1)*		Benthos: • number/biomass of long-lived/vulnerable species • proportion of long-lived /vulnerable species in benthic community	Increase in number/biomass Increase in proportion
Habitat condition (1.6) *Relative abundance and/or biomass, as appropriate (1.6.2)*			
Habitat condition (1.6) *Physical, hydrological and chemical conditions (1.6.3)*		Distribution and pattern of habitats at EUNIS level 3	No decline in distributional range
Ecosystem structure (1.7) *Composition and relative proportions of ecosystem components (habitats and species) (1.7.1)*		Benthos, Fish: • Species richness • Species evenness, Hill's N_1, Hill's N_2 Birds: • Bird values Marine mammals: • Species richness	No decline Values do not exceed the range typical for the monitoring site Values do not exceed the range typical for the monitoring site No decline

Criteria and indicators (EC, 2010)	S	Proposed indicator	Proposed target
2. Non-indigenous species			
Trends in abundance, temporal occurrence and spatial distribution in the wild of non-indigenous species, particularly invasive non indigenous species, notably in risk areas, in relation to the main vectors and pathways of spreading of such species (2.1.1)		Number of non-indigenous species Abundance of non-indigenous species	No increase No increase
Ratio between invasive non-indigenous species and native species in some well studied taxonomic groups (e.g. fish, macroalgae, molluscs) that may provide a measure of change in species composition (e.g. further to the displacement of native species) (2.2.1)		Ratio of non-indigenous:native species in a selection of groups (phytoplankton, benthos, fish)	No increase
Impacts of non-indigenous invasive species at the level of species, habitats and ecosystem, where feasible (2.2.2)		To be determined dependent on species, habitat and ecosystem characteristics	No impact
3. Commercially exploited fish			
Fishing mortality (F) (3.1.1)		Fishing mortality of commercially exploited fish	Below F_{MSY} (ICES advice for values of F_{MSY})
Secondary indicator: Ratio between catch and biomass index (hereinafter catch/biomass ratio) (3.1.2)		Catch/biomass ratio of commercially exploited fish	No increase
Spawning Stock Biomass (SSB) (3.2.1)		SSB of commercially exploited fish	Below SSB_{PA} (ICES advice for values of SSB_{PA})
Secondary indicator: Biomass indices (3.2.2)		Log-transformed abundance of commercially exploited fish	No decline
Proportion of fish larger than the mean size of first sexual maturation (3.3.1)		Proportion of fish larger than the mean size of first sexual maturation	No decrease
Mean maximum length across all species found in research vessel surveys (3.3.2)		Not applicable	
95% percentile of the fish length distribution observed in research vessel surveys (3.3.3)		95% percentile of the fish length distribution observed in research vessel surveys	No decrease
Secondary indicator: Size at first sexual maturation, which may reflect the extent of undesirable genetic effects of exploitation (3.3.4)		Size at first sexual maturation	No decrease
4. Food webs			
Performance of key predator species using their production per unit biomass (productivity) (4.1.1)		OSPAR EcoQO on healthy seal populations Abundance of prey species of grey seal and harbour seal	No decline of >10% in grey seal pup populations or harbour seal populations over a five-year running mean No decrease
Large fish (by weight) (4.2.1)		OSPAR EcoQO proportion of large fish in the fish community	More than 30% of fish should be longer than 40 cm in the IBTS survey Increase in average size (by weight) of pelagic fish
Abundance trends of functionally important selected groups/species (4.3.1)		OSPAR EcoQO on by-catch levels of harbour porpoise	Below 1% of best population estimate
5. Eutrophication			
Nutrients concentration in the water column (5.1.1)		Winter means of dissolved inorganic nitrogen	DIN (µM) = 184,7-5,057*salinity for salinities<30 33 for salinities ≥30
Nutrient ratios (silica, nitrogen and phosphorus), where appropriate (5.1.2)		N:P ratio (based on winter means)	Between 10-37.5

Criteria and indicators (EC, 2010)	S	Proposed indicator	Proposed target
Chlorophyll concentration in the water column (5.2.1)		90-percentile of growing season concentration	Chl-a (µg/l) = 21 for salinities<30.4 144-4.045*salinity for salinities ≥30.4 and <34.5 4.5 for salinities≥34.5
Water transparency related to increase in suspended algae, where relevant (5.2.2)		Not applicable	
Abundance of opportunistic macroalgae (5.2.3)		Not applicable	
Species shift in floristic composition such as diatom to flagellate ratio, benthic to pelagic shifts, as well as bloom events of nuisance/toxic algal blooms (e.g. cyanobacteria) caused by human activities (5.2.4)		Frequency of blooms of *Phaeocystis globosa*	≤2 months per year
Abundance of perennial seaweeds and seagrasses (e.g. fucoids, eelgrass and Neptune grass) adversely impacted by decrease in water transparency (5.3.1)		Not applicable	
Dissolved oxygen, i.e. changes due to increased organic matter decomposition and size of the area concerned (5.3.2)		Annual minimum concentration of oxygen	>= 5 mg/l
6. Sea-floor integrity			
Type, abundance, biomass and areal extent of relevant biogenic substrate (6.1.1)		Abundance and areal extent of biogenic substrate	Increase in abundance and areal extent
Extent of the seabed significantly affected by human activities for the different substrate types (6.1.2)		Proportion of surface area of each habitat (EUNIS level 3) affected by human activities in the last year	Decrease
Presence of particularly sensitive and/or tolerant species (6.2.1)		Number/biomass of long-lived/vulnerable benthos species Proportion of long-lived/vulnerable species in benthic community	Increase in number/biomass Increase in proportion
Multi-metric indexes assessing benthic community condition and functionality, such as species diversity and richness, proportion of opportunistic to sensitive species (6.2.2)		BEQI Species richness Species evenness Hill's N_1 Hill's N_2	Values do not exceed the range typical for the monitoring site
Proportion of biomass or number of individuals in the macrobenthos above some specified length/size (6.2.3)		Length-frequency distribution of bivalves	No decrease
Parameters describing the characteristics (shape, slope and intercept) of the size spectrum of the benthic community (6.2.4)		Not applicable	
7. Hydrographical conditions			
Extent of area affected by permanent alterations (7.1.1)		Total (cumulative) surface area that has permanently changed	*The impact of human activities that permanently change part of a marine area is only to some extent related to the surface area. It is therefore not feasible to set a meaningful target for this indicator*
Spatial extent of habitats affected by the permanent alteration (7.2.1)		Total (cumulative) surface area where permanent changes occur	*See above*
Changes in habitats, in particular the functions provided (e.g. spawning, breeding and feeding areas and migration routes of fish, birds and mammals), due to altered hydrographical conditions (7.2.2)		To be determined dependent on type of activity	

Criteria and indicators (EC, 2010)	S	Proposed indicator	Proposed target
8. Contaminants			
Concentration of the contaminants mentioned above, measured in the relevant matrix (such as biota, sediment and water) in a way that ensures comparability with the assessments under Directive 2000/60/EC (8.1.1)		Concentrations of contaminants in water, sediment, suspended matter and/or biota	WFD-Environmental quality standards (EQS) for contaminants in water OSPAR-Environmental assessment criteria (EAC) for contaminants in sediment and biota
Levels of pollution effects on the ecosystem components concerned, having regard to the selected biological processes and taxonomic groups where a cause/effect relationship has been established and needs to be monitored (8.2.1)		OSPAR EcoQO on level of imposex in dogwhelks and other gastropods Various biological effects indicators	The average level of imposex should be consistent with exposure to TBT concentrations below the environmental assessment criterion OSPAR/ICES EAC's
Occurrence, origin (where possible), extent of significant acute pollution events (e.g. slicks from oil and oil products) and their impact on biota physically affected by this pollution (8.2.2)		OSPAR EcoQO on number of oiled guillemots	The average proportion of oiled common guillemots in all winter months (November to April) should be 10% or less of the total found dead or dying, over a period of at least 5 years
9. Contaminants in seafood			
Actual levels of contaminants that have been detected and number of contaminants which have exceeded maximum regulatory levels (9.1.1)		Levels of contaminants in fish and seafood	Regulatory levels from Commission Regulation (EC) No 1881/2006 and the "Warenwet"
Frequency of regulatory levels being exceeded (9.1.2)		Annual frequency of observations where levels are exceeded	Zero
10. Litter			
Trends in the amount of litter washed ashore and/or deposited on coastlines, including analysis of its composition, spatial distribution and, where possible, source (10.1.1)		The average amount of litter items washed ashore on reference beaches	Decrease
Trends in the amount of litter in the water column (including floating at the surface) and deposited on the sea-floor, including analysis of its composition, spatial distribution and, where possible, source (10.1.2)		OSPAR EcoQO on the level of litter (plastic particles) in fulmar stomachs	Less than 10% of fulmars with more than 0.1 g of plastic in their stomach, over a period of at least five years
Trends in the amount, distribution and, where possible, composition of micro-particles (in particular micro-plastics) (10.1.3)		Not applicable yet	
Trends in the amount and composition of litter ingested by marine animals (e.g. stomach analysis) (10.2.1)		OSPAR EcoQO on the level of litter (plastic particles) in fulmar stomachs	See above
11. Underwater noise			
Proportion of days and their distribution within a calendar year over areas of a determined surface, as well as their spatial distribution, in which anthropogenic sound sources exceed levels that are likely to entail significant impact on marine animals measured as Sound Exposure Level (in dB re 1µPa2.s) or as peak sound pressure level (in dB re 1µPapeak) at one metre, measured over the frequency band 10 Hz to 10 kHz (11.1.1)		Not developed yet	
Trends in the ambient noise level within the 1/3 octave bands 63 and 125 Hz (centre frequency) (re 1µPa		Not developed yet	

Criteria and indicators (EC, 2010)	S	Proposed indicator	Proposed target
RMS; average noise level in these octave bands over a year) measured by observation stations and/or with the use of models if appropriate (11.2.1)			

Evaluation

Indicators and targets have been proposed for nearly all criteria and indicators that were mentioned in the Commission Decision. A number of indicators are not relevant for Dutch marine waters. For several other criteria and indicators from the Commission Decision, no indicators and targets could be proposed as basic knowledge is lacking. This relates to issues like genetic diversity, the occurrence of microparticles, and the levels and effects of underwater noise.

For some GES descriptors (Commercial fish, Eutrophication, Contaminants, Contaminants in seafood) indicators are proposed that have already been developed within other frameworks, and fit well with the Commission Decision. These indicators will be the most useful for the short term, and require relatively little effort for application in management and harmonisation.

For the other GES descriptors, indicators have been proposed that can be applied in the first assessment period. These indicators need additional research to improve their quality and applicability. A main issue for these indicators in general is the fact that the relationship between the behaviour of the indicator and the level of human pressures is not well known. As a consequence, it is uncertain to what extent the indicator is really indicative for changes in the environment in response to human activities. This lack of knowledge also makes it hard to define quantitative targets for the indicators. Another issue is whether changes in the indicator represent more than only changes in some parameter, and can be considered to represent changes in important ecosystem characteristics. This mainly concerns indicators for Biological diversity, Non-indigenous species, Food web, Seafloor integrity and Litter.

For most of the proposed indicators and targets some monitoring is already in place, but monitoring strategies have to be worked out. International harmonisation of indicators and targets and of monitoring strategies is required to ensure a common approach.

In a number of cases, indicators were proposed that only partly address the aspects mentioned in the Commission Decision. Substantial work is needed to develop additional indicators. This is particularly the case for the GES descriptors Biological diversity and Food webs. Biological diversity can be measured relatively easily, but more effort is needed to establish the relationship with pressures and to define target levels. For Food webs, application in terms of practical indicators and targets in the marine environment is still in its infancy. For GES descriptors Litter and Underwater noise, basic knowledge development is necessary before indicators and targets can be defined.

The indicators and targets currently proposed are a pragmatic selection of potential indicators. They are therefore to a large extent based on already commonly known indicators. An additional effort is needed to develop the proposed indicators further, and to develop new indicators that are better able to support the implementation of the MSFD. The main knowledge gap is the insufficient understanding of cause-effect relations in the marine environment.

Improvements to indicator quality and for further development of indicators for the MSFD descriptors are suggested. In the MSFD, a review of indicators and targets is foreseen in a six-year cycle. Dedicated research, preferably at an international level, should allow considerable progress to be made on many, if not most, indicators.

1 Introduction

1.1 Background

The European Marine Strategy Framework Directive (MSFD) (EC, 2008a) entered into force on 15 July 2008. The objective of the MSFD is to achieve or maintain Good Environmental Status (GES) in the marine environment by 2020. As one of the first steps in the implementation of the MSFD, by 15 July 2012 each member state must make an Initial Assessment, determine characteristics of GES and establish environmental indicators and targets.

Deltares and IMARES have been commissioned by the Ministry of Infrastructure and Environment (IenM) and the Ministry of Economic Affairs, Agriculture and Innovation (EL&I) to draft reports that provide scientific advice for the implementation of the MSFD by the Netherlands. For this purpose, three separate reports for the Dutch part of the North Sea have been drafted. These reports focus on:

1 the Initial Assessment,
2 the determination of Good Environmental Status,
3 the establishment of environmental Indicators and Targets.

The reports should be regarded as scientific background reports that serve as advisory documents in the preparation for the Marine Strategy in the Netherlands. The reports are based on knowledge currently available, laid down in reports and the scientific literature, and on unpublished material and expert judgment. The reports do not reflect the opinion of the Ministry of Infrastructure and Environment or the Ministry of Economic Affairs, Agriculture and Innovation.

The Initial Assessment report (Prins et al., 2011a) gives a description of the current state of the Dutch part of the North Sea. It provides information on the physical characteristics of the southern North Sea, and describes human activities in the Dutch part of the North Sea, the associated environmental pressures, and the current environmental status.

The report on the determination of GES (Prins et al., 2011b) gives recommendations on the characteristics of Good Environmental Status. These characteristics have been defined on the basis of the MSFD requirements, the current conditions in the Dutch part of the North Sea (as described in the Initial Assessment) and the commitments laid down in legislation and in national and international policy. The report recommends a definition of GES that is applicable to the Dutch part of the North Sea. It expresses the overall ambition relative to the environmental status compatible with GES.

This, third, report presents a proposal for environmental indicators and targets. The proposal is based on an elaboration of the criteria and indicators in the Commission Decision on criteria and methodological standards on GES of marine waters (EC, 2010), on the GES definition and on a consideration of potential indicators in terms of suitability, quality and practicability. The indicators and targets translate the GES definition into more specific, qualitative or quantitative environmental requirements that must be met to achieve GES.

In conclusion, the background report for the Initial Assessment describes the current state of the marine environment. The report on the determination of GES proposes the overall ambition in terms of the environmental status to be achieved. This ambition is subsequently translated into environmental targets for indicators, that describe a specific characteristic of GES and can either be qualitatively described or quantitatively assessed.

Together, the three reports provide the scientific background for the Dutch Ministry of Infrastructure and Environment (as lead organisation) to develop a marine strategy. A social and economic analysis (required as part of the Initial Assessment) will be reported separately by Rijkswaterstaat's Centre for Water Management.

1.2 The Marine Strategy Framework Directive

The objective of the Directive is to achieve or maintain Good Environmental Status (GES) in the marine environment by 2020. GES means that the seas are clean, healthy and productive and that use of the marine environment is at a level that is sustainable. For this purpose, each member state must develop and implement a Marine Strategy in order to:

a. protect and preserve the marine environment, prevent its deterioration or, where practicable, restore marine ecosystems in areas where they have been adversely affected
b. prevent and reduce inputs in the marine environment and phase out pollution, to ensure that there are no significant impacts on or risks to marine biodiversity, marine ecosystems, human health or legitimate use of the sea.

An ecosystem-based approach to the management of human activities is required. This means that the collective pressures from human activities acting on the marine environment are kept within levels compatible with the achievement of GES, whilst enabling the sustainable use of marine goods and services by present and future generations.

Member states sharing a marine region or subregion should cooperate during the whole process to ensure that their marine strategies are coherent and coordinated and should endeavour to follow a common approach. This approach consists of the following steps:

- making an Initial Assessment of the marine waters, by 15 July 2012,
- determining a set of characteristics of Good Environmental Status, by 15 July 2012,
- establishing a set of Environmental Targets and associated indicators, by 15 July 2012,
- establishing and implementing a Monitoring Programme for assessment and updating of the targets, by 15 July 2014,
- developing a programme of measures to achieve or maintain Good Environmental Status, by 2015 at the latest,
- implementing the programme of measures, by 2016 at the latest,
- achieving GES by 2020,
- every six years after the initial establishment, reviewing the above elements

1.3 Environmental targets and associated indicators

Article 10 of the Marine Strategy Framework Directive (MSFD) describes the requirements for the establishment of a comprehensive set of environmental targets and associated indicators:

- the targets and indicators should guide progress to achieving Good Environmental Status
- the indicative lists of pressures and impacts in Table 2 of Annex III must be taken into account.

- an indicative list of characteristics to be taken into account for setting environmental targets, is provided in Annex IV
- the continuing application of relevant existing environmental targets laid down at national, Community or international level has to be taken into account, ensuring that targets are mutually compatible and relevant transboundary impacts and features are also taken into consideration
- in the Commission Decision on criteria and methodological standards (EC, 2010), the European Commission describes criteria and indicators related to the eleven GES descriptors of Good Environmental Status in Annex I of the MSFD.

Good environmental status is described in Article 3.5 as *"the environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive within their intrinsic conditions, and the use of the marine environment is at a level that is sustainable, thus safeguarding the potential for uses and activities by current and future generations, i.e.:*

a. *the structure, functions and processes of the constituent marine ecosystems, together with the associated physiographic, geographic, geological and climatic factors, allow those ecosystems to function fully and to maintain their resilience to human-induced environmental change. Marine species and habitats are protected, human-induced decline of biodiversity is prevented and diverse biological components function in balance;*
b. *hydro-morphological, physical and chemical properties of the ecosystems, including those properties which result from human activities in the area concerned, support the ecosystems as described above. Anthropogenic inputs of substances and energy, including noise, into the marine environment do not cause pollution effects."*

The Commission Decision (EC, 2010) supplies a list of criteria and indicator groups for each of the eleven GES descriptors. These criteria are the starting point for the establishment of a comprehensive set of environmental indicators, for which target levels need to be set.

The Commission recognises that there is a substantial need to develop additional scientific understanding for assessing Good Environmental Status, to support the ecosystem-based approach to management. The determination of Good Environmental Status may therefore have to be adapted over time. An update of the determination of Good Environmental Status, the initial assessment and the environmental targets is due by 2018. The current recommendations therefore pertain to the initial period of MSFD implementation in the Netherlands.

The Commission Decision notes that the criteria for Good Environmental Status build on existing obligations and European legislation, e.g. the Water Framework Directive (WFD), Bird and Habitat Directives (BHD), Common Fisheries Policy (CFP), and regional conventions like OSPAR in the case of the North Sea.

The assessment and methodologies to be developed must therefore, for most criteria, take into account existing assessment methods for other European directives (in particular WFD, BHD) and policies (e.g. CFP). Also, the ICES/JRC Task group reports (see Cardoso et al. 2010, and references therein), and approaches developed in the framework of regional seas conventions should be considered. For the Dutch part of the North Sea this includes existing assessment methods applied in the frameworks of WFD, BHD, CFP and the OSPAR Ecological Quality Objectives (EcoQOs; OSPAR 2010).

1.4 Outline of the report

Chapter 2 describes the general approach taken in the development of indicators and targets. Criteria for the quality of indicators and approaches for target setting are discussed, and the procedure followed to arrive at a selection of indicators is described. In Chapter 3 an overview is given of the selected indicators and proposed targets. A more detailed description of the scientific and technical background of the indicators is provided in Appendix B. The initial selection of indicators is based on pragmatic choices. Quantitative target levels cannot yet be defined for each of the indicators. In some cases, only directional targets are given. Chapter 4 discusses and evaluates the proposed indicators and targets, gives recommendations for further development and discusses knowledge gaps and future steps.

2 Development of environmental indicators and targets

2.1 Introduction

This chapter describes the background to the development and selection of indicators and the establishment of targets, and the approach taken in order to develop appropriate indicators and associated targets.

2.2 Criteria for indicators and targets

Environmental indicators play a crucial role in the simplification, quantification, standardisation and rational explanation or communication of environmental information to regulators, industry and policy-makers. As such, environmental indicators are vital tools for disclosing information needed to assess and manage human activities that may affect the environment.

Although Article 10 of the MSFD refers to the establishment of “environmental targets and associated indicators”, the steps are in fact in the reverse order: the selection of the right indicators precedes the establishment of environmental targets.

2.2.1 Definition of indicators

Heink & Kowarik (2010) discuss the term "indicator" and its use in ecology and the environment. They suggest the following definition for an indicator[1]:

An indicator in ecology and environmental planning is a component or a measure of environmentally relevant phenomena used to depict or evaluate environmental conditions or changes or to set environmental goals. Environmentally relevant phenomena are pressures, states, and responses as defined by the OECD (2003).

Heink and Kowarik (2010) strongly suggest focusing on describing dose-effect relationships, finding relevant indicating parameters, and developing targets afterwards. They link the use of indicators to the PSR (Pressure-State-Response) model developed by the OECD. This OECD model was used by the European Environmental Agency (EEA) to develop the DPSIR model (Figure 2.1), Smeets & Weterings, 1999). According to the DPSIR framework there is a chain of causal links starting with ‘Driving forces’ (economic sectors, human activities) through ‘Pressures’ (emissions, disturbance) to ‘States’ (physical, chemical and biological) and ‘Impacts’ on society, human health and ecosystem services, eventually leading to political ‘Responses’ (prioritisation, target-setting, indicators), which may be linked back to Drivers, Pressures, States and Impacts. A schematic overview of these relationships is given in the figure below. Though Cardoso et al. (2010) do not explicitly mention the DPSIR, they do adopt the terminology (drivers, pressures and impacts). The EEA document indicates that the relationships between the drivers, pressures, states and impacts should be made as clear as possible, and that indicators can be found at each "level", pressure, state or impact. Calibration of descriptive indicators, i.e. checking the changes in indicator values against changes in pressures, is a very important step in indicator development, but it is also often complex and time-consuming.

