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Initial Assessment

Implementation of the Marine Strategy Framework Directive for the Dutch part of the North Sea
Background document 1 (of 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. It provides information that is pertinent to the Initial Assessment required by Article 8 of the MSFD. This report describes the environmental conditions in the Dutch part of the North Sea, the current human activities and the associated predominant pressures on the ecosystem. It also describes the present environmental status in terms related to eleven qualitative descriptors for Good Environmental Status from Annex I of the MSFD.

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	Mar. 2011	Dr. T.C. Prins		Prof. Dr. R.W.P.M. Laane		Ir. T. Schilperoort	
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State
final

Justification and status of report

These advice report should be regarded as scientific background report, that serve as advisory document in the preparation for the Marine Strategy, to be written by the Ministry of Infrastructure and Environment. The reports is based on currently available knowledge, laid down in reports, scientific literature, and unpublished material and on expert judgment.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 scientific background report. Between April and September 2011 review process by the Ministry of Infrastructure and Environment and the Ministry of Economic Affairs, Agriculture and Innovation took place, after which we finalised these documents 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 content in these reports.

Contents

Executive summary

Introduction to the Marine Strategy Framework Directive

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. It provides information that is pertinent to the Initial Assessment required by Article 8 of the MSFD. This report describes the environmental conditions in the Dutch part of the North Sea, the current human activities and the associated predominant pressures on the ecosystem. It also describes the present environmental status in terms related to eleven qualitative descriptors for Good Environmental Status from Annex I of the MSFD. A social and economic analysis that will form part of the Initial Assessment is being carried out by the Centre for Water Management (Rijkswaterstaat) and will be published separately. The other two reports deal with the determination of characteristics of Good Environmental Status (GES), required by Article 9 of the MSFD, and the establishment of indicators and environmental targets as specified by Article 10 of the MSFD. In the report establishment of Indicators and Environmental Targets the interrelationship between the 3 reports is presented.

Increasing human pressures on the marine environment have led to changing ecosystems around Europe. Since some of these changes are considered undesirable, the EU Commission has adopted the Marine Strategy Framework Directive (MSFD) (EC, 2008) with the aim of achieving Good Environmental Status by 2020.

The Dutch North Sea directly borders seven countries and is part of the southern Greater North Sea. Its southern part has a depth up to approx. 30 m, while the northern part reaches depths of approximately 50 m. Temperatures range between approx. 2 and 20 ºC and in the summer stratification occurs only in the deeper northern part. The water masses in the North Sea circulate in an anticlockwise gyre, mainly driven by tidal forcing. The input of Atlantic Ocean water through the Channel strongly influences water masses. Wave action, tidal currents and river discharges lead to relatively high concentrations of suspended particulate matter in coastal areas, while light penetration and salinity are particularly low in these areas.

The sediment on the Dutch Continental Shelf is mainly sandy or muddy, with the exception of the Cleaver Bank, where a mosaic of sediment types occurs. Various areas are distinguished based on differences in their physical characteristics, habitats and ecological values: Dogger Bank, Cleaver Bank, Frisian Front, Brown Ridge, Oyster Grounds, Gas Seeps, Borkum Stones, Zeeuwse Banks and the coastal waters.

Climate change has contributed to a temperature increase of 1-2 ºC in the North Sea. Rising temperature is expected to increase the duration and extent of stratification and ocean acidification, with potentially serious adverse ecological effects such as the alteration of calcification processes. However, it remains difficult to predict actual impacts.

Human activities and pressures on the ecosystem

The Dutch part of the North Sea is one of the most intensively exploited seas in the world. It is highly productive and intensively exploited by fisheries. More than a hundred facilities exploit the oil and gas fields on the northern continental shelf, for which an extensive network of pipelines has been laid. Increasing amounts of sand are extracted and used for coastal protection in the form of coastal nourishments and for commercial purposes on land. Shipping is another major activity, as this part of the North Sea is a corridor for international maritime transport and a link to a number of large harbours in NW Europe. Military activities are restricted to a few areas in the North Sea. Generally speaking the demand for space is increasing, in particular for offshore wind farms.

Human activities impose pressures on the environment. This report identifies pressures that have various impacts on the GES descriptors. Table 3.3 of this report gives a complete overview of the relationship between activities, pressures and the GES descriptors. The dominant pressures are:

- physical loss of and damage to habitats
- biological disturbance through extraction of species (included non-target catches)
- contamination by hazardous substances and nutrients
- disturbance related to litter and to underwater noise

We have only limited knowledge on which to base quantitative assessments of the effects of pressures on GES descriptors. GES descriptors are interconnected (see Figure 1.1) and methods for assessing the cumulative effects of all activities in combination are still being developed. An Initial Assessment is presented for each GES descriptor below, summarising the most relevant activities and pressures acting upon the descriptor in question, and providing an overview of the current status.

Current environmental status

- **Descriptor 1: Biological diversity**

Pressures:

Many of the activities and the associated pressures in the Dutch part of the North Sea have an impact on biological diversity, by affecting species distribution or abundance, or by impacting on habitat condition. The most important activities in this respect are commercial fishing, maritime transportation, and nutrients from land-based emissions. Pressures such as the removal of species (e.g. by fishing), extraction of target and non-target species, loss of and damage to habitats are still present.

Abundance and status:
Species level
Information on species distribution, population size and population condition is available only for a selection of groups (marine mammals, birds, commercial fish species, macrozoobenthos, phytoplankton).

Coastal and offshore areas of the Dutch part of the North Sea are very important for marine birds. Generally, bird populations have increased compared to the data collected in the first round of monitoring. Only populations of the common scooter and kittiwake show a decline, which is thought to be related to a decrease in food availability.

Numbers of grey seal, harbour seal and harbour porpoise have increased or stabilised since the mid-1980s. The increase might be due to exclusion from hunting, reduction of PCB concentrations, availability of prey species and less competition with other predators.

Three different fish communities can be distinguished in the North Sea, related to environmental conditions like water depth and temperature. Trends in fish stocks show that fish species not directly targeted by fisheries have increased. Large species with low fecundity have decreased in population size since 1977. These fish species may be replaced by species that are less sensitive to disturbance. Overall, fish species richness has increased, probably due to environmental effects (rising temperatures) as well as anthropogenic influences (