[1] *Other terms such as ‘index’ or ‘metric’ are commonly used for some composed indicative unit, but in this document the term ‘indicator’ is used for all relevant parameters – composed, recalculated or otherwise – that are encompassed by the definition above.*

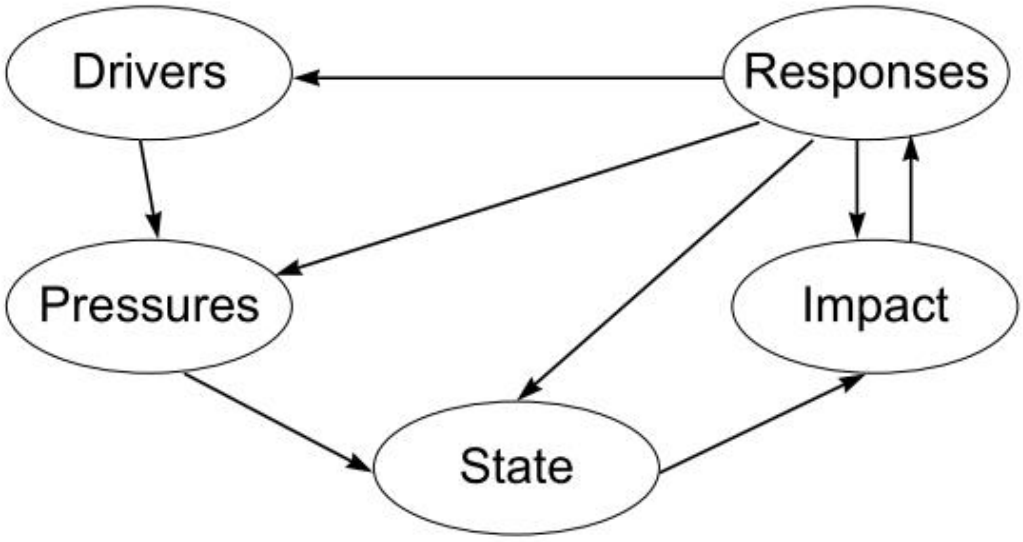

Figure 2.1 The DPSIR framework

In the development of indicators, it is helpful to identify where they fit into the DPSIR cycle. Note that DPSIR merely represents a logical method of linking the cause and effects of human influence on ecosystem components, and a way of measuring and managing this influence.

This report proposes environmental indicators to describe pressures, environmental status or impacts in accordance with the Commission Decision (EC, 2010). Indicators for drivers and policy responses are not included.

2.2.2 Criteria for environmental indicators

In the 1990s, the Netherlands developed indicators to assess aquatic ecosystem quality, for both the freshwater and the marine environment (Laane & Van den Ende, 1995). Criteria for the quality of indicators were also identified. Many documents on indicator definitions and criteria for indicators have been published since, all of which essentially consider the same issues. More recently, similar criteria were drawn up by ICES (ICES, 2001) and applied in the context of development of the Ecological Quality Objectives (EcoQOs) by OSPAR (OSPAR, 2010).

Based on the above and various other references pertaining to the development of indicators (UNCSD, 2001; ICES, 2003, 2005; EEA, 2003; OSPAR, 2005; World Bank, 2002; FAO, 2003; UN/ECE, 1993; Rice, 2003; AID environment, 2004; Rice and Rochet, 2005), the following list of eight criteria has been derived for environmental indicators:

1 *Understandable*. The power of an indicator depends on its broad acceptance and the common understanding of its concreteness. To achieve a general acceptance of the

validity of the indicator by all relevant stakeholders a considerable proportion of the indicators (or suites of indicators) must be relatively easy to understand by a non-scientific audience and decision-makers.

2 *Responsiveness/sensitivity*. The indicator must detect environmental changes in a timely way. Indicators should therefore be relatively closely linked in time to human-induced stressors. For compensation and mitigation purposes they should be able to detect changes in timeframes and on scales that are relevant to the measures being taken. The indicators should be sufficiently sensitive to show trends in human-induced changes.

3 *Specificity*. Several environmental factors and human activities may contribute to the indicator's response. The risk of misinterpretation of this cause/effect relationship is substantially reduced when the indicator is primarily responsive to a single human activity, with low responsiveness to other causes of change.

4 *Accuracy*. It is essential that all necessary elements can be measured accurately in a monitoring programme, with appropriate quality (e.g. a coherent monitoring programme with appropriate frequency and spatial coverage, and quality assurance).

5 *Applicability*. The indicator should be measurable over a large proportion of the area to which it applies.

6 *Historical data*. Indicators should be based, as much as possible, on existing time-series of data to allow realistic objectives to be set. Reliable data on historical levels are needed to construct area-specific background levels against which the current levels may be assessed and evaluated. Background levels are commonly considered when setting reference levels.

7 *Measurement*. The indicator must be measured easily and with a low error. This means that the underlying techniques and parameters exhibit low measurement error, are stable during the sampling period and are robust.

8 *Ecological relevance / theoretical basis*. The ecological relevance of the indicators needs to be high. The indicator needs a clear scientific basis, linking it to significant aspects of the status of the ecosystem.

The eight criteria have been used to evaluate the quality of the proposed indicators (see §4.2).

2.2.3 The establishment of targets

The status of an indicator is assessed in relation to a target. Environmental targets can be defined either as an acceptable state of the environment that should be attained, or as a limit/threshold value that should not be exceeded. Limits represent an environmental condition that should not deteriorate further, in order to prevent the risk of an unacceptable state (Rice, 2003, Cochrane et al., 2010).

Targets representing an acceptable/desirable state, are generally defined in relation to a baseline. In the report for ICES/JRC Task Group 1 (Cochrane et al., 2010) a conceptual framework is presented showing how to use baseline conditions for the definition of target

values. This framework was further developed in preparation for an OSPAR workshop (OSPAR, 2011). Various methods can be used to define targets (see Figure 2.2):

A Reference conditions / reference state are used as a baseline
- A.I Existing reference conditions: the target is set in relation to what is considered to be a condition with none or very minor impacts from human pressures, based on reference (unimpacted) sites (e.g. WFD approach).
- A.II Historical reference conditions: the target is set in relation to what is considered to be a condition with none or very minor impacts based on historical information (e.g. general approach recommended by OSPAR for EcoQOs)
- A.III Modelling of reference conditions: the target is set in relation to a modelled unimpacted state (e.g. approach also used under the WFD)
- A.IV A combination of these methods for arriving at a target based on conditions with no or minor impacts.

B A point in the past is used as a baseline. The target is set in relation to the first data point in a time series. This does not necessarily represent an unimpacted or not significantly impacted state

C Current state as a baseline: target set in relation to the current state at the time of inception of a particular environmental policy (e.g. Habitat Directive approach where the state of the environment in 1994 was used as a baseline)

D Directional targets: target set as a desired trend in state in relation to the chosen baseline i.e. an improvement in state where a final end point is not identified. In this approach, it is important to define clearly what the current state is.

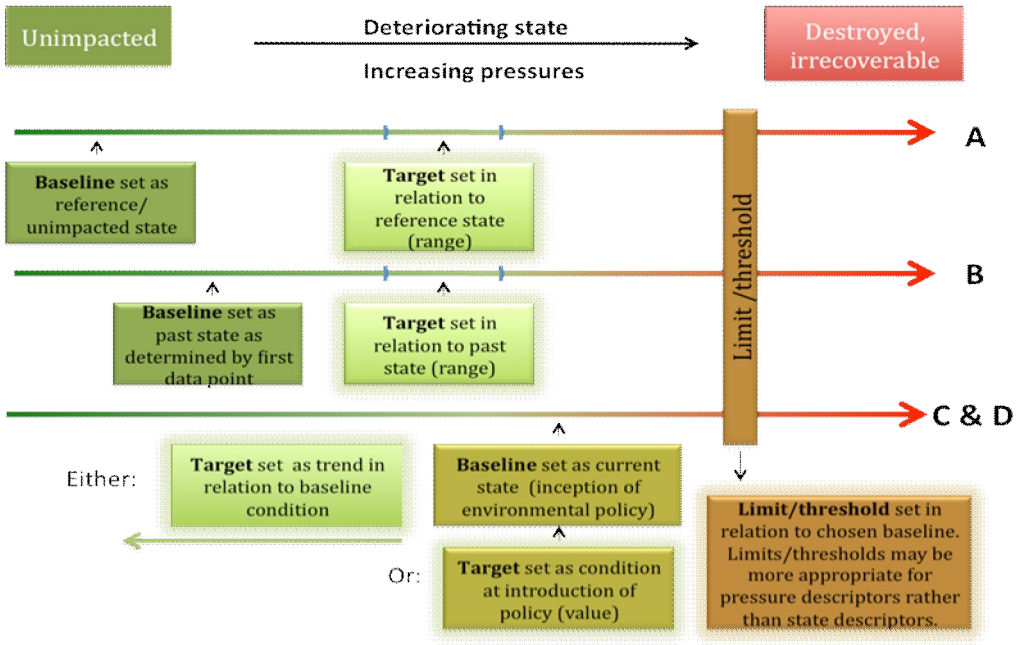

Figure 2.2 The conceptual relationship between reference and baseline conditions, targets and limits. Environmental status can be considered as a gradation from unimpacted conditions to destroyed or an irrecoverable state (top of figure). Assessment systems variously set reference, baseline, target or limit points (or ranges) along this gradient to assist in status assessment and for monitoring progress against time and actions. Here four different approaches are shown (A, B, C, D). From: OSPAR (2011).

The use of reference conditions (no or minor impacts) as a baseline (line A in Figure 2.2) often presents considerable difficulties due to the lack of suitable data and due to the fact that natural ecosystem dynamics in the intervening period are not taken into account. One point of consideration is the implicit assumption that ecosystems impacted by human pressures may revert along a linear trajectory to their original condition, once the pressure is diminished sufficiently. This assumption does not take into account the effect of multiple changes in environmental conditions and in ecosystem dynamics, caused by regime shifts, climate change and inherent ecosystem properties (Duarte et al., 2009). According to Duarte et al. (2009) attempting to restore historical conditions could in many cases be depicted as a "return to Neverland".

Baseline conditions often include a degree of deterioration from unimpacted conditions (lines B, C, D in Figure 2.2) Baseline conditions deviating from unimpacted/reference conditions are often used because they are easier to define and mark the start of available monitoring data or the introduction of a policy initiative. Referring to a state in the past where some deterioration from an unimpacted state has already occurred tends to create a situation known as "shifting baselines" (Pauly, 1995). This refers to a view where an already degraded state of the environment is seen as the original baseline of this state, which can result in a gradual accommodation to an increasingly degrading environmental status.

Cardoso et al. (2010) address a number of issues concerning the setting of environmental targets:

- Targets are human constructs, often resulting from political processes reflecting societal values. Reference levels (or points) correspond to features that are intrinsic to the ecosystem and hence are not human constructs but the results of natural processes.
- A level or target might be set at an unimpacted state, but it is highly likely that the values would exceed those for which Good Environmental Status would be achieved in the context of sustainable use of the seas as defined in the Directive.
- Any reference level or target should account for natural variation.
- In setting reference levels and targets it is necessary to take into account drivers of large-scale change. Climate change is the most obvious example of this.
- Some hydrographical drivers of environmental status may change their state periodically due to natural processes (for example the state of the North Atlantic Oscillation). These changes may cause large but natural changes in many biological features of the ecosystems, resulting in more than one natural stable state for a healthy marine ecosystem. In these cases, a number of different reference levels for GES for an indicator may be needed, with the appropriate one depending on the recent status of the hydrographical drivers.
- Several important pieces of European legislation have also prompted the development of indicators and setting of targets or reference levels.
- In many cases, research is needed to improve the understanding of suitable estimates of reference levels or targets required for the indicators. Nonetheless, paucity of knowledge should not unduly delay assessment using existing knowledge. Often existing knowledge is adequate to establish reasonable values of levels or targets, or at least the range in which an appropriate level or target should lie relative to status quo.

In this report, targets are set at levels commonly regarded as desirable from the viewpoint of other policies or directives, such as OSPAR or the WFD, or at levels that experts involved in this study have assumed to reflect the state of the ecosystem where the use of ecosystem goods and services is at a sustainable level. In many cases, where quantitative targets could not be defined, directional targets are proposed. Social and economic concerns in the setting of targets have not been taken into consideration.

2.3 Overall development process

Various workshops and expert meetings were organised with scientists from Deltares and IMARES to discuss potential indicators for the eleven descriptors. The starting point for the discussion was the list of criteria and indicators in the Commission Decision (EC, 2010). The indicators proposed in this report are based on expert opinion. Detailed information on the scientific background for the proposed indicators (including references to relevant literature) is provided in factsheets that are included in appendix B.

At an early moment in the process, the eleven descriptors and associated indicators mentioned in the Commission Decision were organised into three different groups based on previous development in other policy or research frameworks, level of scientific knowledge and the degree of ecological integration:

1 The first group consists of indicators and targets that already exist. This concerns indicators developed earlier, for instance in the framework of other EU legislation or OSPAR.
   a OSPAR: a set of indicators and targets has been developed in the context of the six OSPAR strategies. A number of these Ecological Quality Objectives (EcoQOs) have been applied in the North Sea (OSPAR, 2009). It should be noted that indicators and targets set in the OSPAR EcoQOs do not necessary fully comply with the requirements of the MSFD. The EcoQOs may be useful and applicable, but have to be (re)viewed in an MSFD context (Good Environmental Status). A number of EcoQOs are now operational (OSPAR, 2009).
   b Natura 2000: conservation objectives for the Natura 2000 sites in the North Sea were recently proposed (Jak et al., 2009).
   c WFD: for the implementation of the Water Framework Directive (WFD), indicators and targets have been developed with respect to physico-chemical characteristics, phytoplankton and benthic invertebrates, partly matching descriptors 5 (Eutrophication) 6 (Seafloor integrity), 8 (Contaminants). For the implementation of the WFD, indicators for the coastal waters of the North Sea developed in the Netherlands (Van der Molen & Pot, 2007) have been subject to WFD intercalibration (Carletti and Heiskanen, 2009).
   d CFP: a suite of environmental indicators has been put forward to support scientific advice regarding the Common Fisheries Policy (EC, 2008b).
   e An overview of available indicators from other studies (e.g. GONZ, AMOEBE, Nature Target Types, etc.) was produced by Langenberg & Troost (2008).

2 The second group consists of proposed indicators for which targets had not yet been set. Often, relationships between the indicators and human activities in a DPSIR context are uncertain. This is, for example, the case for indicators relating to non-indigenous species (2), seafloor integrity (6) and hydrographical conditions (7).

3 A third group consists of indicators that still require mid- to long-term development to become operational, as a consequence of limited understanding of the cause-effect relationships between human activities and environmental effects in the marine environment. The selection of appropriate indicators and the setting of targets that represent Good Environmental Status are complicated matters. This applies in particular to biological diversity (1), food webs (4), litter (10) and underwater noise (11). The main focus will need to be on how to describe the different criteria in measurable, ecological terms that have some relationship with manageable activities.

Article 10 of the MSFD describes the general requirements for the establishment of targets and indicators (see §1.3). Annex IV of the MSFD gives an indicative list of characteristics for the setting of environmental targets. Some of these characteristics are included in the criteria for indicators mentioned in §2.2.2. For the establishment of targets, attention has been focused on

- compatibility of targets with the definition of Good Environmental Status and commitments under international or regional agreements, and national policies and legislation,
- definition of targets in terms of measurable properties,
- consistency of the set of targets.

3 Overview of proposed indicators and targets

This chapter gives an overview of the proposed indicators and targets which are ready for application and have been selected on the basis of expert knowledge. The table below (Table 3.1) gives a summary of the proposed indicators and targets. A brief description is provided in sections 3.1 to 3.11. Details can be found in appendix B containing fact sheets on all indicators

Table 3.1 Overview of the criteria and indicators in the Commission Decision (EC, 2010) and the proposed indicators and targets. Numbers refer to the numbering in EC (2010). S indicates status: red: no indicator; orange: indicator needs some elaboration; green: existing indicator; hatching: indicator partly covers EC (2010).

Criteria and indicators (EC, 2010)	S	Proposed indicator	Proposed target
1. Biological diversity			
Species distribution (1.1) *Distributional range (1.1.1)*		Benthos: • number/biomass of long-lived/vulnerable species • proportion of long-lived/vulnerable species in benthic community Fish: • number of species with a long-term negative trend • Threat indicator Birds: • Vulnerable species Marine mammals: • Number of grey seal, harbour seal, harbour porpoise	Increase in number/biomass Increase in proportion Zero Reduction in the rate of increase No decline No decline
Species distribution (1.1) *Distributional pattern within the latter, where appropriate (1.1.2)*			
Species distribution (1.1) *Area covered by the species (for sessile/benthic species) (1.1.3)*			
Population size (1.2) *Population abundance and/or biomass, as appropriate (1.2.1)*			
Population condition (1.3) *Population demographic characteristics (e.g. body size or age class structure, sex ratio, fecundity rates, survival/mortality rates) (1.3.1)*		Fish: • OSPAR EcoQO proportion of large fish in the fish community • Size diversity index Marine mammals: • OSPAR EcoQO on healthy seal populations	More than 30% of fish should be longer than 40 cm in the IBTS Increase towards a value of 1 No decline of >10% in grey seal pup populations or harbour seal populations over a five-year running mean
Population condition (1.3) *Population genetic structure, where appropriate (1.3.2).*		Not applicable yet	
Habitat distribution (1.4) *Distributional range (1.4.1)*		Distribution and pattern of habitats at EUNIS level 3	No decline in distributional range
Habitat distribution (1.4) *Distributional pattern (1.4.2)*			
Habitat extent (1.5) *Habitat area (1.5.1)*			
Habitat extent (1.5) *Habitat volume, where relevant (1.5.2)*			
Habitat condition (1.6) *Condition of the typical species and communities (1.6.1)*		Benthos: • number/biomass of long-lived/vulnerable species • proportion of long-lived	Increase in number/biomass Increase in proportion
Habitat condition (1.6)			

Criteria and indicators (EC, 2010)	S	Proposed indicator	Proposed target
Relative abundance and/or biomass, as appropriate (1.6.2)		/vulnerable species in benthic community	
Habitat condition (1.6) *Physical, hydrological and chemical conditions (1.6.3)*		Distribution and pattern of habitats at EUNIS level 3	No decline in distributional range
Ecosystem structure (1.7) *Composition and relative proportions of ecosystem components (habitats and species) (1.7.1)*		<u>Benthos, Fish:</u> • Species richness • Species evenness, Hill's N_1, Hill's N_2 <u>Birds:</u> • Bird values <u>Marine mammals:</u> • Species richness	No decline Values do not exceed the range typical for the monitoring site Values do not exceed the range typical for the monitoring site No decline
2. Non-indigenous species			
Trends in abundance, temporal occurrence and spatial distribution in the wild of non-indigenous species, particularly invasive non indigenous species, notably in risk areas, in relation to the main vectors and pathways of spreading of such species (2.1.1)		Number of non-indigenous species Abundance of non-indigenous species	No increase No increase
Ratio between invasive non-indigenous species and native species in some well studied taxonomic groups (e.g. fish, macroalgae, molluscs) that may provide a measure of change in species composition (e.g. further to the displacement of native species) (2.2.1)		Ratio of non-indigenous:native species in a selection of groups (phytoplankton, benthos, fish)	No increase
Impacts of non-indigenous invasive species at the level of species, habitats and ecosystem, where feasible (2.2.2)		To be determined dependent on species, habitat and ecosystem characteristics	No impact
3. Commercially exploited fish			
Fishing mortality (F) (3.1.1)		Fishing mortality of commercially exploited fish	Below F_{MSY} (ICES advice for values of F_{MSY})
Secondary indicator: Ratio between catch and biomass index (hereinafter catch/biomass ratio) (3.1.2)		Catch/biomass ratio of commercially exploited fish	No increase
Spawning Stock Biomass (SSB) (3.2.1)		SSB of commercially exploited fish	Below SSB_{PA} (ICES advice for values of SSB_{PA})
Secondary indicator: Biomass indices (3.2.2)		Log-transformed abundance of commercially exploited fish	No decline
Proportion of fish larger than the mean size of first sexual maturation (3.3.1)		Proportion of fish larger than the mean size of first sexual maturation	No decrease
Mean maximum length across all species found in research vessel surveys (3.3.2)		Not applicable	
95% percentile of the fish length distribution observed in research vessel surveys (3.3.3)		95% percentile of the fish length distribution observed in research vessel surveys	No decrease
Secondary indicator: Size at first sexual maturation, which may reflect the extent of undesirable genetic effects of exploitation (3.3.4)		Size at first sexual maturation	No decrease
4. Food webs			
Performance of key predator species using their production per unit biomass (productivity) (4.1.1)		OSPAR EcoQO on healthy seal populations Abundance of prey species of grey	No decline of >10% in grey seal pup populations or harbour seal populations over a five-year running mean No decrease

Criteria and indicators (EC, 2010)	S	Proposed indicator	Proposed target
		seal and harbour seal	
Large fish (by weight) (4.2.1)		OSPAR EcoQO proportion of large fish in the fish community	More than 30% of fish should be longer than 40 cm in the IBTS survey Increase in average size (by weight) of pelagic fish
Abundance trends of functionally important selected groups/species (4.3.1)		OSPAR EcoQO on by-catch levels of harbour porpoise	Below 1% of best population estimate
5. Eutrophication			
Nutrients concentration in the water column (5.1.1)		Winter means of dissolved inorganic nitrogen	DIN (µM) = 184,7-5,057*salinity for salinities<30 33 for salinities ≥30
Nutrient ratios (silica, nitrogen and phosphorus), where appropriate (5.1.2)		N:P ratio (based on winter means)	Between 10-37.5
Chlorophyll concentration in the water column (5.2.1)		90-percentile of growing season concentration	Chl-a (µg/l) = 21 for salinities<30.4 144-4.045*salinity for salinities ≥30.4 and <34.5 4.5 for salinities≥34.5
Water transparency related to increase in suspended algae, where relevant (5.2.2)		Not applicable	
Abundance of opportunistic macroalgae (5.2.3)		Not applicable	
Species shift in floristic composition such as diatom to flagellate ratio, benthic to pelagic shifts, as well as bloom events of nuisance/toxic algal blooms (e.g. cyanobacteria) caused by human activities (5.2.4)		Frequency of blooms of *Phaeocystis globosa*	≤2 months per year
Abundance of perennial seaweeds and seagrasses (e.g. fucoids, eelgrass and Neptune grass) adversely impacted by decrease in water transparency (5.3.1)		Not applicable	
Dissolved oxygen, i.e. changes due to increased organic matter decomposition and size of the area concerned (5.3.2)		Annual minimum concentration of oxygen	>= 5 mg/l
6. Sea-floor integrity			
Type, abundance, biomass and areal extent of relevant biogenic substrate (6.1.1)		Abundance and areal extent of biogenic substrate	Increase in abundance and areal extent
Extent of the seabed significantly affected by human activities for the different substrate types (6.1.2)		Proportion of surface area of each habitat (EUNIS level 3) affected by human activities in the last year	Decrease
Presence of particularly sensitive and/or tolerant species (6.2.1)		Number/biomass of long-lived/vulnerable benthos species Proportion of long-lived/vulnerable species in benthic community	Increase in number/biomass Increase in proportion
Multi-metric indexes assessing benthic community condition and functionality, such as species diversity and richness, proportion of opportunistic to sensitive species (6.2.2)		BEQI Species richness Species evenness Hill's N_1 Hill's N_2	Values do not exceed the range typical for the monitoring site
Proportion of biomass or number of individuals in the macrobenthos above some specified length/size (6.2.3)		Length-frequency distribution of bivalves	No decrease
Parameters describing the characteristics (shape, slope and intercept) of the size spectrum of the benthic community (6.2.4)		Not applicable	
7. Hydrographical conditions			
Extent of area affected by		Total (cumulative) surface area that	*The impact of human activities that*

Criteria and indicators (EC, 2010)	S	Proposed indicator	Proposed target
permanent alterations (7.1.1)		has permanently changed	*permanently change part of a marine area is only to some extent related to the surface area. It is therefore not feasible to set a meaningful target for this indicator*
Spatial extent of habitats affected by the permanent alteration (7.2.1)		Total (cumulative) surface area where permanent changes occur	*See above*
Changes in habitats, in particular the functions provided (e.g. spawning, breeding and feeding areas and migration routes of fish, birds and mammals), due to altered hydrographical conditions (7.2.2)		To be determined dependent on type of activity	
8. Contaminants			
Concentration of the contaminants mentioned above, measured in the relevant matrix (such as biota, sediment and water) in a way that ensures comparability with the assessments under Directive 2000/60/EC (8.1.1)		Concentrations of contaminants in water, sediment, suspended matter and/or biota	WFD-Environmental quality standards (EQS) for contaminants in water OSPAR-Environmental assessment criteria (EAC) for contaminants in sediment and biota
Levels of pollution effects on the ecosystem components concerned, having regard to the selected biological processes and taxonomic groups where a cause/effect relationship has been established and needs to be monitored (8.2.1)		OSPAR EcoQO on level of imposex in dogwhelks and other gastropods Various biological effects indicators	The average level of imposex should be consistent with exposure to TBT concentrations below the environmental assessment criterion OSPAR/ICES EAC's
Occurrence, origin (where possible), extent of significant acute pollution events (e.g. slicks from oil and oil products) and their impact on biota physically affected by this pollution (8.2.2)		OSPAR EcoQO on number of oiled guillemots	The average proportion of oiled common guillemots in all winter months (November to April) should be 10% or less of the total found dead or dying, over a period of at least 5 years
9. Contaminants in seafood			
Actual levels of contaminants that have been detected and number of contaminants which have exceeded maximum regulatory levels (9.1.1)		Levels of contaminants in fish and seafood	Regulatory levels from Commission Regulation (EC) No 1881/2006 and the "Warenwet"
Frequency of regulatory levels being exceeded (9.1.2)		Annual frequency of observations where levels are exceeded	Zero
10. Litter			
Trends in the amount of litter washed ashore and/or deposited on coastlines, including analysis of its composition, spatial distribution and, where possible, source (10.1.1)		The average amount of litter items washed ashore on reference beaches	Decrease
Trends in the amount of litter in the water column (including floating at the surface) and deposited on the sea-floor, including analysis of its composition, spatial distribution and, where possible, source (10.1.2)		OSPAR EcoQO on the level of litter (plastic particles) in fulmar stomachs	Less than 10% of fulmars with more than 0.1 g of plastic in their stomach, over a period of at least five years
Trends in the amount, distribution and, where possible, composition of micro-particles (in particular micro-plastics) (10.1.3)		Not applicable yet	
Trends in the amount and composition of litter ingested by marine animals (e.g. stomach analysis) (10.2.1)		OSPAR EcoQO on the level of litter (plastic particles) in fulmar stomachs	See above
11. Underwater noise			
Proportion of days and their distribution within a calendar year over areas of a determined surface,		Not developed yet	

Criteria and indicators (EC, 2010)	S	Proposed indicator	Proposed target
as well as their spatial distribution, in which anthropogenic sound sources exceed levels that are likely to entail significant impact on marine animals measured as Sound Exposure Level (in dB re 1µPa2.s) or as peak sound pressure level (in dB re 1µPapeak) at one metre, measured over the frequency band 10 Hz to 10 kHz (11.1.1)			
Trends in the ambient noise level within the 1/3 octave bands 63 and 125 Hz (centre frequency) (re 1µPa RMS; average noise level in these octave bands over a year) measured by observation stations and/or with the use of models if appropriate (11.2.1)		Not developed yet	

3.1 Biological diversity

3.1.1 Species level: species distribution and population size

Criteria and indicators (EC, 2010)	Proposed indicators*	Proposed target
Species distribution (1.1) *Distributional range (1.1.1)*	**Benthos:** • number/biomass of long-lived/vulnerable species	Increase in number/biomass
Species distribution (1.1) *Distributional pattern within the latter, where appropriate (1.1.2)*	• proportion of long-lived/vulnerable species in benthic community	Increase in proportion
Species distribution (1.1) *Area covered by the species (for sessile/benthic species) (1.1.3)*	**Fish:** • number of species with a long-term negative trend • Threat indicator	Zero Reduction in the rate of increase
Population size (1.2) *Population abundance and/or biomass, as appropriate (1.2.1)*	**Birds**: • Vulnerable species **Marine mammals:** • Number of grey seal, harbour seal, harbour porpoise	No decline No decline

*See Appendix B for more detailed information on the indicators

Indicator: Species distribution and population size

Rationale behind the indicators

The aim of descriptor 1 is to make sure that the current loss of biodiversity is halted, and that biodiversity is restored, where necessary. This therefore means that information is needed on (1) the state of biodiversity (e.g. the current species richness), and (2) on the rate of biodiversity loss. To ascertain the latter, those stocks, species, higher taxa and habitats that are most at risk (ICES, 2011) need to be monitored. In general, flexible lists of species at risk are proposed, which can change over time. These lists can be adapted in the evaluation cycle of the MSFD.

To select species that are most in danger of extinction, the focus should be on those species that are threatened or declining. The OSPAR Texel-Faial criteria (OSPAR, 2003, see Appendix B) provide some help in selecting such species, although they are not 100% applicable. The selection of very rare species should be avoided (not enough data) and key-stone species have not yet been identified. However, criterion 4 on sensitivity and criterion 6

on decline were used (see Appendix B). Which criterion is used for which taxon depends on data availability.

Data are available for four taxonomic groups: benthos, fish, birds and marine mammals. For other groups no or only limited data are available. The selection of species comprises (see Table 3.2 for more details):

- Benthos: Vulnerable benthic species: macrobenthic species (BIOMON survey) that can potentially live for > 10 y (age class 5; rarity class 1-2; Bos et al., 2011). These include brittle star and bivalve species,
- Fish: Declining fish species: species with a long term (>25 y) negative trend. This species list might differ between assessment periods,
- Fish: Threat indicator for fish, describes population status for a suite of fish species using World Conservation Union (IUCN) Red List decline criteria,
- Birds: bird species scored as vulnerable (or low-resilience, 4 and 5 points) (Leopold et al., in prep; Bos et al., 2011),
- Mammals: all species regularly present.

The threat indicator is indicative of the number of fish species qualifying as “critically endangered” (Dulvy et al. 2006). Negative trends in this selection of species relate to the potential loss of a population/species, and thus to biodiversity loss.

Note that benthic species as a group has been included here, while this group has obviously also been included in descriptor 6, Seafloor integrity. Doublings in indicator groups throughout the various descriptors is the logical result of the decision to present each descriptor as a ‘stand-alone’ indicator group. Obviously, both indicators and targets were harmonised where relevant.

Rationale behind the targets

Negative trends in population size in this selection of species relate to the potential loss of a population/species, and thus to loss of biodiversity. Absence or a reduction in the rate of this trend is assumed to represent a halt in biodiversity loss.

- Benthos: Increase in number/biomass of long-lived species and a larger proportion in the total benthic community. Long-lived species have disappeared as a result of human pressure (Rumohr & Kujawski, 2000) and are expected to return under prevailing physiographical, geographical and climatic conditions,
- Fish: Reduction to zero of the number of fish species with a long-term negative trend,
- Birds: No decline in numbers of the selected indicator species, unless positively related to human activities (e.g. discarding). The OSPAR EcoQo for bird population provides guidance (ICES, 2008) on dealing with natural fluctuations,
- Mammals: No decline in numbers,
- For all targets: Evaluation of each species on the list is needed to establish the reason for decline, and to differentiate between natural causes of decline and human causes.

Comparability with criteria and indicators in Commission Decision

The indicators partly cover the intention of criterion 1.1. and 1.2 in the Commission Decision (EC, 2010). Not all species are taken into account, but only a selection of species as proxies for species groups. For example, plankton is not taken into account in this indicator.

Table 3.2 Biodiversity indicators for species distribution and population size.

INDICATORS FOR LOSS OF BIODIVERSITY	**species level**			
	Selected group	**Species list (2011)**	**Aim**	**Remarks**
BENTHOS				
Vulnerable benthos species are those species that can live for a long time and reproduce slowly. Densities of such species have been significantly reduced, compared to the past (Rumohr & Kujawski 2000). Long-lived species are used a proxy for vulnerability (or resilience) (Bos et al. 2011).	In the hotspots project (Bos et al. 2011), maximum ages for many benthic species were determined by a literature study. We suggest macrobenthic species be used (BIOMON survey) that can potentially live for > 10 y (age class 5), and occur frequently (to allow sampling, rarity class 1+2)	*Amphiura filiformis* *Arctica islandica* *Chamelea striatula* *Dosinia exoleta* *Dosinia lupinus* *Thracia papyracea* (Bos et al. 2011)	Increase in number/biomass of long-lived/vulnerable species and higher share in the total benthic community	The list of vulnerable species listed here needs to be updated regularly
FISH				
Declining fish species: species with a long-term negative trend (Bos et al. 2011)	Species that show a negative trend for >25 y (Bos et al. 2011)	*Cyclopterus lumpus* *Gadus morhua* *Gasterosteus aculeatus* *Merlangius merlangus* *Sardina pilchardus* *Squalus acanthias* *Trisopterus minutus* (Bos et al. 2011)	Reduce the number of fish species with a long-term negative trend to zero	Additional study needed to determine the reason for a decline (anthropogenic or natural cause)
BIRDS				
Vulnerable bird species are those species with low reproductive output (Bos et al. 2011)	Bird species scored as vulnerable (or low resilience, 4 and 5 points) (Leopold et al. in prep) (Bos et al. 2011)	*Fulmarus glacialis* *Morus bassanus* *Stercorarius skua* *Uria aalge* *Alca torda* (Bos et al. 2011)	Long-term stable populations (e.g. following philosophy of proposed ecological quality objective (EcoQO) on seabird population trends (ICES 2008))	The vulnerable bird species listed here is fixed (reproductive output is not flexible)
MARINE MAMMALS				
All marine mammals are vulnerable and should be considered (only few species)	All species regularly present	Grey seal Harbour seal Harbour porpoise	No decline in numbers	

3.1.2 Species level: Population condition

Criteria and indicators (EC, 2010)	Proposed indicators*	Proposed target
Population condition (1.3) *Population demographic characteristics (e.g. body size or age class structure, sex ratio, fecundity rates, survival/mortality rates) (1.3.1)*	**Fish:** • OSPAR EcoQO proportion of large fish in the fish community • Size diversity index **Marine mammals:** • OSPAR EcoQO on healthy seal populations	More than 30% of fish should be longer than 40 cm in the IBTS Increase towards a value of 1 No decline of >10% in grey seal pup populations or harbour seal populations over a five-year running mean
Population condition (1.3) *Population genetic structure, where appropriate (1.3.2).*	Genetic structure: Not applicable yet	

*See Appendix B for more detailed information on the indicators

Indicator: Population condition

Rationale behind the indicators

Demographic characteristics reflect the condition of populations. Unhealthy population condition is potentially detrimental to biodiversity. The indicators for fish (proportion of large fish, size diversity index) and marine mammals (EcoQO's on seal populations) are a selection of ready-to-use parameters, describing population characteristics. The EcoQO on the proportion of large fish in the IBTS survey (Greenstreet, 2008; Heslenfeld & Enserink, 2008; Greenstreet et al., 2011) shows the distribution of fish length in the fish community (not in fish populations), which can indicate changes in community composition. This information is considered to be in line with the intention of EC (2010). The size diversity index of fish (Rochet & Benoît, submitted) is indicative of an unbalanced population composition when deviating from 1.

As there is lack of knowledge on the genetic structure of populations, no indicators can be identified to address this issue.

Rationale behind the targets

Negative changes in population characteristics relate either directly or indirectly to biodiversity loss. The timeframe in which these targets will be achieved needs to be decided.

Comparability with criteria and indicators in Commission Decision

The indicators partly cover the intention of criterion 1.3 in the Commission Decision (EC, 2010). Not all species are taken into account, only a selection of species as proxies for

species groups. Plankton, benthos and birds are not taken into account in this indicator due to a lack of current population condition indicators for these groups.

3.1.3 Habitat level: habitat distribution, extent and condition

Criteria and indicators (EC, 2010)	Proposed indicators*	Proposed target
Habitat distribution (1.4) *Distributional range (1.4.1)*	Distribution and pattern of habitats at EUNIS level 3**	No decline in distributional range
Habitat distribution (1.4) *Distributional pattern (1.4.2)*		
Habitat extent (1.5) *Habitat area (1.5.1)*		
Habitat extent (1.5) *Habitat volume, where relevant (1.5.2)*		
Habitat condition (1.6) *Condition of the typical species and communities (1.6.1)*	Benthos: • number/biomass of long-lived/vulnerable species • proportion of long-lived /vulnerable species in benthic community	Increase in number/biomass Increase in proportion
Habitat condition (1.6) *Relative abundance and/or biomass, as appropriate (1.6.2)*		
Habitat condition (1.6) *Physical, hydrological and chemical conditions (1.6.3)*	Distribution and pattern of habitats at EUNIS level 3**	No decline in distributional range

*See Appendix B for more detailed information on the indicators

** The EUNIS Habitat types classification is a comprehensive pan-European system to facilitate the harmonised description and collection of data across Europe through the use of criteria for habitat identification; it covers all types of habitats from natural to artificial, from terrestrial to freshwater and marine waters. EUNIS maps consist of five levels, increasing in physical and biological complexity from level 1 to 5. Level 3 describes the benthos at the community/assemblage level; see also the website: http://eunis.eea.europa.eu/.

Indicator: Distribution and pattern of habitats

Rationale behind the indicator

Habitats defined at EUNIS level 3 or by benthic community maps (Bos et al., 2011) can be used to describe the distribution and extent of habitats. The distribution and the pattern of habitats may reflect spatial differences in biodiversity.

EUNIS level 3, which defines habitats on the basis of abiotic features (e.g. depth, sediment characteristics) is proposed as there is a lack of information from monitoring on habitats at EUNIS level 4 (communities). Benthic habitat maps as provided by Lindeboom et al. (2008) and Bos et al. (2011) can be used to complement this indicator.

Habitat maps at EUNIS level 3 also give an indication of the chemico-physical and hydrological conditions, as the maps are based on abiotic features.

Habitat volume has not been taken into account due to lack of relevance. It is not clear to which process or characteristic this indicator should relate.

Rationale behind the target

Loss of habitats reflects a loss of biodiversity. Impacts of human activities on benthic habitats are covered by Seafloor integrity.

Comparability with criteria and indicators in Commission Decision

The indicator covers the intention of criterion 1.4 in the Commission Decision (EC, 2010). .

Indicator: Number/biomass of long-lived/vulnerable species and proportion in the benthic community

Rationale behind the indicator

Vulnerable benthic species are those species that have longevity and low reproduction. Densities of such species have been significantly reduced compared to the recent past (Rumohr & Kujawski 2000). Long-lived species have been used as a proxy for vulnerability (or resilience) (Bos et al. 2011). The hotspots project (Bos et al., 2011) determined maximum ages for many benthic species from the literature. It is proposed that, for the description of habitat condition, the same selection of macrobenthic species is used as for the indicator on benthic species distribution (Table 3.2). Trend in population size of a selection of benthic species (vulnerable species) is used as a proxy for habitat condition for a limited number of habitats.

Rationale behind the target

Negative changes in population properties of long-lived/vulnerable benthos species relate either directly or indirectly to the potential loss of a population/species and decrease in habitat condition. A higher (relative) abundance of vulnerable species reflects a less impacted system.

Comparability with criteria and indicators in Commission Decision

The indicators partly cover the intention of criterion 1.6 in the Commission Decision (EC, 2010). Not all species are taken into account, but only a selection of benthic species that are defined as vulnerable. It should be noted that habitat types have been described and are being protected under Natura 2000. However, the Habitat Directive has its own conservation goals (area-specific) and should not replace those described for the MSFD. Harmonisation will need to take place at a later stage.

3.1.4 Ecosystem structure

Criteria and indicators (EC, 2010)	Proposed indicators*	Proposed target
Ecosystem structure (1.7) *Composition and relative proportions of ecosystem components (habitats and species) (1.7.1)*	**Benthos, Fish:** • Species richness • Species evenness, Hill's N_1, Hill's N_2 **Birds:** • Bird values **Marine mammals:** • Species richness	No decline Values do not exceed the range typical for the monitoring site Values do not exceed the range typical for the monitoring site No decline

*See Appendix B for more detailed information on the indicators

Indicator: Species indicators for benthos, birds, fish and marine mammals

Rationale behind the indicator

The state of biodiversity can be expressed in terms of species numbers, species evenness and other indicators of the specific assemblages. Species richness, or the number of species present in a community, has been widely applied as a metric of biodiversity, and is understandable for the general public. Evenness incorporates information on each of the species present in the assemblage. In practice, both metrics apply to the assemblage sampled by the survey and not the community per se (ICES 2011). It is proposed that Hill numbers also be included, since these cover the continuum, from unweighted species richness to a bigger emphasis on evenness. For birds, Bird Values (Leopold et al. in prep.) are proposed.

Rationale behind the target

Negative changes in species richness relate directly to biodiversity loss.

Target-setting for the evenness and Hill indices is more difficult. The targets are defined as a range with a minimum and maximum value that must not be exceeded. The range must be defined on the basis of existing data, and represents the natural and spatial variability of the relevant parameters under an acceptable level of human pressure. It is not possible *a priori* to determine values for the evenness and Hill indices that indicate a good status, i.e. whether a more even distribution of species is ”better” or not. Large changes in the indices, outside a predefined range, should be evaluated to determine whether the changes can be attributed to human pressures, or are caused by natural factors.

Comparability with criteria and indicators in Commission Decision

These indicators partly cover the intention of criterion 1.7 in the Commission Decision (EC, 2010). Not all species groups are taken into account. Habitats are not included, but are partly reflected by indices for benthic communities.

3.1.5 Comparison of indicators and targets with current state

The table below gives an overview of the current indicator values, insofar they have already been established in available data and reports.

Table 3.3 Proposed indicators and targets, and current state

1. Biological diversity				
Criteria and indicators (EC, 2010)	Proposed indicator	Proposed target	Assessment	
			Current state	Period
Distributional range (1.1.1) *Distributional pattern within the latter, where appropriate (1.1.2)* *Area covered by the species (for sessile/benthic species) (1.1.3)* *Population abundance and/or biomass, as appropriate (1.2.1)*	**Benthos:** • number/biomass of long-lived/vulnerable species • proportion of long-lived/vulnerable species in benthic community **Fish:** • number of species with a long-term negative trend • Threat indicator **Birds**: • Vulnerable species **Marine mammals:** Number of grey seal, harbour seal, harbour porpoise	Increase in number/biomass Increase in proportion Zero Reduction in the rate of increase No decline No decline	*Requires further data analysis for proper asssments*	
Population demographic characteristics (e.g. body size or age class structure, sex ratio, fecundity rates, survival/mortality rates) (1.3.1)	**Fish:** • OSPAR EcoQO proportion of large fish in the fish community • Size diversity index **Marine mammals:** • OSPAR EcoQO	More than 30% of fish should be longer than 40 cm in the IBTS survey Increase towards a value of 1 No decline of >10% in grey	Target not met. Last assessment result: 22% *Requires further data analysis for proper assessments* Target met	2008 2002-2006

	on healthy seal populations	seal pup populations or harbour seal populations over a five-year running mean		
Population genetic structure, where appropriate (1.3.2).	Not yet applicable			
Distributional range (1.4.1) *Distributional pattern (1.4.2)* *Habitat area (1.5.1)* *Habitat volume, where relevant (1.5.2)*	Distribution and pattern of habitats at EUNIS level 3	No decline in distributional range	*Requires further data analysis for proper assessments*	
Condition of the typical species and communities (1.6.1) *Relative abundance and/or biomass, as appropriate (1.6.2)*	**Benthos:** • number/biomass of long-lived/vulnerable species • proportion of long-lived/vulnerable species in benthic community	Increase in number/biomass Increase in proportion	*Requires further data analysis for proper assessments*	
Physical, hydrological and chemical conditions (1.6.3)	Same as 1.4.1			
Composition and relative proportions of ecosystem components (habitats and species) (1.7.1)	**Benthos, Fish:** • Species richness • Species evenness, Hill's N_1, Hill's N_2 **Birds:** • Bird values **Marine mammals:** • Species richness	No decline Values do not exceed the range typical for the monitoring site Values do not exceed the range typical for the monitoring site No decline	*Requires further data analysis for proper assessments*	

3.2 Non-indigenous species

3.2.1 Abundance and state characterisation of non-indigenous species

Criteria and indicators (EC, 2010)	Proposed indicator*	Proposed target
Trends in abundance, temporal occurrence and spatial distribution in the wild of non-indigenous species, particularly invasive non indigenous species, notably in risk areas, in relation to the main vectors and pathways of spreading of such species (2.1.1)	Number of non-indigenous species Abundance of non-indigenous species	No increase No increase

*See Appendix B for more detailed information on the indicators

Indicator: Number of non-indigenous species and abundance of non-indigenous species

Rationale behind the indicators

The total number of non-indigenous species indicates whether there have been new introductions of species, with an increased chance of changes in the ecosystem that may cause unpredictable and irreversible changes to marine ecosystems. However, due to the species and environment specificity of each case, there is no single qualitative relationship between the number of introductions of non-indigenous species and the impacts. As a consequence, the indicator is a proxy for a potential risk of impacts from non-indigenous species, but not a reliable predictor of the actual risk.

There is no regular monitoring to detect non-indigenous species. Current monitoring programmes could be used to follow trends in some well-studied groups, like phytoplankton, benthic invertebrates and fish. However, it should be noted that the lack of detection of non-indigenous species, even in the above groups, does not guarantee the absence of new species. The detection of non-indigenous species is likely to lag behind their actual introduction.

Rationale behind the targets

As there is no well-established relationship between the number of non-indigenous species and the risk of impacts from their introduction, it is not possible to set a limit. Therefore, only a directional target (no increase) can be set.

As there is no regular monitoring, this target can only be applied to specific groups that are currently monitored (phytoplankton, benthic invertebrates, fish).

Comparability with criteria and indicators in Commission Decision

This indicator covers the intention of indicator 2.1.1 in the Commission Decision (EC, 2010). However, data are only available for some species groups, and no monitoring specifically targets this subject.

3.2.2 Environmental impact of invasive non-indigenous species

Criteria and indicators (EC, 2010)	Proposed indicator*	Proposed target
Ratio between invasive non-indigenous species and native species in some well studied taxonomic groups (e.g. fish, macroalgae, molluscs) that may provide a measure of change in species composition (e.g. further to the displacement of native species) (2.2.1)	Ratio of non-indigenous:native species in a selection of groups (phytoplankton, benthos, fish)	No increase
Impacts of non-indigenous invasive species at the level of species, habitats and ecosystem, where feasible (2.2.2)	To be determined dependent on species, habitat and ecosystem characteristics	No impact

*See Appendix B for more detailed information on the indicators

Indicator: Ratio of non-indigenous:native species

Rationale behind the indicators

The ratio indicates to what extent a taxonomic group is potentially affected by the introduction of non-indigenous species. However, the sensitivity of the ratio as an indicator of changes in pressures is species- and habitat-dependent and needs to be considered on a case-by-case basis. Moreover, the ratio is not an indicator of ecological impacts, only a proxy of potential risk.

There is no regular monitoring to detect non-indigenous species. Current monitoring programmes can only be used to follow trends in some well-studied groups, like phytoplankton, benthic invertebrates and fish.

Rationale behind the target

There should be no increase in the ratio of numbers or density of non-indigenous species. Where appropriate and relevant, biomass ratios can be used. This indicator expresses an increase in the risk of negative impacts due to introductions of non-indigenous species. However, as there is no well-established relationship between the ratio and the risk of

impacts from the introduction of non-indigenous species, it is not possible to set a limit. Therefore, only a directional target can be set.

Comparability with criteria and indicators in Commission Decision

This indicator covers the intention of indicator 2.2.1 in the Commission Decision (EC, 2010). However, data are only available for some species groups, and no monitoring specifically targets this subject.

Indicator: Impacts of non-indigenous species

The type of impact of non-indigenous species on other species, on habitats or on ecosystems depends on the species and on the characteristics of the habitat or ecosystem. It is not possible to define a suitable set of indicators for these changes *a priori*.

3.2.3 Comparison of indicators and targets with current state

The table below gives an overview of the current indicator values, insofar they have already been established in available data and reports.

Table 3.4 Proposed indicators and targets, and current state

2. Non-indigenous species			
Criteria and indicators (EC, 2010)	**Proposed indicator**	**Proposed target**	**Assessment** **Current state**
Trends in abundance, temporal occurrence and spatial distribution in the wild of non-indigenous species, particularly invasive non indigenous species, notably in risk areas, in relation to the main vectors and pathways of spreading of such species (2.1.1)	Number of non-indigenous species Abundance of non-indigenous species	No increase No increase	*Requires further data analysis* *Requires further data analysis*
Ratio between invasive non-indigenous species and native species in some well studied taxonomic groups (e.g. fish, macroalgae, molluscs) that may	Ratio of non-indigenous:native species in a selection of groups (phytoplankton, benthos, fish)	No increase	*Requires further data analysis*

provide a measure of change in species composition (e.g. further to the displacement of native species) (2.2.1)			
Impacts of non-indigenous invasive species at the level of species, habitats and ecosystem, where feasible (2.2.2)	To be determined dependent on species, habitat and ecosystem characteristics	No impact	-

3.3 Commercially exploited fish and shellfish

3.3.1 Level of pressure of the fishing activity

Criteria and indicators (EC, 2010)	Proposed indicator*	Proposed target
Fishing mortality (F) (3.1.1)	Fishing mortality of commercially exploited fish**	Below F_{MSY} (ICES advice for values of F_{MSY})
Secondary indicator: Ratio between catch and biomass index (hereinafter catch/biomass ratio) (3.1.2)	Catch/biomass ratio of commercially exploited fish**	No increase

*See Appendix B for more detailed information on the indicators

** Some indicators and targets for commercially exploited fishes and shellfish are currently under discussion by ICES. Forthcoming ICES recommendations should be considered.

Indicator: Fishing mortality

Rationale behind the indicator

The indicator describes the level of pressure of the fishing activity on commercially exploited fish species. Stocks should be exploited sustainably in order to be "within safe biological limits". F is an indicator of exploitation rate and is the outcome of an analytical stock assessment. Values for F for all commercially important exploited fish stocks are available from ICES. F is estimated from appropriate analytical assessments based on the analysis of catch in terms of age or length, and ancillary information.

The primary indicator for the level of pressure of the fishing activity is fishing mortality (F). If analytical assessments yielding values for F are not available the secondary indicator of the level of pressure of the fishing activity is the ratio between catch and biomass index ("catch/biomass ratio").

Rationale behind the target

$F < F_{MSY}$: This target is similar to the ICES recommendation. All international conventions stipulate that fisheries management should maintain or restore stocks to levels where they can produce Maximum Sustainable Yield (F_{MSY}). In order to achieve this, the value of the primary indicator F should be equal to or lower than F_{MSY}. It is important to bear in mind that F_{MSY} is set in relation to the assumed exploitation pattern. If the fishery turns to more (or less) selective fishing practices, F_{MSY} needs to be adapted. Major changes in the fishing fleet may also change the exploitation pattern, and hence F_{MSY} . ICES provides F and F_{MSY} values for most North Sea commercially exploited fish stocks. However, the target points F_{MSY} have not been formally agreed by ICES and are therefore provisional at the moment.

For the secondary indicator, the catch/biomass ratio, abundance and/or biomass can be obtained from any consistent catch per unit effort (CPUE) series, preferably based on surveys, as this increases consistency. The catch data should also be based on a consistent

CPUE series from a fishery that can be expected to deliver a representative time-series. No reference point has been set for this indicator. Therefore, until such reference points are identified and agreed upon, the only remaining scientific target is the absence of a degradation gradient in the catch/biomass ratio (= increase in ratio).

Comparability with criteria and indicators in Commission Decision

This indicator covers the intention of criterion 3.1 in the Commission Decision (EC, 2010).

3.3.2 Reproductive capacity of the stock

Criteria and indicators (EC, 2010)	Proposed indicator*	Proposed target
Spawning Stock Biomass (SSB) (3.2.1)	SSB of commercially exploited fish**	Below SSB_{PA} (ICES advice for values of SSB_{PA})
Secondary indicator: Biomass indices (3.2.2)	Log-transformed abundance of commercially exploited fish**	No decline

*See Appendix B for more detailed information on the indicators

** Some indicators and targets for commercially exploited fishes and shellfish are currently under discussion by ICES. Forthcoming ICES recommendations should be considered.

Indicator: Spawning stock biomass

Rationale behind the indicator

The primary indicator for the reproductive capacity of the stock is Spawning Stock Biomass (SSB). Stocks should have full reproductive capacity in order for them to be “within safe biological limits”. SSB is an indicator of reproductive capacity and is the outcome of an analytical stock assessment. Values for SSB for all commercially important exploited fish stocks are available from ICES. SSB is estimated from appropriate analytical assessments based on the analysis of catch in terms of age or length and ancillary information.

If analytical assessments yielding values for SSB are not available the secondary indicator of reproductive capacity of the stock is biomass indices. This can be used if such indices can be obtained for the fraction of the population that is sexually mature. In such cases, these indices need to be used when scientific judgment is able to determine, through detailed analysis of the historical trends of the indicator combined with other information on the historical performance of the fishery, that there is high probability that the stock will be able to replenish itself under the prevailing exploitation conditions. Combined with the indicator describing the age/size distribution (criterion 3.3) biomass indices are considered sufficiently representative of the reproductive capacity attribute. The log-transformed abundance can be used, as it is thought to provide a better signal to noise ratio. This indicator can be used for stocks for which no analytical stock assessment is available. However, in data-poor stocks where fish are found in low abundance, the signal in the biomass indices becomes noisy.

Rationale behind the target

According to the European Commission Decision the reference value SSBmsy, i.e. the SSB that would achieve MSY under a fishing mortality equal to Fmsy, reflects full reproductive capacity. Any observed value that is equal to or greater than SSBmsy is considered to meet the criterion. However, as it is not biologically possible for all stocks to reach this reference point at the same time, it is not clear whether SSBmsy is a useful reference point. An acceptable alternative reference point would be that SSB of all stocks were above SSBpa. ICES uses SSBpa as a reference point. ICES provides SSB and SSBpa values for most North Sea commercially exploited fish stocks.

The secondary indicator will be used for most non-commercial species and some less-studied commercial species. A “no decline” target is a safe position at this moment, since we have insufficient knowledge of most of these species to set a more appropriate target. Further studies are needed.

Comparability with criteria and indicators in Commission Decision

This indicator covers the intention of indicator 3.2.1 in the Commission Decision (EC, 2010).

3.3.3 Population age and size distribution

Criteria and indicators (EC, 2010)	Proposed indicator*	Proposed target
Proportion of fish larger than the mean size of first sexual maturation (3.3.1)	Proportion of fish larger than the mean size of first sexual maturation**	No decrease
Mean maximum length across all species found in research vessel surveys (3.3.2)	Not applicable**	
95% percentile of the fish length distribution observed in research vessel surveys (3.3.3)	95% percentile of the fish length distribution observed in research vessel surveys**	No decrease
Secondary indicator: Size at first sexual maturation, which may reflect the extent of undesirable genetic effects of exploitation (3.3.4)	Size at first sexual maturation**	No decrease

*See Appendix B for more detailed information on the indicators

** Some indicators and targets for commercially exploited fishes and shellfish are currently under discussion by ICES. Forthcoming ICES recommendations should be considered.

Indicator: Population age and size distribution

Rationale behind the indicators

Stocks should "exhibit a population age and size distribution that is indicative of a healthy stock". The general consensus is that the health of the stock increases as the age and size distribution consists of more and older fish. Of the three primary indicators the 95% percentile of the population length distribution probably captures this best. This indicator provides a summary of size distribution with an emphasis on the larger fish. It is expected to be sensitive to fishing and other human activities.

ICES considers the indicator "Mean maximum length across all species found in research vessel surveys (3.3.2)" inappropriate, and will advise against using it.

When information for the primary indicators is not available the secondary indicator may be used. This secondary indicator, size at first maturation, may reflect the extent of undesirable genetic effects of exploitation.

Rationale behind the target

No reference points have yet been set to distinguish a "healthy" stock from an "unhealthy" stock in terms of age and size distribution, as there is currently not enough scientific evidence or knowledge to determine such points. As a result, it is only possible to detect that a stock is "unhealthy" by monitoring occurrence of a degradation gradient in the indicators. In other words, the only remaining scientific criterion for GES is the absence of a degradation gradient in the indicators. The question is whether the indicator should be applied to information from the commercial species only, or from the entire fish community. Furthermore, this is not a standard ICES output. It is possible to reproduce numbers from the surveys, but when certain species are low in abundance, the signal will become noisy.

Comparability with criteria and indicators in Commission Decision

This indicator partly covers the intention of indicator 3.3.1 in the Commission Decision (EC, 2010).

These criteria have not been applied or tested to pelagic fish and the results of acoustic surveys. It is therefore unclear at present whether these indicators are suitable for pelagic fish (herring, mackerel, horse mackerel and sprat).

3.3.4 Comparison of indicators and targets with current state

The table below gives an overview of the current indicator values, insofar they have already been established in available data and reports.

Table 3.5 Proposed indicators and targets, and current state

3. Commercially exploited fish and shellfish			
Criteria and indicators (EC, 2010)	**Proposed indicator**	**Proposed target**	**Assessment** **Current state**
Fishing mortality (F) (3.1.1)	Fishing mortality of commercially exploited fish	Below F_{MSY} (ICES recommendation for F_{MSY} values)	*Requires further data analysis for proper assessment*
Secondary indicator: Ratio between catch and biomass index (hereinafter catch/biomass ratio) (3.1.2)	Catch/biomass ratio of commercially exploited fish	No increase	*Requires further data analysis for proper assessment*
Spawning Stock Biomass (SSB) (3.2.1)	SSB of commercially exploited fish	Below SSB_{PA} (ICES recommendation for SSB_{PA} values)	*Requires further data analysis for proper assessment*
Secondary indicator: Biomass indices (3.2.2)	Log-transformed abundance of commercially exploited fish	No decline	*Requires further data analysis for proper assessment*
Proportion of fish larger than the mean size of first sexual maturation (3.3.1)	Proportion of fish larger than the mean size at first sexual maturation	No decrease	*Requires further data analysis for proper assessment*
Mean maximum length across all species found in research vessel surveys (3.3.2)	Not applicable		*Requires further data analysis for proper assessment*
95% percentile of the fish length distribution observed in research vessel surveys (3.3.3)	95% percentile of the fish length distribution observed in research vessel surveys	No decrease	*Requires further data analysis for proper assessment*
Secondary indicator: Size at first sexual maturation, which may reflect the extent of undesirable genetic effects of exploitation (3.3.4)	Size at first sexual maturation	No decrease	*Requires further data analysis for proper assessment*

3.4 Food webs

3.4.1 Productivity (production per unit biomass) of key species or trophic groups

Criteria and indicators (EC, 2010)	Proposed indicator*	Proposed target
Performance of key predator species using their production per unit biomass (productivity) (4.1.1)	OSPAR EcoQO on healthy seal populations	No decline of >10% in grey seal pup populations or harbour seal populations over a five-year running mean
	Abundance of prey species of grey seal and harbour seal	No decrease

*See Appendix B for more detailed information on the indicators

Indicator: Performance of key predator species

Rationale behind the indicators

Top predators such as seals and porpoises are charismatic indicator species. Since OSPAR has developed an EcoQO for seal pup production (grey seal) and seal population (harbour seals), it would be pragmatic to adopt these indicators for the MSFD. Performance of key predator species is interpreted here as production or population size, but this should be considered relative to other production levels in the food web. Performance of key predator species is therefore combined with information on key prey species.

Data on the abundance of prey fish species can be obtained from regular fish monitoring programmes. The focus should be on species that are the main prey items of seals. The diet of grey seals consists of a variety of fish species. Examples include sand eel *Ammodytes* sp., several flatfish species (sole *Solea solea*, dab *Limanda limanda*, flounder *Platichthys flesus* and plaice *Pleuronectus platessa*), cod *Gadus morhua* and whiting *Merlangius merlangus*. The diet of harbour seals consists of a variety of fish species. Examples include flatfish species (sole, flounder and plaice), cod, whiting, sand eel *Ammodytes* sp. and herring *Clupea harengus*.

Rationale behind the targets

The target levels for both grey seal pup production and harbour seal population are identical to the targets used by OSPAR. Since no quantitative relationships have been established between prey species abundance and grey seal pup production or harbour seal population, only directional targets can be set at present.

Comparability with criteria and indicators in Commission Decision

This indicator covers only partly the indicator 4.1.1 in the Commission Decision (EC, 2010). At present, it covers two top predator species and their prey items. This should be supplemented

with other key predator species, and a more integrated approach looking at predator-prey relationships.

3.4.2 Proportion of selected species at the top of food webs

Criteria and indicators (EC, 2010)	Proposed indicator*	Proposed target
Large fish (by weight) (4.2.1)	OSPAR EcoQO proportion of large fish in the fish community	More than 30% of fish should be longer than 40 cm in the IBTS survey Increase in average size (by weight) of pelagic fish

*See Appendix B for more detailed information on the indicators

Indicator: Proportion of large fish

Rationale behind the indicator

The criterion in the Commission Decision focuses on the proportion of selected species at the top of the food web, but the indicator only focuses on fish. This is currently regularly monitored for demersal fish species in OSPAR countries (EcoQO proportion of large fish). The indicator could be extended to include the proportion of large fish in populations of pelagic species. This should be considered in the next phase of development of goals and indicators for the MSFD. Data are available from regular monitoring programmes.

Rationale behind the target

The target level for the proportion of large demersal fish is identical to the target used by OSPAR. Since no quantitative targets have been developed for pelagic fish species, only directional targets can be set at present.

Comparability with criteria and indicators in Commission Decision

This indicator covers indicator 4.2.1 in the Commission Decision (EC, 2010), although further development of the targets for pelagic fish is needed. This should be considered in a next phase of development of goals and indicators for the MSFD.

3.4.3 Abundance/distribution of key trophic groups/species

Criteria and indicators (EC, 2010)	Proposed indicator*	Proposed target
Abundance trends of functionally important selected groups/species (4.3.1)	OSPAR EcoQO on by-catch levels of harbour porpoise	Below 1% of best population estimate

**See Appendix B for more detailed information on the indicators*

Indicator: By-catch levels of harbour porpoise

Rationale behind the indicator

The functionally important species referred to in the Commission Decision (EC, 2010) include species that are targeted by human activities or that are indirectly affected by them (in particular by-catch and discards). Since there is an international indicator for by-catch of harbour porpoises (OSPAR, ASCOBANS. North Sea Conference), it can be adopted for the MSFD as a pragmatic first step. However, the monitoring of by-catch and population estimates of harbour porpoises in the North Sea are currently inadequate.

Rationale behind the target

In its resolutions on the incidental take of small cetaceans, ASCOBANS defines limiting levels of anthropogenic removal as no more than 1.7% of local populations, provided they are healthy (population size at least 80% of carrying capacity) (ASCOBANS, 2000, 2006). The agreement underlines the intermediate precautionary objective to reduce by-catch levels to less than 1% of the best available population estimate and has the general aim of minimising by-catch (i.e. ultimately reducing it to zero). At the 5th meeting of parties to ASCOBANS (2006) a resolution was adopted to "reiterate the recommendations of Resolution 3 of MOP 3 particularly that total anthropogenic removal is reduced by the Parties to below the threshold of 'unacceptable interactions' with the precautionary objective to reduce by-catch to less than 1% of the best available abundance estimate and the general aim to minimise by-catch (i.e. to ultimately reduce to zero)." The 1.7% interim objective was not mentioned.

The OSPAR EcoQO on by-catch of harbour porpoises is based on the interim ASCOBANS and North Sea Conference agreements requiring that annual by-catches should be reduced to below 1.7% of the best population estimate (OSPAR, 2005; Heslenfeld & Enserink, 2008). The more stringent ASCOBANS target of an annual by-catch level for harbour porpoises of less than 1% of the best available abundance estimate is proposed as target for the MSFD indicator, in line with the most recent ASCOBANS and North Sea Conference agreements.

Comparability with criteria and indicators in Commission Decision

This indicator only covers a small part of indicator 4.3.1 in the Commission Decision (EC, 2010). It focuses on the abundance and distribution of functionally important species or trophic groups. A wide variety of indicators could be included here, ranging from species or group specific indicators to a more integrated approach. However, indicators at this level require further study before they can be applied.

3.4.4 Comparison of indicators and targets with current state

The table below gives an overview of the current indicator values, insofar they have already been established in available data and reports.

Table 3.6 Proposed indicators and targets, and current state

4. Food webs				
Criteria and indicators (EC, 2010)	**Proposed indicator**	**Proposed target**	**Assessment**	
			Current state	**Period**
Performance of key predator species using their production per unit biomass (productivity) (4.1.1)	OSPAR EcoQO on healthy seal populations	No decline >10% in grey seal pup populations or harbour seal populations over a five-year running mean	Target met	2002-2006
	Abundance of prey species of grey seal and harbour seal	No decrease	R*equires further data analysis for proper assessment*	
Large fish (by weight) (4.2.1)	OSPAR EcoQO proportion of large fish in the fish community	More than 30% of fish should be longer than 40 cm in the IBTS survey	Target not met. Last assessment result: 22%	2008
Abundance trends of functionally important selected groups/species (4.3.1)	OSPAR EcoQO on by-catch levels of harbour porpoise	Below 1.7% of best population estimate	*No data available*	

3.5 Human-induced eutrophication

3.5.1 Nutrient levels

Criteria and indicators (EC, 2010)	Proposed indicator*	Proposed target
Nutrients concentration in the water column (5.1.1)	Winter means of dissolved inorganic nitrogen	DIN (µM) = 184,7-5,057*salinity for salinities<30 33 for salinities ≥30
Nutrient ratios (silica, nitrogen and phosphorus), where appropriate (5.1.2)	N:P ratio (based on winter means)	Between 10-37.5

*See Appendix B for more detailed information on the indicators

Indicator: Nutrient concentrations

Rationale behind the indicator

The average concentration of DIN (NH_4^++NO_2^-+NO_3^-) in the winter period December-February in relation to a salinity related target level is used for this indicator. Alternatively, mean concentrations of total nitrogen during the phytoplankton growing season March-September could be used. River discharges are the major source of elevated nutrient concentrations. Nutrient concentrations in coastal waters are influenced by riverine nutrient loads. Levels of nutrients above the natural background level reflect the pressure caused by anthropogenic nutrient loads. Nutrient concentrations measured in a transect along a salinity gradient show a proportional response to changes in nutrient loadings, and are a suitable indicator of nutrient loads to the marine environment. Nitrogen concentrations are also used as an indicator in the WFD and in the OSPAR Comprehensive Procedure.

In the present situation, riverine phosphorus loads to the Dutch part of the North Sea have been reduced by more than 50% compared to the 1980s, and phosphorus is not causing eutrophication problems in the Dutch part of the North Sea. Levels of phosphorus are therefore not an indicator of eutrophication.

Rationale behind the targets

The target level for DIN concentrations is similar to the target used in the WFD for the boundary between good and moderate status. This choice is based on the fact that within the WFD, this boundary is accepted as the target, and the arguments in favour of it are consistent with the reasoning in the MSFD: both strive for a generic nutrient level that reflects an acceptable impact of human input (50% above background level). The WFD applies to the near-coastal strip of 1 nautical mile, which is relatively strongly influenced by riverine loads of N. The WFD target value for coastal waters is therefore assumed to be appropriate for the coastal waters in the southern North Sea. Offshore areas that are less influenced by river discharges, might need an adapted (read: lower) target level.

Comparability with criteria and indicators in Commission Decision

This indicator covers the intention of indicator 5.1.1 in the Commission Decision (EC, 2010). Since only nitrogen is considered relevant for the eutrophication status of Dutch marine waters, other nutrients (phosphorus, silica) was not included.

Indicator: Nutrient (N:P) ratios

Rationale behind the indicator

A ratio for C:N:P of 106:16:1 is suggested as a general stoichiometric ratio for marine phytoplankton. In addition, a common ratio for Si:N of 1 is assumed to be the typical ratio for diatoms. Strong deviations of observed ratios from the values of N:P=16 and N:Si=1 can be considered an indicator of anthropogenic nutrient enrichment. In addition, deviations in this ratio may indicate growth conditions favouring shifts in phytoplankton composition.

N:P ratios and N:Si ratios show elevated levels in Dutch coastal waters as a consequence of the enrichment with nitrogen. The ratios can be used as indicators for eutrophication in Dutch coastal waters, but provide no additional information if the nitrogen levels are already used as an indicator for nutrient enrichment. N:P ratios are also used as an indicator in the OSPAR Comprehensive Procedure.

Rationale behind the target

The target level for N:P ratios is derived from the OSPAR limit levels for DIN and dissolved inorganic phosphorus.

Comparability with criteria and indicators in Commission Decision

This indicator covers the intention of indicator 5.1.2 in the Commission Decision (EC, 2010).

3.5.2 Direct effects of nutrient enrichment

Criteria and indicators (EC, 2010)	Proposed indicator*	Proposed target
Chlorophyll concentration in the water column (5.2.1)	90-percentile of growing season concentration**	Chl-a (µg/l) = 21 for salinities<30.4 144-4.045*salinity for salinities ≥30.4 and <34.5 4.5 for salinities≥34.5
Water transparency related to increase in suspended algae, where relevant (5.2.2)	Water transparency: Not applicable	
Abundance of opportunistic macroalgae (5.2.3)	Opportunistic macroalgae: Not applicable	
Species shift in floristic composition such as diatom to flagellate ratio, benthic to pelagic shifts, as well as bloom events of nuisance/toxic algal blooms (e.g. cyanobacteria) caused by human activities (5.2.4)	Frequency of blooms of *Phaeocystis globosa*	≤2 months per year

*See Appendix B for more detailed information on the indicators

*A six period is applied to account for interannual variability

Indicator: Chlorophyll concentration

Rationale behind the indicator

The objective of the indicator is to describe changes in phytoplankton biomass as one of the direct effects of human-induced eutrophication. Elevated concentrations of chlorophyll-a (compared to a reference level) are considered indicative of eutrophication. This indicator is similar to the submetric used for phytoplankton in the WFD for the coastal water bodies, and comparable to the metric used as part of the OSPAR Comprehensive Procedure (COMPP).

Rationale behind the target

The targets defined under the WFD apply to two different water body types: euhaline waters (Zeeland coast, Wadden Sea coast: average salinity 32.5) and polyhaline waters (Delta coast, Holland coast, Ems-Dollard coast: average salinity 30.4). OSPAR uses a target of 15 µg/l for coastal waters (up to 40 km offshore) and 4.5 µg/l for offshore waters. Consequently, there are large differences in targets between different areas in the North Sea, while

observations show more gradual changes in concentrations along a transect from coast to offshore.

Comparability with criteria and indicators in Commission Decision

The *Phaeocystis* indicator partly covers indicator 5.2.4 in the Commission Decision (EC, 2010). Other aspects, such as the diatom to flagellate ratio, could also be useful as indicators. However, there are no indications of changes in this ratio in Dutch marine waters as a consequence of eutrophication, and its applicability as an indicator is uncertain.

Indicator: Water transparency

In Dutch coastal waters natural levels of suspended particulate matter are relatively high. Light extinction in Dutch coastal waters is mainly determined by suspended particulate matter concentrations (Suijlen & Duin, 2001). Water transparency mainly reflects natural variations in SPM. Consequently, water transparency is not applicable as a sensitive indicator for eutrophication in Dutch marine waters.

Indicator: Opportunistic macroalgae

Eutrophication may result in increased biomass of opportunistic macroalgae. This occurs mainly in shallow environments. In Dutch coastal waters, however, hydrodynamic conditions and natural levels of suspended particulate matter are not suitable for the growth of macroalgae (Van der Molen & Pot, 2007). This indicator is not applicable therefore in Dutch marine waters.

Indicator: *Phaeocystis* blooms

Rationale behind the indicator

The frequency of blooms of the nuisance alga *Phaeocystis globosa* during the growing season March-September is used as indicator for species shifts in the phytoplankton. The objective of the indicator is to describe shifts in phytoplankton composition as one of the direct effects of human-induced eutrophication. There is a link between nutrient loads and the occurrence of dense blooms of *Phaeocystis*. *Phaeocystis* blooms are also used as an indicator of the eutrophication status of Dutch coastal waters in the OSPAR Comprehensive Procedure and in the WFD.

Rationale behind the target

The target is defined as a limit level that must not be exceeded. The target defined for coastal waters under the WFD (no *Phaeocystis* blooms with more than 10^6 cells/l during more than two months) can be applied to the entire Dutch part of the North Sea. Generally, *Phaeocystis* blooms are not observed in offshore waters.

Comparability with criteria and indicators in Commission Decision

The *Phaeocystis* indicator partly covers indicator 5.2.4 in the Commission Decision (EC, 2010). Other aspects, such as the diatom to flagellate ratio, could also be useful as indicators. However, there are no indications of changes in this ratio in Dutch marine waters as a consequence of eutrophication, and its applicability as an indicator is uncertain.

3.5.3 Indirect effects of nutrient enrichment

Criteria and indicators (EC, 2010)	Proposed indicator*	Proposed target
Abundance of perennial seaweeds and seagrasses (e.g. fucoids, eelgrass and Neptune grass) adversely impacted by decrease in water transparency (5.3.1)	Seaweeds and seagrasses: Not applicable	
Dissolved oxygen, i.e. changes due to increased organic matter decomposition and size of the area concerned (5.3.2)	Annual minimum concentration of oxygen	>= 5 mg/l

*See Appendix B for more detailed information on the indicators

Indicator: Seaweeds and seagrasses

Eutrophication may result in increased biomass of phytoplankton and reduced light penetration in the water column, resulting in adverse growing conditions for sessile marine plants like perennial seaweeds and seagrasses. This occurs mainly in shallow environments with low turbidity. In Dutch coastal waters, however, hydrodynamic conditions and natural levels of suspended particulate matter are not suitable for the growth of perennial seaweeds and seagrasses (Van der Molen & Pot, 2007). Therefore, this indicator is not applicable in Dutch marine waters.

Indicator: Dissolved oxygen

Rationale behind the indicator

Oxygen deficiency, in particular in waters near the bottom (below the pycnocline), can result from the sinking and decomposition of the excess organic matter produced as a result of eutrophication. Oxygen deficiency may occur as a consequence of locally produced organic matter, but can also be caused by organic matter deposition following advective transport. Hypoxia often requires specific hydrodynamic conditions, like sustained stratification. Hypoxia leads to mortality of marine life. Oxygen concentrations in the well-mixed areas of the Dutch

part of the North Sea (coastal waters and offshore Southern Bight) never fall below 6 mg/l. In stratified parts of the North Sea (Oyster Grounds), oxygen concentrations have been known to fall well below 6 mg/l in summer (Prins et al., 2011a). Low oxygen levels at the Oyster Grounds indicate that this area has the potential to develop hypoxia. This indicator is also part of the OSPAR COMPP, and oxygen is a supporting physico-chemical element in the WFD.

Rationale behind the target

The target value for dissolved oxygen concentrations is also used in the OSPAR COMPP and in the WFD.

Comparability with criteria and indicators in Commission Decision

This indicator entirely covers indicator 5.3.2 in the Commission Decision (EC, 2010).

3.5.4 Comparison of indicators and targets with current state

The table below gives an overview of the current indicator values, insofar they have already been established in available data and reports.

Table 3.7 Proposed indicators and targets, and current state

5. Human-induced eutrophication				
Criteria and indicators (EC, 2010)	**Proposed indicator**	**Proposed target**	**Assessment**	
			Current state	**Period***
Nutrients concentration in the water column (5.1.1)	Winter means of dissolved inorganic nitrogen	DIN (µM) = 184,7-5,057*salinity for salinities<30 33 for salinities ≥30	Target not met in coastal waters (10 monitoring stations up to 50 km offshore) in 80% of observations Target met in offshore waters (7 stations) in 90% of observations	2002-2007
Nutrient ratios (silica, nitrogen and phosphorus), where appropriate (5.1.2)	N:P ratio (based on winter means)	Between 10 and 37.5	Target met in coastal waters in 70% of observations	2002-2007
Chlorophyll concentration in the water column (5.2.1)	90th percentile of growing season concentration	Chl-a (µg/l) = 21 for salinities <30.4 144-4.045*salinity for salinities ≥30.4 and <34.5 4.5 for salinities ≥34.5	Target not met in coastal waters in 50% of observations Target met in offshore waters in 70% of observations	2002-2007
Water transparency related to increase in suspended algae, where relevant (5.2.2)	Not applicable			
Abundance of opportunistic macroalgae (5.2.3)	Not applicable			
Species shift in floristic composition such as	Frequency of blooms of	≤2 months per year	Target met in coastal waters in 70% of	2002-2007

diatom to flagellate ratio, benthic to pelagic shifts, as well as bloom events of nuisance/toxic algal blooms (e.g. cyanobacteria) caused by human activities (5.2.4)	*Phaeocystis globosa*		observations Target met in offshore waters in 95% of observations	
Abundance of perennial seaweeds and seagrasses (e.g. fucoids, eelgrass and Neptune grass) adversely impacted by decrease in water transparency (5.3.1)	Not applicable			
Dissolved oxygen, i.e. changes due to increased organic matter decomposition and size of the area concerned (5.3.2)	Annual minimum concentration of oxygen	>= 5 mg/l	Target not met at Oyster Grounds in 2003	2002-2007

3.6 Seafloor integrity

3.6.1 Physical damage, having regard to substrate characteristics

Criteria and indicators (EC, 2010)	Proposed indicator*	Proposed target
Type, abundance, biomass and areal extent of relevant biogenic substrate (6.1.1)	Abundance and areal extent of biogenic substrate	Increase in abundance and areal extent
Extent of the seabed significantly affected by human activities for the different substrate types (6.1.2)	Proportion of surface area of each habitat (EUNIS level 3) affected by human activities in the last year	Decrease

*See Appendix B for more detailed information on the indicators

Indicator: Biogenic substrate

Rationale behind the indicator

Biogenic reefs are considered important in conservation terms due to their relative rarity and their specific habitat-forming properties. Biogenic substrate is generally considered to be sensitive to physical disturbance. However, sensitivity differs between species, and the relationship between abundance, areal extent and pressures is not well quantified. Additional discussion is needed as to what exactly constitutes a biogenic reef. Several species can be considered, and a non-limitative list of species should be used. Examples of species that form biogenic substrate are the tube-dwelling polychaetes *Lanice conchilega* and *Sabellaria spinulosa,* and the bivalves *Modiolus modiolus* and *Ensis directus*.

Rationale behind the target

An increase in the abundance and areal extent of biogenic substrate is proposed as target. The assumption is that activities like extensive bottom trawling and sand extraction have had a significant effect on sensitive biogenic substrates in general. As a quantitative relationship with human pressures has not been firmly established, only a directional target can be defined.

Comparability with criteria and indicators in Commission Decision

The indicator on biogenic substrate entirely covers indicator 6.1.1 in the Commission Decision (EC, 2010).

Indicator: Proportion of benthic habitats affected by human activities

Rationale behind the indicator

The surface area of the seabed affected by activities like beam trawling, sand extraction or coastal nourishments, construction activities, etc. can be quantified, and related to the total surface area of various benthic habitats. As the habitats may differ in type of activities and type of impacts, it is necessary to make a distinction between the habitats. It is proposed that the EUNIS level 3 habitats be used for the definition of the habitats.

The indicator is a proxy for the disturbance of the seabed caused by a variety of activities that have different impacts depending on the nature of the activity. Since knowledge of the quantitative impacts of the various activities on benthic habitats and communities is limited, it is proposed that the indicator be limited to a relatively easily quantifiable metric. Data on the occurrence of several types of fisheries are collected for the Data Collection Framework (EC, 2008b); data on other types of activities like extraction are available from licensing records.

Rationale behind the target

An decrease in the proportion of the habitats disturbed by human activities can be considered to be indicative of a reduced pressure. As no quantitative relationship between the areal extent of disturbance and the quality of benthic habitats and communities has been firmly established, only a directional target (decrease in proportion) can be defined at present.

Comparability with criteria and indicators in Commission Decision

The indicator proposed for 6.1.2 in the Commission Decision links reasonably well to the intention of he Commission Decision. The Commission Decision mentions the extent of the seabed “significantly affected” which is not easy to define. It also refers to “substrate type”, which seems an ecologically less relevant unit than habitat types.

3.6.2 Condition of benthic community

Criteria and indicators (EC, 2010)	Proposed indicator*	Proposed target
Presence of particularly sensitive and/or tolerant species (6.2.1)	Number/biomass of long-lived/vulnerable benthos species Proportion of long-lived/vulnerable species in benthic community	Increase in number/biomass Increase in proportion
Multi-metric indexes assessing benthic community condition and functionality, such as species diversity and richness, proportion of opportunistic to sensitive species (6.2.2)	BEQI Species richness Species evenness Hill's N_1 Hill's N_2	Values do not exceed the range typical for the monitoring site
Proportion of biomass or number of individuals in the macrobenthos above some specified length/size (6.2.3)	Length-frequency distribution of bivalves	No decrease
Parameters describing the characteristics (shape, slope and intercept) of the size spectrum of the benthic community (6.2.4)	Not applicable	

*See Appendix B for more detailed information on the indicators

Indicator: Number/biomass of long-lived/vulnerable species and proportion in the benthic community

Rationale behind the indicator

The abundance of sensitive species is an indicator of disturbance of the seafloor and the impacts of disturbance on the benthic community. Sensitive species, particularly bivalves with high longevity, are in decline, possibly as a consequence of physical disturbance. Several species can be considered sensitive to disturbance by bottom trawling, sand extraction, coastal nourishments, or construction activities. A non-limitative list of species should be used. As a starting point, the list used for biodiversity (Table 3.2) could be used. Other species to be considered are large molluscs like the red whelk *Neptunea antiqua*, the common whelk *Buccinum undatum*, and the horse mussel *Modiolus modiolus*. Data on the abundance of sensitive species can be obtained from the monitoring of benthic epifauna and infauna.

The choice of sensitive species rather than tolerant species is based on the fact that the abundance and presence of sensitive species seems to be better linked to pressures than

that of tolerant and opportunistic species. The latter group is always present in highly dynamic areas.

Rationale behind the target

As a quantitative relationship between physical disturbance and the abundance of sensitive species has not been firmly established, only a directional target can be defined at present.

Comparability with criteria and indicators in Commission Decision

The indicator covers indicators 6.2.1 the Commission Decision (EC, 2010). The length-frequency distribution of bivalve species partly addresses indicator 6.2.3 in the Commission Decision (EC, 2010). Sizes of benthic invertebrates, other than some bivalve species, are not monitored. The Commission Decision mentions the proportion above some specified length "in the macrobenthos". It is probably more meaningful to look at a selection of species instead of looking at the entire community.

Indicator: Multi-metric indexes

Rationale behind the indicator

Species indices, as applied to benthos for Biological diversity (§ 3.1.4) and the Benthic Ecosystem Quality Index (BEQI) index. The BEQI index is a composite of various submetrics describing the quality of the benthic community compared to a reference[2]. Species indices are commonly used to describe spatial and temporal changes in the benthic community. The BEQI index is used to describe the benthic community in the WFD. Both indices can be used to describe spatial differences and temporal changes in the benthic community. However, the relationship between human pressures and the values of the indicators is not well quantified, so it is uncertain to what extent changes in the indicators reflect the impact of human activities.

Data for the indicators are available from the benthos monitoring programme.

Rationale behind the target

As the quantitative relationships between pressures and indicator values are not well established, the target can only be defined as a range of natural variation, based on existing data from the MWTL programme. Deviations outside that range are not by definition an indication of adverse effects, but should prompt further research to determine the cause.

[2] *The BEQI has been developed in a WFD context. At the moment, the BEQI is being revised, and a BEQI-2 is almost ready.The BEQI-2 WFD metric for transitional and coastal waters consists of a benthic area assessment and a benthic quality assessment. The BEQI-2 consists of a combination of the indicators Species richness, Shannon index (log base 2) and the adapted AMBI. Once tested, this revised index should be considered for adoption under the MSFD.*

Comparability with criteria and indicators in Commission Decision

The indicator covers indicator 6.2.2 in the Commission Decision (EC, 2010).

Indicator: Length-frequency distribution of bivalve species

Rationale behind the indicator

Physical disturbance of the benthic community may result in increased mortality or reduced growth, and could shift a community towards smaller or younger individuals. For bivalves this can be detected as a change in the length-frequency distribution. It is probable that the strength of the response differs between bivalve species, depending on size and maximum age. It may therefore be more useful to select a number of species, based on maximum size and longevity. The relationship between the indicator and physical pressures is not well established yet. Data on bivalve size distributions can be obtained from benthos monitoring and shellfish surveys.

Rationale behind the target

As no quantitative relationship between pressures and the indicator values has been established, only a directional target can be defined at present.

Comparability with criteria and indicators in Commission Decision

The length-frequency distribution of bivalve species partly addresses indicator 6.2.3 in the Commission Decision (EC, 2010). Sizes of benthic invertebrates, other than some bivalve species, are not monitored. The Commission Decision mentions the proportion above some specified length “in the macrobenthos”. It is probably more meaningful to look at a selection of species instead of looking at the entire community.

Indicator: Size spectrum of the benthic community

The biomass size spectrum is assumed to reflect the productivity of the ecosystem and characteristics of the benthic community (Rice et al., 2010). However, the relationship between this indicator and pressures has not been established. Moreover, data on sizes of benthic fauna, except some bivalve species, are not collected in Dutch monitoring programmes. If this indicator is applied to bivalves alone, it becomes essentially the same as indicator 6.2.3. Therefore, it is proposed that indicator 6.2.4 is not used.

3.6.3 Comparison of indicators and targets with current state

The table below gives an overview of the current indicator values, insofar they have already been established in available data and reports.

Table 3.8 Proposed indicators and targets, and current state

6. Seafloor integrity			
Criteria and indicators (EC, 2010)	**Proposed indicator**	**Proposed target**	**Assessment** **Current state**
Type, abundance, biomass and areal extent of relevant biogenic substrate (6.1.1)	Abundance and areal extent of biogenic substrate	Increase in abundance and areal extent	*Requires further data analysis for proper assessment*
Extent of the seabed significantly affected by human activities for the different substrate types (6.1.2)	Proportion of surface area of each habitat (EUNIS level 3) affected by human activities in the last year	Decrease	*Requires further data analysis for proper assessment*
Presence of particularly sensitive and/or tolerant species (6.2.1)	Abundance of sensitive benthic species in relation to tolerant/opportunistic species	Relative increase of sensitive species (in relation to tolerant species)	*Requires further data analysis for proper assessment*
Multi-metric indexes assessing benthic community condition and functionality, such as species diversity and richness, proportion of opportunistic to sensitive species (6.2.2)	BEQI Species richness Species evenness Hill's N_1 Hill's N_2	Values do not exceed the range typical of the monitoring site *(also see Biological diversity)*	*Requires further data analysis for proper assessment*
Proportion of biomass or number of individuals in the macrobenthos above some specified length/size (6.2.3)	Length-frequency distribution of bivalves	No decrease	*Requires further data analysis for proper assessment*
Parameters describing the characteristics (shape, slope and intercept) of the size spectrum of the benthic community (6.2.4)	Not applicable		

3.7 Hydrographical conditions

3.7.1 Spatial characterisation and impact of permanent hydrographical changes

Criteria and indicators (EC, 2010)	Proposed indicator*	Proposed target
Extent of area affected by permanent alterations (7.1.1)	Total (cumulative) surface area that has permanently changed	*The impact of human activities that permanently change part of a marine area is only to some extent related to the surface area. It is therefore not feasible to set a meaningful target for this indicator*
Spatial extent of habitats affected by the permanent alteration (7.2.1)	Total (cumulative) surface area where permanent changes occur	*See above*
Changes in habitats, in particular the functions provided (e.g. spawning, breeding and feeding areas and migration routes of fish, birds and mammals), due to altered hydrographical conditions (7.2.2)	To be determined dependent on type of activity	

*See Appendix B for more detailed information on the indicators

Indicator: Total (cumulative) surface area that has permanently changed

Rationale behind the indicator

The total surface area can be considered a first proxy of the potential ecological impacts of a project.

Rationale behind the target

The impact of human activities that permanently change part of a marine area is related to only some extent to the surface area. It is not feasible to set a meaningful target for this indicator.

Comparability with criteria and indicators in Commission Decision

This indicator covers indicator 7.1.1 in the Commission Decision (EC, 2010).

Indicator: Total (cumulative) surface area where changes occur

Rationale behind the indicator

The total surface area can be considered a proxy of the potential ecological impacts of a project.

Rationale behind the target

The impact of permanently changed habitats is related to some extent only to the surface area and very much dependent on the local situation. It is not feasible to set a meaningful quantitative target for this indicator.

Comparability with criteria and indicators in Commission Decision

This indicator covers indicator 7.2.1 in the Commission Decision (EC, 2010).

Indicator: Changes in habitats, in particular the functions provided

The type of impact changes in hydrographical conditions have on habitats and habitat functions depends on the type of human activities involved. It is not possible to define a suitable set of indicators for these changes in advance. Indicators might range from changes in phytoplankton production or changes in benthic community composition to changes in fish recruitment or the breeding success of birds.

3.7.2 Comparison of indicators and targets with current state

The table below gives an overview of the current indicator values, insofar they have already been established in available data and reports.

Table 3.9 Proposed indicators and targets, and current state

7. Hydrographical conditions				
Criteria and indicators (EC, 2010)	**Proposed indicator**	**Proposed target**	**Assessment**	
			Current state	**Period**
Extent of area affected by permanent alterations (7.1.1)	Total (cumulative) surface area that has permanently changed	*The impact of human activities that permanently change part of a marine area is related to only some extent to the surface area. It is not therefore feasible to set a meaningful target for this indicator*	Maasvlakte 2: 20 km^2 Sand Engine: 1 km^2	2009-2011

Spatial extent of habitats affected by the permanent alteration (7.2.1)	Total (cumulative) surface area where permanent changes occur	*See above*	Research projects in progress	
Changes in habitats, in particular the functions provided (e.g. spawning, breeding and feeding areas and migration routes of fish, birds and mammals), due to altered hydrographical conditions (7.2.2)	To be determined dependent on type of activity			

3.8 Contaminants

3.8.1 Concentration of contaminants

Criteria and indicators (EC, 2010)	Proposed indicator*	Proposed target
Concentration of the contaminants mentioned above, measured in the relevant matrix (such as biota, sediment and water) in a way that ensures comparability with the assessments under Directive 2000/60/EC (8.1.1)	Concentrations of contaminants in water, sediment, suspended matter and/or biota	WFD-Environmental quality standards (EQS) for contaminants in water OSPAR-Environmental assessment criteria (EAC) for contaminants in sediment and biota

*See Appendix B for more detailed information on the indicators

Indicator: Concentrations of contaminants in water, sediment, suspended matter and/or biota

Rationale behind the indicator

The indicator focuses on measuring contaminants in various matrices (water, sediment, suspended matter and biota) to ensure detection of pollution.

Monitoring data on contaminants are available for polychlorinated biphenyls (PCB), polycyclic aromatic hydrocarbons (PAH), bromated flame retardants (BFR), chlorinated phenolic compounds, metals, alkylphenols, short-chained chlorinated paraffins, organotin compounds, polyfluoroalkyl substances (PFAS), pesticides and volatile organic compounds (VOC).

Rationale behind the target

The proposed environmental target levels are mainly EQSs (WFD) and EAC (OSPAR). The EQSs (WFD) are recommended as environmental target levels in water and the EAC (OSPAR) in sediment and biota. The EQSs are listed in the WFD and Directive 2008/105/EC, and the EAC are used by OSPAR/CEMP.

Comparability with criteria and indicators in Commission Decision

This indicator covers indicator 8.1.1 in the Commission Decision (EC, 2010).

3.8.2 Effects of contaminants

Criteria and indicators (EC, 2010)	Proposed indicator*	Proposed target
Levels of pollution effects on the ecosystem components concerned, having regard to the selected biological processes and taxonomic groups where a cause/effect relationship has been established and needs to be monitored (8.2.1)	OSPAR EcoQO on level of imposex in dogwhelks and other gastropods Various biological effects indicators	The average level of imposex should be consistent with exposure to TBT concentrations below the environmental assessment criterion OSPAR/ICES EAC's
Occurrence, origin (where possible), extent of significant acute pollution events (e.g. slicks from oil and oil products) and their impact on biota physically affected by this pollution (8.2.2)	OSPAR EcoQO on number of oiled guillemots	The average proportion of oiled common guillemots in all winter months (November to April) should be 10% or less of the total found dead or dying, over a period of at least 5 years

**See Appendix B for more detailed information on the indicators*

Indicator: Levels of pollution effects

Rationale behind the indicator

Biological indicators measure effects of contaminants at different levels, i.e. population/community, individual and sub-cellular health. OSPAR/ICES recommend a list of biological effects indicators to identify in the ecosystem components of integrated monitoring, and assessment of chemical and biological effects monitoring for contaminants (OSPAR, 2010, Lyons et al., 2011). Methods that relate directly to specific contaminants are exceptions rather than the rule.

- The OSPAR EcoQO on the level of imposex in dogwhelks and other gastropods describes the specific biological effects of TBT.
- Specific biological effects in bile metabolites of fish are an indicator of PAH.
- EROD is a sensitive indicator of contaminant uptake in fish, providing evidence of induction of enzyme activity by contaminants.
- ICES has developed a fish disease index (FDI), which includes an assessment of externally visible lesions and parasites, macroscopic liver neoplasms, and histopathological liver lesions, providing evidence of effects of contaminants. Fish disease data are collected under the JAMP/CEMP.
- It has been shown that dioxins and dioxin-like compounds cause adverse effects in a wide range of aquatic species, particularly those at high trophic levels. The most relevant indicator to detect exposure to dioxin and dioxin-like compounds in sediment is

the application of the dioxin receptor-based in vitro test (DR-Luc, also known as DR-CALUX® (Dioxin Response Chemical Activated LUciferase gene eXpression).

The biological effect methods can provide a surveillance indicator as they are suitable for a range of mechanisms of toxic action. The inclusion of CYP1A/EROD, PAH-bile metabolites, FDI in fish and TBT-induced imposex in gastropods as biological methods into OSPAR activities has provided insight into the usefulness of these methods.

Description of the target

The target for the OSPAR EcoQO on imposex is to reduce the level of imposex.

Background assessment levels (BAC) and environmental assessment criteria (EAC) have been developed by OSPAR/ICES for proposed biological effect measurements. Concentrations above the EAC are likely to give rise to unacceptable biological effects. Targets are the EAC. The EAC may be considered as being related to the EQSs applied to concentrations of contaminants in water.

Comparability with criteria and indicators in Commission Decision

This indicator covers indicator 8.2.1 in the Commission Decision (EC, 2010).

Indicator: Significant acute pollution events

Rationale behind the indicator

The OSPAR EcoQO on the proportion of oiled common guillemots among those found dead or dying on beaches is used as an indicator for the occurrence of oil pollution at sea.

Rationale behind the target

This target is similar to the OSPAR EcoQO.

Comparability with criteria and indicators in Commission Decision

This indicator covers indicator 8.2.2 in the Commission Decision (EC, 2010).

3.8.3 Comparison of indicators and targets with current state

The table below gives an overview of the current indicator values, insofar they have already been established in available data and reports.

Table 3.10 Proposed indicators and targets, and current state

8. Contaminants				
Criteria and indicators (EC, 2010)	**Proposed indicator**	**Proposed target**	**Assessment**	
			Current state	**Period**
Concentration of the contaminants mentioned above, measured in the relevant matrix (such as biota, sediment and water) in a way that ensures comparability with the assessments under Directive 2000/60/EC (8.1.1)	Concentrations of contaminants in water, sediment, suspended matter and/or biota	WFD-Ecological quality standards (EQS) for contaminants in water OSPAR-Environmental assessment criteria (EAC) for contaminants in sediment and biota	EQS not met for TBT but levels decreasing OSPAR-EAC not met in coastal waters for several metals (cadmium, lead, mercury), some PCB congeners and some PAHs (benzo[ghi]perylene, benz[a]anthracene, chrysene)	2006-2008 2003-2007
Levels of pollution effects on the ecosystem components concerned, having regard to the selected biological processes and taxonomic groups where a cause/effect relationship has been established and needs to be monitored (8.2.1)	OSPAR EcoQO on level of imposex in dogwhelks and other gastropods Various biological effects indicators	The average level of imposex should be consistent with exposure to TBT concentrations below the environmental assessment criterion OSPAR/ICES EAC	OSPAR EcoQO is not met *Requires further data analysis for assessment*	>2003
Occurrence, origin (where possible), extent of significant acute pollution events (e.g. slicks from oil and oil products) and their impact on biota physically affected by this pollution (8.2.2)	OSPAR EcoQO on number of oiled guillemots	The average proportion of oiled common guillemots in all winter months (November to April) should be 10% or less of the total found dead or dying, over a period of at least five years	Belgian border-Texel / Texel-Elbe: Adults: 40%/23% Juveniles:12%/28%, but decreasing	2006/2007

3.9 Contaminants in fish and seafood

3.9.1 Level, number and frequency of contaminants

Criteria and indicators (EC, 2010)	Proposed indicator*	Proposed target
Actual levels of contaminants that have been detected and number of contaminants which have exceeded maximum regulatory levels (9.1.1)	Levels of contaminants in fish and seafood	Regulatory levels from Commission Regulation (EC) No 1881/2006 and the "Warenwet"
Frequency of regulatory levels being exceeded (9.1.2)	Annual frequency of observations where levels are exceeded	Zero

*See Appendix B for more detailed information on the indicators

Indicator: Levels of contaminants in fish and seafood, in comparison to regulatory levels

Rationale behind the indicator

The indicator describes levels of contaminants in a selection of seafood, as part of current monitoring programmes. Levels of contaminants in fish and other seafood are influenced by emissions of contaminants.

Two Dutch monitoring programmes are currently operational. One is part of the OSPAR JAMP and determines levels of contaminants in flatfish (flounder) and mussels. The second programme is run by the Ministry of EL&I, focusing on food safety, and analyses levels of contaminants in fish and seafood, including products collected at fish auctions (not necessarily originating from the Dutch part of the North Sea). The chemical groups analysed are metals, organotin, PBDEs, PCBs, PAHs, dioxins, furans and dioxin-like PCBs.

Description of the target

Targets can be set as a limit level. Targets are the regulatory levels from Commission Regulation (EC) No 1881/2006 and the national "Commodities Act" (*Warenwet*).

Comparability with criteria and indicators in Commission Decision

This indicator covers indicator 9.1.1 in the Commission Decision (EC, 2010).

Indicator: Annual frequency of occasions when samples exceed regulatory levels

Rationale behind the indicator

Regulatory levels must not be exceeded. The frequency of violations of these levels is indicative of the impact of contaminant levels on food safety. The data can be obtained from the current monitoring programmes.

Description of the target

Regulatory levels for contaminants in fish and other seafood must not be exceeded. As the descriptor uses regulatory levels, limit values are strictly defined.

Comparability with criteria and indicators in Commission Decision

This indicator covers indicator 9.1.2 in the Commission Decision (EC, 2010).

3.9.2 Comparison of indicators and targets with current state

The table below gives an overview of the current indicator values, insofar they have already been established in available data and reports.

Table 3.11 Proposed indicators and targets, and current state

9. Contaminants in fish and seafood				
Criteria and indicators (EC, 2010)	**Proposed indicator**	**Proposed target**	**Assessment**	
			Current state	**Period**
Actual levels of contaminants that have been detected and number of contaminants which have exceeded maximum regulatory levels (9.1.1)	Levels of contaminants in fish and seafood	Regulatory levels from Commission Regulation (EC) No 1881/2006 and the Commodities Act	Target met	2004-2008
Frequency of regulatory levels being exceeded (9.1.2)	Annual frequency of observations where levels are exceeded	Zero	Target met	2004-2008

3.10 Litter

3.10.1 Characteristics of litter and impacts of litter on marine life

Criteria and indicators (EC, 2010)	Proposed indicator*	Proposed target
Trends in the amount of litter washed ashore and/or deposited on coastlines, including analysis of its composition, spatial distribution and, where possible, source (10.1.1)	The average amount of litter items washed ashore on reference beaches	Decrease
Trends in the amount of litter in the water column (including floating at the surface) and deposited on the sea-floor, including analysis of its composition, spatial distribution and, where possible, source (10.1.2)	OSPAR EcoQO on the level of litter (plastic particles) in fulmar stomachs	Less than 10% of fulmars with more than 0.1 g of plastic in their stomach, over a period of at least five years
Trends in the amount, distribution and, where possible, composition of micro-particles (in particular micro-plastics) (10.1.3)	Not applicable yet	
Trends in the amount and composition of litter ingested by marine animals (e.g. stomach analysis) (10.2.1)	OSPAR EcoQO on the level of litter (plastic particles) in fulmar stomachs	See above

*See Appendix B for more detailed information on the indicators

Indicator: The average number of litter items washed ashore on reference beaches

Rationale behind the indicator

The amount of litter that is found at a number of selected beaches, monitored in a standardised programme, can be used to follow the trend in the amounts of litter on the coast. Coastal litter surveys, depending on their frequency and the detail of methods, can reveal trends in quantities of litter, including changes in sources. This may be considered a proxy for the amount of litter present in the marine environment.

Current beach litter monitoring programmes have methodological problems, however. Until these are properly addressed, it is hard to establish the sensitivity and robustness of the indicator.

Data are available from the OSPAR Beach Litter Monitoring programme, but methodological problems need to be solved. The protocol needs to be adapted to prevent *e.g.* the cleaning of beaches right before a litter survey, for example.

Rationale behind the target

As no quantitative relationship between pressures, the indicator value and environmental impacts has been firmly established, only a directional target can be defined.

Comparability with criteria and indicators in Commission Decision

This indicator covers indicator 10.1.1 in the Commission Decision (EC, 2010).

Indicator: OSPAR EcoQO on plastic particles in seabird stomachs

Rationale behind the indicator

This indicator is a well-established and robust marine litter indicator. The amount of plastics ingested by beached fulmars have developed into a North Sea-wide standard for evaluating temporal trends and regional differences.

The indicator is used as a proxy for the amount of plastic particles floating on the water, reflected in the proportion of northern fulmar with more than 0.1 g of plastic particles in their stomach. The monitoring of the stomach contents of fulmars is an operational (OSPAR) and effective 'surface litter' monitoring instrument, as this bird species is a surface feeder.

No monitoring occurs for other types of litter (in the water column, on the seafloor).

Rationale behind the target

This target is similar to the OSPAR EcoQO.

Comparability with criteria and indicators in Commission Decision

This indicator only partly covers indicator 10.1.2 in the Commission Decision (EC, 2010), as it only addresses floating litter.

This indicator partly covers indicator 10.2.2 in the Commission Decision (EC, 2010), as it only addresses plastics ingested by the northern fulmar.

Indicator: Trends in the amount, distribution and, where possible, composition of micro-particles

There is considerable concern about microplastics due to their slow rate of degradation and the potential chemical and physical hazard to marine food webs. It is likely that items of debris exist into the nanoparticle scale.

Monitoring techniques are currently limited by our ability to collect and identify very small particles. A proper standardised methodology still needs to be developed, but this may be even more true of the sampling strategy.

At the moment, it is not possible to define an indicator and targets, due to a lack of knowledge.

3.10.2 Comparison of indicators and targets with current state

The table below gives an overview of the current indicator values, insofar they have already been established in available data and reports.

Table 3.12 Proposed indicators and targets, and current state

10. Litter				
Criteria and indicators (EC, 2010)	**Proposed indicator**	**Proposed target**	**Assessment**	
			Current state	**Period**
Trends in the amount of litter washed ashore and/or deposited on coastlines, including analysis of its composition, spatial distribution and, where possible, source (10.1.1)	The average number of litter items washed ashore on reference beaches	Decrease	Four reference beaches: 100 m transects: 200-600 (2009: 321) 1 km transects: 60-120 (2009: 59) *Trend not assessed*	2002-2009
Trends in the amount of litter in the water column (including floating at the surface) and deposited on the sea-floor, including analysis of its composition, spatial distribution and, where possible, source (10.1.2)	OSPAR EcoQO on the level of litter (plastic particles) in fulmar stomachs	Fewer than 10% of fulmars with more than 0.1 g of plastic in their stomach, over a period of at least five years	Target not met Last assessment result: 58%	2005-2009
Trends in the amount, distribution and, where possible, composition of micro-particles (in particular micro-plastics) (10.1.3)	Not yet applicable			
Trends in the amount and composition of litter ingested by marine animals (e.g. stomach analysis) (10.2.1)	OSPAR EcoQO on the level of litter (plastic particles) in fulmar stomachs	See above	Target not met Last assessment result: 58%	2005-2009

3.11 Energy, including underwater noise

3.11.1 Distribution in time and place

Criteria and indicators (EC, 2010)	Proposed indicator	Proposed target
Proportion of days and their distribution within a calendar year over areas of a determined surface, as well as their spatial distribution, in which anthropogenic sound sources exceed levels that are likely to entail significant impact on marine animals measured as Sound Exposure Level (in dB re 1µPa2.s) or as peak sound pressure level (in dB re 1µPapeak) at one metre, measured over the frequency band 10 Hz to 10 kHz (11.1.1)	Not developed yet	
Trends in the ambient noise level within the 1/3 octave bands 63 and 125 Hz (centre frequency) (re 1µPa RMS; average noise level in these octave bands over a year) measured by observation stations and/or with the use of models if appropriate (11.2.1)	Not developed yet	

The Commission Decision proposes two indicators for this descriptor . At present, an EC technical subgroup on underwater noise is working on further definitions and possible indicators.

3.11.2 Comparison of indicators and targets with current state

No indicators and targets have been developed yet, so an assessment of current indicator values is not possible yet.

3.12 Multiple application of indicators

In an number of cases, the same indicators have been proposed for different criteria and indicators in the Commission Decision. This was done in cases where the criteria and indicators ask for similar types of information, like for example information on the benthic community that can be applied to descriptor 1 (Biological diversity) as well as for Descriptor 6 (Seafloor integrity). Multiple application of the same indicators also supports the consistency in the indicator set. Table 3.15 gives an overview of the indicators that have been applied in more than one case.

Table 3.13 Overview of proposed indicators that are applied to several criteria and indicators from EC (2010).

Proposed indicator	Criteria and indicators in EC (2010)
number/biomass of long-lived/vulnerable benthic species proportion of long-lived/vulnerable species in benthic community	• Species distribution and population size (1.1 and 1.2) • Habitat condition (1.6.1 and 1.6.2)
OSPAR EcoQO proportion of large fish in the fish community	• Species distribution and population size (1.1 and 1.2) • Large fish (4.2.1)
OSPAR EcoQO on healthy seal populations	• Species distribution and population size (1.1 and 1.2) • Performance of key predator species (4.1.1)
Distribution and pattern of habitats at EUNIS level 3	• Habitat distribution and habitat extent (1.4 and 1.5) • Habitat condition (1.6.3)
Species richness, evenness, Hill's indexes	• Ecosystem structure (1.7.1) • Multi-metric indexes for the benthic community (6.2.2)

3.13 Pressure indicators

The the criteria and indicators in the Commission Decision and the indicators proposed in the previous sections are nearly all ecological indicators that focus mainly on state and impact. For management purposes it may be useful to gain more insight on trends in human activities and in the associated pressures on the ecosystem. Information that is already available from various sources could easily be used to develop indicators on human pressures. Table 3.16 gives a provisional list of indicators that could be applied to monitor either the level of a human activity as a proxy for pressures, or a pressure itself. It should be added that not all indicators attribute evenly to a descriptor (for example, ships will add more to background noise than platforms).

Table 3.14 Provisional list of indicators for human activities and pressures that could be applied in Dutch marine waters. Grey boxes indicate to which GES descriptors the indicators apply.

	GES descriptors										
	1	2	3	4	5	6	7	8	9	10	11
Indicators	Biological diversity	Non-indigenous species	Commercially exploited fish and shellfish	Food webs	Eutrophication	Sea-floor integrity	Hydrographical conditions	Contaminants	Contaminants in fish and seafood	Litter	Underwater noise
Risk of introduction of NIS by shipping (IMO Ballast Water Convention G7 guideline on env. risk analysis)		■									
Number of mariculture units		■			■					■	
Fishing aggregation - extent and frequency (ICES)	■		■	■		■					
Fishing distribution – extent and frequency (ICES)	■		■	■		■					
Size of fleet (tn or number) (ICES)	■		■	■		■				■	
Discard rate	■		■	■							
(Weighted) days at sea			■								
Area impacted by human activities (extent and frequency)	■			■		■					
Volume of sand extraction	■			■		■					
Volume of coastal nourishments	■			■		■					
Number of ship movements		■						■		■	■
Number of oil and gas platforms								■		■	■
Number of wind turbines						■					■
Surface area of windfarms						■					■
Emissions at sea of nutrients, synthetic and non-synthetic substances					■			■	■		
Atmospheric deposition of nutrients, synthetic and non-synthetic substances					■			■	■		
Riverine discharges of nutrients, synthetic and non-synthetic substances					■			■	■		
Frequency of explosions of ammunition											■
Frequency of loud sound produced by seismic exploration											■

4 Evaluation and discussion

This chapter first treats the indicators for each of the eleven GES descriptors separately. The current level of development of indicators and targets, the existence of an adequate monitoring programme and the most important knowledge gaps are discussed. The level of development of indicators and targets is described as poor, limited, reasonable or good: "poor" means that an indicator may be available, but the relationship with pressures is uncertain or not quantified; "good" means that an indicator is fully developed, the relationship with pressures is clear and quantified and quantitative targets have been set.

Next, more generic knowledge gaps, and the approach for further development of indicators is discussed.

4.1 Biological diversity

The level of development of indicators and targets within this descriptor is poor to reasonable, depending on the indicator group (species, habitats, etc.).

Indicators

The Commission Decision (EC, 2010) requires a large set of indicators at species level, population level, habitat level and ecosystem level. The Commission Decision refers to Table 1 in Annex III of the MSFD that gives an indicative list of biological features, including phytoplankton, zooplankton, invertebrate fauna, fish, mammals, birds and any other species belonging to the regional sea, including non-indigenous species. The Commission Decision additionally requests information about habitats, including a description of all physical, chemical, and biological characteristics and about ecosystem structure and functioning, including resilience and connectivity issues.

Taken literally, such demands equate to a complete description of the structure and functioning of the marine ecosystem, which obviously is an immense task. Prioritising "...in relation to the importance of impacts and threats to marine ecosystems and its components…" (EC, 2010) resolves this issue somewhat but assumes we are sufficiently aware of the greatest impacts and threats related to biodiversity. Using a risk-based approach the indicators for this descriptor were focused on vulnerable species and habitats, i.e. on species and habitats that are in decline or threatened by anthropogenic pressures, and for which data are available.

Species

The criteria and indicators from EC (2010) have been filled in for the species groups benthos, fish, birds and mammals. Population and community characteristics are used to describe these groups. The choice of indicators is based on the one hand on pragmatism – what is available in terms of data – and, on the other hand, on a theoretical assumption: if something goes wrong with biological diversity in the system, these species will be indicative for species groups at lower trophic levels. However, limited data from dedicated monitoring programmes are available, and our knowledge of the vulnerability of biological diversity to pressures is likewise limited.

Diversity indices for phytoplankton have been elaborated in the past (Kabuta and Duijts, 2000). Given the lack of identified relationships between phytoplankton species diversity and human pressures, these indices were not considered useful. For this reason, no species indicators for phytoplankton have been included.

Habitats

Indicators are mainly available for benthic habitats, and encompass physical characteristics and biological data on species composition and densities. Pelagic habitats may be described by physical characteristics such as depth, temperature, current velocities, salinity, stratification, and chemical and biological characteristics, but at present there is no operational description of pelagic habitats.

Ecosystem structure

At the ecosystem level, the Commission Decision (EC, 2010) asks for indicators describing "composition and relative proportions of ecosystem components (habitats and species)". It is unclear, both in the Commission Decision (EC, 2010) and in the TG 1 report (Cochrane et al., 2010), what is meant with this description. In this report, indicators describing the species richness of benthos, fish, birds and marine mammals have been proposed as a first step to address this issue.

Targets

Targets have been set for the proposed indicators on biological diversity, but they are only qualitative and directional targets, such as "no decline". Although these targets can be based on currently available datasets, they still need further elaboration: what data sources, reference year(s), what time period for assessment, etc.

Monitoring

As the MSFD and the EC decision point out, biological diversity needs explicit attention in connection with the need to assess a "healthy, productive and resilient" marine ecosystem, and how this can be translated into a dedicated research and monitoring programme. Such efforts are best undertaken internationally on a regional sea basis.

Current monitoring in Dutch marine waters provides some information, mainly relating to benthic species and habitats, fish, birds and marine mammals. The monitoring programme does not cover the entire range of marine metazoan organisms. Furthermore, data for most species do not cover seasonal variability, so the indicators may be strongly seasonally biased. And finally, the spatial coverage of the monitoring is limited.

Knowledge gaps

The currently proposed indicators give an indication of biological diversity in the marine environment and any changes that occur. However, to what extent these indicators reflect the nature and extent of human impacts is not sufficiently clear. While these indicators can be applied for the time being, a further analysis of the response (or lack of response) of these indicators to human pressures is needed.

As a consequence of the lack of understanding of the quantitative relation between pressures and indicators, only qualitative (directional) targets have been proposed (with the exception of the already existing EcoQOs). A more quantitative translation of the concept of Good Environmental Status into biodiversity parameters is only possible requires better knowledge, not only of the relation between pressures and indicator response, but also of the relation between indicator values and ecosystem functioning.

Furthermore, the extent to which these indicators can be considered representative of developments in biological diversity in the North Sea needs further study. Species that have disappeared from the North Sea, ecosystem components (e.g. bacteria and viruses, phyto- or zooplankton, gelatinous zooplankton) or characteristics (e.g. genetic variability) that have not been included yet may need to be taken into account more explicitly.

4.2 Non-indigenous species

The level of development of indicators and targets is poor to limited.

Indicators:

This descriptor requires an overview of the number of non-indigenous species (NIS) in an area, their distribution and the nature and extent of effects they have on their environment. Only limited information is available about abundance, trends and distribution, and only for certain species groups. The relationship with pressures is obvious (e.g. shipping, aquaculture) but not quantified, and knowledge of vectors is not always species-specific.

Targets:

Relations between the number of non-indigenous species, the ratio of non-indigenous:native species, or the abundance of non-indigenous species and impacts are not established. Consequently, it is not possible to define threshold levels for these indicators, below which impacts will not occur, and only a directional target can be set.

Monitoring:

There is currently no dedicated monitoring programme for any of the aspects associated with NIS, such as vectors of introduction, species abundance and distribution, or impacts. NIOO-CEME and NIOZ have datasets from which important trends on NIS can be extracted. Monitoring of vectors and NIS should be developed in order to acquire more insight into the basic processes of introduction. Currently, some data can be obtained from routine monitoring of phytoplankton, benthos and fish.

Knowledge gaps

More information is needed on NIS, their numbers and distribution and their actual or potential effect on the ecosystems they colonise. Also, more information is needed on their vectors and the susceptibility of the receiving environment.

The chances that native species will disappear or decline, or that ecosystem functions or habitat structure will be disrupted due to invasive species, is likely to depend on the

characteristics of the invading species and of the environment. There is a lack of knowledge on these characteristics.

A more dedicated monitoring effort is needed to obtain more insight into the number of NIS, their abundance and their distribution, and the relative importance of the different vectors. Furthermore, the characteristics that determine to colonization of NIS, and the characteristics of invasive species, need to be better understood.

4.3 Commercially exploited fish and shellfish

Indicator and target development for commercially exploited fish is reasonable to good.

Indicators:

The primary indicators can only be calculated on the basis of analytical stock assessments. These are conducted for many, but not all, commercial fish stocks. However, even if stock assessments are conducted the reference levels are not always known. It is probably not unreasonable to assume that the stocks, for which all relevant information is available (based on stock assessments), are sufficiently representative to allow assessment of the status of commercial fish species in the North Sea.

Population sizes of commercially exploited bivalves are assessed annually, but other shellfish (shrimp, crab, lobster) are not assessed.

The secondary indicators can be calculated for all relevant species from data gathered in ongoing monitoring programmes.

Targets:

Targets have been set for several indicators mentioned above (i.e. F and SSB). The targets for fish are based on internationally agreed ICES recommendations. No targets exist for the indicators concerning age and size distribution. Whether this is possible in the near future, and appropriate, needs to be assessed.

Monitoring:

Monitoring of most species takes the form of dedicated market sampling and surveys by research vessels. Surveys of bivalve species monitor abundance and size.

Knowledge gaps

The data on most commercial fish species are adequate for management purposes in an MSFD context.

Reference levels for the size distribution of viable stocks (e.g. 95th percentile of fish length) need further development.

4.4 Food web

The level of development of indicators and targets for this descriptor is poor to limited.

Indicators

The three indicator groups have been filled in with some relevant indicators, mostly ones defined previously by OSPAR (EcoQOs for seal populations, harbour porpoise and proportion of large fish). Food web can be considered the most difficult descriptor to address using concrete indicators and targets.

The Task Group report (Rogers et al., 2010) gives a good overview of how food web theory and knowledge can be used in the MSFD, and the EC decision gives a synopsis of indicators. It is unclear how and why the three indicator groups from the EC decision have been drawn from the Task Group report. While the TG report describes two distinctive characteristics of food webs, namely energy flows and food web structure, the EC decision selects only parts of these as indicator groups. “Productivity of key species or trophic groups” seems to be related to energy flows. “Proportion of selected species at the top of food webs” and “Abundance/distribution of key trophic groups/species” seem to be related to structure.

There is no clear definition in the Task Group report or any other MSFD document of the concept of “key species”, whether they are prey, predator or some other functional type. Some descriptions of key species in Rogers et al. (2010) concern species that have a narrow prey choice and thus a strong interaction, such as kittiwakes and sand eels. The concept of “keystone species” has been described as “a species whose effect is large, and disproportionately large relative to its abundance” (Power et al. 1996). However, the concept of key species is considered attractive in a theoretical sense, but it is broadly applied, poorly defined, and non-specific (see e.g. Mills et al., 1993, Payton et al., 2003). There is no a *priori* reason to limit key species to key predator species.

What constitutes a key species is probably context dependent. Depending on the context, redundant species may become keystone species when circumstances change. It is clear from the available literature (e.g. Mills et al., 1993; Power et al., 1996; Payton et al., 2003) that keystone species can be defined only after food web analysis. Hence, what constitutes a key species in a specific food web and in certain circumstances can only be established *a posteriori*. Ragnarsson et al. (2003) performed such a food web analysis, described as the “The North Sea significant food web”, as part of the EU *European Fisheries Ecosystem Plan* (EFEP) project. It describes species that render important ecosystem services, extending beyond their ecological importance, and also includes species and habitats of economic, societal and functional importance. This description has been updated recently in Paramor et al. (2009).

In the current indicator set, only a few species have been selected, since these are species for which abundant data on population size and reproduction are available in the Netherlands. The available indicators are a first and pragmatic selection of parameters that may be indicative of the functioning and structure of the ecosystem. It is unclear whether the selected species can be considered key species in the North Sea. Furthermore, the quality of the indicators is poor: the relationship of the proposed indicators with the pressures, and with the structure and functioning of the ecosystem they represent, is weak.

Targets

The targets for the selected indicators are mainly derived from EcoQOs established in an OSPAR context and from agreements in ASCOBANS (Harbour porpoise by-catch). No clear

targets yet exist for prey species due to a lack of knowledge on the necessary prey stock size for a healthy seal population.

Monitoring

Monitoring is currently adequate for the EcoQOs for harbour and grey seals. However, there is no adequate monitoring programme for the EcoQO on by-catch levels of harbour porpoise, neither for information on population estimates of harbour porpoises nor for information on by-catch of harbour porpoises. More data about fish stocks, benthic populations, seabird populations etc. are available, and could be used for a next step towards the further development of this descriptor.

Knowledge gaps

It has been acknowledged (Rogers et al. 2010) that finding the right Food web indicators is difficult. The set of indicators and targets presented here are only a first step towards a more extensive set of indicators for food web structure and functioning. A next step would be to integrate data on other species (e.g. key predator species) and habitats into a conceptual food web description. Information could be drawn from projects such as EFEP. The ultimate goal, assigning keystone species as described in the Commission Decision, can only be achieved after food web analysis. Some work has already been done, although the emphasis is mainly on fish (Ecopath; Mackinson and Daskalov, 2007) or on the lower trophic levels (for example, ERSEM; Blackford et al., 2004).

To advance this descriptor, an international effort such as that currently being undertaken (e.g. technical subgroups for Litter and Underwater energy) would be very useful in the short run. Long-term efforts are needed to resolve the issue of food web modelling for keystone species.

4.5 Eutrophication

The development of indicators and targets for eutrophication is good.

Indicators

Indicators have been well established for nutrient concentrations, nutrient ratios, chlorophyll-a, species shifts in floristic composition, and oxygen concentration, based on earlier indicator development within OSPAR and WFD. Species shifts are only partly addressed, however. The other criteria in the Commission Decision – transparency, macroalgae and perennial seaweeds – are not relevant in Dutch marine waters. Relationships with pressures are clear and quantified.

Targets

Target and/or limit levels have been proposed for all relevant indicators, based on already established targets (WFD, OSPAR).

Monitoring

Monitoring programmes exist for nutrients, chlorophyll-a and phytoplankton composition (biweekly to monthly).

Knowledge gaps

With the implementation of measures for the WFD, a gradual decrease in marine eutrophication can be expected. Attention should be paid to the consistency between targets for eutrophication and targets for other descriptors, in particular biodiversity and food webs.

4.6 Seafloor integrity

The development of indicators and targets for seafloor integrity is limited to reasonable.

Indicators

The first indicator group aims at describing the characteristics of biogenic substrate. A description of biogenic substrate is found in the Task Group report (Rice et al. 2010): “structures created by living organisms”. It is not clear however, whether this is assumed to be limited to substrate created by organisms extending above the seabed, or whether it could also include sub-bottom structures such as those created by the mud shrimp *Callianassa subterranean*. Epibenthic biogenic structures are assumed to be relatively vulnerable to physical impact, and play an important role in near-bed physical processes. However, large infauna species are equally important for physical processes like bioturbation and bio-irrigation. Disturbing or killing these may impede benthic functioning. Hence, although the choice of biogenic substrate seems a logical indicator for physical damage, it remains unclear what it is.

The extent of habitat significantly affected by human pressures seems to be a clearly pressure-related indicator, but the term “significantly affected” has not been defined. Quantitative relationships between the type of disturbance, the extent of a disturbance and the ecological functioning of a habitat are not well established.

The criterion ”condition of the benthic community” consists of four indicator groups. All indicators describe some structural characteristic: species composition, biomass, length/size and multimetrics. Most of these parameters have been used extensively in ecological studies, but their applicability as pressure-related indicators is doubtful (Boon et al. 2011). Many parameters or indices lack a quantitative relationship with pressures.

Targets

Targets for seafloor integrity do not currently exist. As yet there is no scientifically sound answer to the question of which level or direction is appropriate for a state indicator in order to represent a benthic ecosystem under GES. Many benthic parameters show high natural variability in the shallow and dynamic Dutch North Sea.

Monitoring

Currently, monitoring is in place for various purposes. The spatial and temporal scale of current monitoring may not be sufficient for the application of the indicators, however.

Knowledge gaps

Various benthic parameters can be applied as seafloor integrity indicators. However, most parameters need further development, as it is not clear yet to what extent they are indicative of human impacts.

First of all, agreement on what is a biogenic habitat is needed. We suggest that both structures within and above the seabed should be considered biogenic substrate. Attention should be paid to a density limit, to exclude low-density levels of substrate-forming organisms.

Quantitative relationships between indicators and pressures need to be established, in order to set more quantitative targets in stead of the directional targets that were proposed in this report.

In the dynamic North Sea, parameters can probably vary within a large (natural) range without hampering the functioning of the benthic ecosystem. This range needs to be established.

An iterative method, evaluating observations and improving indicator and target development, is recommended.

4.7 Hydrographical conditions

Indicator and target development for this descriptor is poor.

Indicators

Although indicators can be described qualitatively for this descriptor, the proper hydrographical parameters that constitute “conditions” differ from case to case. They may concern pelagic and/or benthic habitats, and the relevant parameter will thus vary widely, from sediment particle size to salinity or current speed, for example. An underlying assumption in the indicators is that impacts are related to surface area, which probably also differs from case to case.

Targets

Given the problems of finding the “right” indicator, target levels have not been set for any of the indicator groups.

Monitoring

Monitoring is not done on a regular basis, but usually takes place on a project-related basis.

Knowledge gaps

There is no common set of parameters that are relevant for projects that cause permanent alterations in hydrographical conditions. This set of parameters and associated targets can probably only be developed on a case-by-case basis. This hampers a harmonized approach for this descriptor.

4.8 Contaminants

The level of development of indicators and targets for this descriptor is limited to good.

Indicators

European and OSPAR guidelines and targets have been set for many substances in water, sediment or biota. For some substances, the so-called ”emerging” substances that are suspected of having adverse environmental effects, target levels have not yet been set.

Indicators for the effects of contaminants on individuals, populations and ecosystems are less well developed.

Targets

Target levels in water, sediments and biota have been set by the EC or by OSPAR for most substances. OSPAR has developed an indicator for oil pollution, but it should be kept in mind that the target level is not related to effects on populations or ecosystems.

Monitoring

Dedicated monitoring programmes exist in a WFD and OSPAR context.

Knowledge gaps

Target levels for individual substances in water and sediment that have been set within EU and/or OSPAR frameworks can be used as a standard. Additional research needs to be carried out on the behaviour of emerging substances and their fate in the environment.

Target levels for the effects of substances have been defined for a limited number of biological effect indicators (bio-assays) only.

4.9 Contaminants in seafood

Indicator and target development for this descriptor is good.

Indicators

The indicators for contaminants in seafood are well described in other EU directives. National and EU guidelines exist for a well-defined list of substances.

Targets

Target levels are similar to those laid down in existing regulations.

Monitoring

Monitoring of contaminant concentrations in seafood products occurs in extensive market sampling programmes. Some programmes are coordinated and carried out internationally (ICES).

Knowledge gaps

None

4.10 Litter

Indicator and target development for this descriptor is poor to limited.

Indicators

EC (2010) asks for indicators for trends in beach litter, in litter in the water column (floating, water column and on the seafloor) and in the amount and composition of micro-particles. Although it is clear what these categories of litter encompass, it is not entirely clear what indicators can be used, i.e. how quantities and qualities of litter can best be expressed to identify trends. Data are available from beach litter surveys carried out in an OSPAR context on four beaches in the Netherlands. However, although the surveys are carried out in a standardised and repeatable way, there are still shortcomings in the recording of litter characteristics and data analysis.

Data for litter in the water column are lacking in general. The EcoQO for plastic particles in fulmar stomachs is proposed as a proxy for the amount of small floating litter items.

Micro-particles have not yet been sampled in the North Sea. No data exist on quantities or composition.

The EcoQO for plastic particles in fulmar stomachs is used as an indicator for impacts on marine life. However, it is unclear to what extent this indicator represents impacts on other ecosystem components and impacts of other types of litter.

Targets

Generally speaking, targets for litter have been expressed as decreases in trends. Although this seems straightforward, the lack of data on the amount and composition of litter makes it difficult to specify the trends to a measurable level. For example, a goal describing a decline in beach litter needs to specify the type of litter, locations, monitoring requirements and data analysis.

Monitoring

A dedicated monitoring programme exists for beach litter in an OSPAR context. OSPAR has published a guideline for monitoring marine litter on the beaches in the OSPAR maritime area.

With the exception of the fulmar EcoQO, no dedicated monitoring programmes exist for offshore litter.

Knowledge gaps

The current set of indicators gives a very limited picture of the pollution effects of litter. An EC Technical Subgroup currently focusing on litter will deliver a plan on how to best proceed.

For the application of the beach litter indicator, the monitoring programme needs to be standardised and data need to be further analysed to optimize the programme. This needs to be addressed before indicators and targets for beach litter can be developed further.

A sampling methodology needs to be developed for offshore litter before any further steps for indicator and target development, monitoring and assessment can be taken. Given the complexity of the distribution and composition of litter in the offshore environment, studies need to be undertaken to develop standardised sampling methods and strategies, to gain insight into the amount and types of litter in the water column. Separate monitoring will probably also be needed for the three types of litter floating on the surface, floating in the water column and deposited on the seafloor.

Micro-particles are a relatively unstudied issue in the North Sea. As with offshore litter, both sampling methods and strategies need to be developed before any monitoring programme can be set up.

4.11 Underwater energy (sound)

Indicator and target development for this descriptor is poor.

Indicators

Two criteria have been developed for underwater energy, focused on impulsive underwater sound and on continuous underwater sound.

Thus far, international discussions have focused largely on impulsive underwater sound. No good candidate has yet been found for a level that can be regarded as causing “significant impact” on marine life. The Terms of Reference for the discussions within the EC Technical Subgroup Noise focus on the following issues:

- Identifying and reviewing existing data and monitoring methods on underwater noise
- Developing proposals for methodological standards to monitor loud impulsive noise
- Developing proposals to monitor low-frequency continuous sounds
- Assessing the need to develop indicators for other forms of energy (not mentioned in EC decision)
- Developing objectives, environmental targets and associated indicators

Progress is expected on the first two issues, since they depend largely on agreement for acoustics and for modelling. The fifth issue is more difficult to agree on although some preliminary assumptions can be used as a basis. One important step is to set TTS (Temporary Threshold Shift ~ temporary deafness) levels for mammals and fish, and to derive some avoidance level that can be used to assess spatial loss of habitat which may affect fitness of individuals and populations. How this develops depends largely on international agreement in the EC Technical Subgroup.

Continuous sound (fourth issue above) has not yet been discussed in the Technical Subgroup. In general, the same issues concerning measurements and units also apply to continuous sound.

Targets

Target levels for physiological effects are likely to be species-specific. Currently, preliminary TTS data are available for harbour porpoise and harbour seal. No such data exist for fish species. Behavioural effect levels (avoidance) are likely to be context-dependent, but only anecdotal empirical data are available. Assumptions therefore need to be made for behavioural effect levels.

Monitoring

No dedicated monitoring programmes exist for impulsive underwater sound. Monitoring takes place as part of specific projects such as during piling of windfarms or sonar deployments. No standardised methodology yet exists for the measurement of underwater sound, although the Study Group is likely to make progress on this.

Knowledge gaps

The most important and pressing issues are being studied by the EC Study Group on underwater sound. The best way forward is probably to measure and describe underwater sound sources with the best available techniques, and not to discard any data that become available. Effects on marine mammals and fish need to be monitored concurrently with the monitoring of sound. The effects may vary from behavioural effects (avoidance) to injury or death. Monitoring of such effects is not standardised, and needs to be developed.

4.12 Evaluation of indicator and target qualities

This section discusses the qualities of the indicators in the context of criteria for indicators and types of targets as mentioned in § 2.2.

4.12.1 Indicator quality

Expert judgment was used to evaluate the quality of the indicators, according to the eight criteria for indicator quality (§2.2) aggregated at the level of descriptors. The scores give an average value for each descriptor, and should be viewed as indicative.

Table 4.1 gives an overview of the scores. The symbols indicate a score from poor-limited (-) to limited-reasonable (0) and reasonable-good (+). A “x” indicates that insufficient information is available to give an assessment.

Some of the applied criteria, especially Sensitivity, Specificity and Ecological relevance are of crucial importance for the functioning of indicators in the DPSIR cycle: how well they are linked to human activities and how good the scientific ecological underpinning is.

Table 4.1 Scoring of the proposed indicators on the eight criteria from § 2.2.2

Symbols indicate: poor-limited (-); limited-reasonable (0); reasonable-good (+);insufficient information (x)

Criteria	Biological diversity	Non-indigenous species	Commercially exploited fish and shellfish	Food webs	Eutrophication	Seafloor integrity	Hydrographical conditions	Contaminants	Contaminants in fish and seafood	Litter	Underwater noise
Understandable for non-specialists	+	+	+	0	+	0	0	+	+	0	-
Sensitivity	x	-	+	X	0	x	X	0	+	-	x
Specificity	x	0	0	X	0	x	X	0	+	+	x
Accuracy	0	0	0	0	+	0	X	0	+	-	x
Applicability	0	0	+	-	+	0	X	+	+	0	x
Historical data	0	-	0	-	0	0	X	0	0	x	x
Measurement	-	-	0	0	+	0	X	0	+	0	-
Ecological relevance	0	-	+	-	+	0	X	0	0	-	x

Sensitivity relates to the power of the indicator to reflect changes in pressures (human-induced or otherwise), while specificity indicates how well an indicator discriminates between pressures. Most Indicators, and in particular those for biological diversity, food web and seafloor integrity, have low sensitivity and specificity, mainly due to lacks in understanding. For instance, the extent to which changes in values of species diversity indicators are related to pressures, and how this compares to natural variability has barely been studied. Sensitivity is not well known for non-indigenous species and litter.

Ecological relevance relates to the scientific basis of the indicator and its ability to represent significant aspects of the ecosystem, as addressed by the descriptor.

The proposed indicators for non-indigenous species, food web and litter represent only a small part of what is required in the Commission Decision. The link between those indicators and the status of the ecosystem for these descriptors is weak. For example, the indicators on marine mammals for Food webs give no indication of food web functioning as a whole, but only give an indication of the functioning of some top predators.

Many indicators are sufficiently understandable for non-specialists. Many descriptors also include more complex indicators, mostly relating to ecosystem effects on structure and functioning. No indicators have yet been proposed for underwater sound, but the indicators suggested in the Commission Decision are very technical and not easily understood by non-specialists.

Accuracy (error rate) is weak for the indicators currently proposed for litter, mainly because monitoring methods are still in development.

Applicability (can it be measured over a large proportion of the area?) for food webs is low, as the proposed indicators for seals are mainly restricted to coastal waters.

Historical data are available from biological monitoring. Data covering several decades are available for physical and chemical parameters. For species indicators, such as benthos, fish and birds, historical datasets go back to the mid-20th century

Measurement relates to the ease and costs of monitoring. This is particularly an issue for monitoring focused on species. There are no standardized sampling methods for many parameters, such as mammals and birds, habitats, NIS, litter and underwater noise.

It must be stressed that it is not likely to find indicators that will fulfil all criteria equally well. For example, an indicator that scores well for ecological relevance (and its scientific underpinning) may be less understandable for non-specialists. To deal with this, such an indicator could be complemented by an indicator that scores well on general understanding, even if it scores lower on the other criteria.

4.12.2 Target quality

Possible targets were discussed for each indicator. The targets show different degrees of development, consistent with the grouping of the indicators. The main discussion points are:

1 In terms of the targets developed previously (for example, as OSPAR EcoQOs), their usefulness as MSFD target needs to be ascertained. What was the background to the target? Is it an unimpacted baseline condition or a target that can be compatible with good environmental status?
2 Indicators without a quantitative target (only directional targets) need a starting point for further study: what are the current values (baseline) and to what pressures do these relate?
3 Two reference levels are of special importance: target levels, and limit levels that should never be exceeded. Unimpacted levels (pristine levels) are very hard if not impossible to establish.
4 Some targets will have a biological basis. This applies mainly to the limit reference levels. Fish populations have two levels: B_{lim}, the limit stock biomass below which recruitment may become impaired (which should be avoided at all times), and B_{pa}, which takes uncertainty into account and applies a precautionary approach avoiding impaired recruitment.
5 Target setting will have to deal with uncertainty. Setting a target means accepting a certain risk of a decline in ecological status, but also accepting a certain risk of targets being too strict. This also requires a normative discussion about what risk is acceptable.
6 No timeframe was developed yet for many indicators presented in this report. This is especially important for the directional targets: at what point in time must a certain level be attained? Such concrete goals and timeframes need to be developed.

Some indicators and their targets originate from existing assessment methods (WFD, OSPAR, ICES) where some level of international agreement has been part of the process leading to the targets. Other targets are proposals based on expert judgment. Targets such as “no decline” for biodiversity indicators should be seen as provisional and pragmatic targets; it is unclear if decline in diversity of any group would lead to irreversible deterioration of the environment. For many indicators, knowledge of cause-effect relationships in the marine environment is too limited to determine well-defined, quantitative targets.

4.13 General knowledge gaps

In addition to the knowledge gaps discussed above, a number of common knowledge gaps can be identified. These knowledge gaps are related to the following issues:

- calibration of indicators,
- target-setting,
- consistency of indicators and targets,
- harmonisation
- further development of indicators

One of the most important knowledge gaps in the development of indicators and targets is related to the calibration of indicators in the DPSIR scheme. What is the power of the indicator to express the level of pressure(s) and how does it discriminate from natural variability? In particular in a multi-pressure environment, it is uncertain how indicators behave. To make progress in the application of indicators, studies to evaluate the performance of the proposed indicators in relation to pressures are an absolute necessity. This is not just a scientific interest. This knowledge is vital for decisions on cost-effective measures.

Another common knowledge gap is related to the indicator values. While target levels have been proposed for some indicators, it is often not clear what target level would be indicative of good environmental status. For many of the proposed indicators our level of understanding of the functioning of the ecosystem in relation to sustainable use is inadequate. A more pragmatic approach, used for several indicators, is to define directional targets, setting the direction in comparison to the current situation. This approach is only a temporary solution, as it remains unspecified when good environmental status will be achieved. Adaptive management, combining monitoring and research and a continuous reviewing of the targets, is the way forward in this case.

The consistency of the set of descriptors will be discussed briefly in the next paragraph, showing relationships one ”level” below that of the descriptors. At the level of indicator groups, the relationships between the descriptors are strongly entangled: there are interactions between the various ecosystem components that are covered by indicator groups from different descriptors. This means that the targets are interdependent, and this has to be taken into account to prevent conflicting targets for closely related indicators. Targets set for one indicator should not interfere with the targets for other indicators.

Indicators and targets need to be harmonised with other countries at the regional sea level, to arrive at shared views of current status and the distance from target (good environmental status). The intercalibration process in the WFD has shown that this is a complex and time consuming process. Indicators and targets must also be harmonised with other pieces of legislation such as Water Framework Directive, Bird and Habitat Directives and Common Fisheries Policy. For indicators that had already been developed for WFD, OSPAR and CFP, the same targets are proposed in this report, ensuring harmonisation between MSFD and other regulations. However, in the further development of indicators and targets this has to be taken into account.

The indicators and targets currently proposed are a pragmatic selection of potential indicators. They are therefore to a large extent based on already commonly known indicators. Time and focus and, more especially, ambition are needed to develop the proposed indicators further, and to develop new indicators that are better able to support the implementation of the MSFD. The suggested indicators do not imply that monitoring can or should be limited to these parameters. The further development of indicators will require a

sustained monitoring effort and dedicated research to improve and expand on the current set of indicators.

4.14 Relationships between criteria and indicators for the eleven GES descriptors

The eleven GES descriptors from Annex I of the MSFD constitute a system aiming at describing marine ecosystem status. Although neither the MSFD itself nor the Commission Decision (EC, 2010) give guidance on how the eleven descriptors are related, a certain structure can be discerned in these descriptors. Borja et al. (2010) present a conceptual model that describes the hierarchy in the eleven GES descriptors, and the connections between descriptors and pressures. The conceptual model of Borja et al. (2010) emphasises that there are a number of GES descriptors that are directly related to specific pressures, while other descriptors (in particular Biological diversity and Food webs) have a more indirect relationship to many different pressures. The model suggests a hierarchy at the level of descriptors, ranked from strongly pressure-related to a high-level biological integration. This should be reflected in the determination of GES and the establishment of indicators and targets, where the achievement of GES for the higher-level descriptors depends in part on the achievement of GES for the more pressure-related descriptors. In other words, the hierarchy and relationships at this level mean that at some point the indicators and targets need to form a consistent and coherent set of parameters and values. In order to address this issue, the relationships between the various indicator groups in the EC decision have been described and are depicted in the figure below.

Elaborating on the conceptual model of Borja et al. (2010), we propose a model whereby a number of GES descriptors (2, 5, 8, 9, 10, 11) and their indicators are related to “input” pressures, i.e. pressures caused by the input of substances, organisms, litter or energy. These descriptors are shown on the right-hand side of Figure 4.1. A few other descriptors (3, 6, 7) are mainly related to physical or biological disturbance, through extraction of species or disturbance of habitats (shown on the left-hand side of Figure 4.1). The two descriptors Biological diversity and Food webs are, as suggested by Borja et al. (2010), more indirectly influenced by pressures and could be considered to integrate the effects of human pressures on the other descriptors.

In this report indicators have been proposed on the basis of rather pragmatic choices, but as many targets are defined as directional targets, there are no inconsistencies in the present values. In the future, with further development of indicators and the setting of associated targets, the coherence between indicators and targets will become more important and requires attention in the further development of indicators and targets.

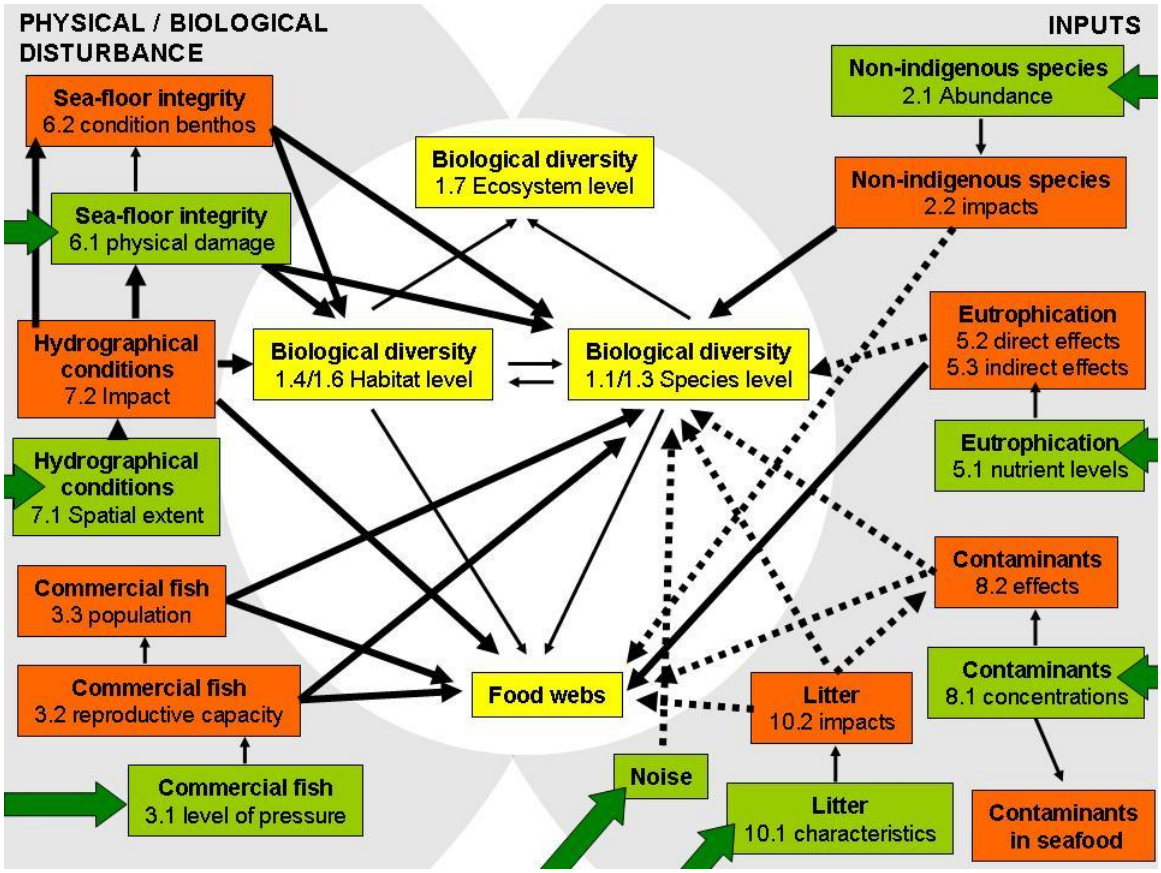

Figure 4.1 A conceptual model showing how the criteria (and related indicators) for the 11 qualitative descriptors are linked. Continuous lines indicate strong links, dotted lines indicate weaker links. Dark green arrows indicate human pressures. Green boxes refer to pressure-related criteria, yellow boxes refer to state-related criteria, orange boxes refer to impact-related criteria.

4.15 Concluding remarks

In conclusion, indicators have been developed that address many if not most of the criteria in EC (2010) for a number of descriptors (Commercial fish, Eutrophication, Contaminants, Contaminants in seafood). The proposed indicators will be the most useful for the short term, and require relatively little effort for application in management and harmonisation.

In addition, the other proposed indicators will be useful for an initial round of assessment and management. These indicators need additional research to improve their quality and applicability, as discussed above. The main issues for these indicators are their relationship with pressures, and the representativeness of ecosystem state. This mainly concerns indicators for Seafloor integrity, Non-indigenous species (number of NIS), and Biological diversity (notably species diversity), and the EcoQOs that are currently suggested for Food web and Litter. Research and practical development are needed, particularly to describe the quantitative relationships between the indicator parameters and the pressures.

For a number of descriptors, the proposed indicators address only some aspects of what the descriptor is intended to cover, according to the Commission Decision. Here, substantial work

is needed to develop additional indicators. Biological diversity, Food webs, Hydrographical conditions, Litter and Underwater energy present the most difficulty in developing concrete and practical indicators. Biodiversity and Food web are closely related descriptors that are not directly related to pressures and management. Long-term development is needed to advance these descriptors. It will probably prove easier to deliver practical indicators for Biological diversity than for Food webs. Biological diversity can be measured relatively easily, but more effort is needed to establish the relationship with pressures and to define target levels. For Food webs, however, while structure and functioning (key species, productivity, predator-prey dynamics) are extensively discussed theoretical concepts, application in terms of practical indicators and targets in the marine environment is still in its infancy.

Hydrographical conditions are not clearly defined in the EC decision. The description is too unspecific and effects are probably too case-specific to be described in general indicators and targets. Litter needs major work to improve sampling and analysis methodology. Underwater noise is hampered by lack of agreement concerning measurement and the relevant units for expressing effects on marine life. Research is currently underway and international study groups are trying to address these shortcomings.

Although the Dutch monitoring programmes cover some species groups (coastal birds, seals, benthos, commercial fish and shellfish) relatively well, many other species are not well covered, especially the lower trophic levels, non-commercial fish and shellfish, cetaceans, and offshore birds. Furthermore, few data are available on vulnerable species, predator-prey and trophic relationships. Whether the existing monitoring programmes are up to the demands of the MSFD and the indicators proposed in this study remains to be seen.

Our knowledge of the ecological functioning of the North Sea is basic. Various aspects of how species and habitats interact, and what constitutes a “healthy, resilient and productive” North Sea remain elusive. Although the EC has stipulated that no loss of ecosystem services should occur, such loss still needs to be expressed in terms of structural and functional parameters which can actually be measured.

This report suggests ways of improving indicator quality and further developing indicators for the MSFD descriptors. Dedicated research, preferably at an international level, could achieve considerable progress on many if not most indicators. Research may lead to a better scientific understanding of the thresholds at which major undesirable ecosystem changes occur. The key question remains, however, how to define healthy seas and oceans. This is a societal question rather than an ecological question.

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B Factsheets

See separate file

C Glossary of species names

Scientific name	English	Dutch
Alca torda	Razorbill	alk
Ammodytes marinus	lesser sandeel	zandspiering
Ammodytes tobianus	small sandeel	zandspiering
Amphiura filiformis	brittle star	draadarmige slangster
Arctica islandica	ocean quahog	noordkromp
Chamelea striatula	striped venus	venusschelp
Clupea harengus	Herring	haring
Cyclopterus lumpus	lumpsucker	snotolf
Dosinia exoleta	rayed artemis	artemisschelp
Dosinia lupinus	smoooth artemis	dichtgestreepte artemisschelp
Fratercula arctica	Puffin	papegaaiduiker
Fulmarus glacialis	Fulmar	Noordse stormvogel
Gadus morhua	Cod	kabeljauw
Gasterosteus aculeatus	three-spined stickleback	driedoornige stekelbaars
Halichoerus grypus	grey seal	grijze zeehond
Limanda limanda	Dab	schar
Merlangius merlangus	Whiting	wijting
Morus bassanus	Gannet	jan-van-gent
Phoca vitulina	Harbour seal	gewone zeehond
Phocoena phocoena	Harbour porpoise	bruinvis
Platichthys flesus	flounder	bot
Pleuronectus platessa	Plaice	schol
Sardina pilchardus	Pilchard	sardien
Scomber scombrus	mackerel	makreel
Solea solea	Sole	tong
Squalus acanthias	spiny dogfish	doornhaai
Sprattus sprattus	Sprat	sprot
Stercorarius skua	great skua	grote jager
Thracia papyracea	paper thracia	gewone papierschelp
Trachurus picturatus	horse mackerel	horsmakreel
Trisopterus minutus	poor-cod	kleine steenbolk
Uria aalge	guillemot	zeekoet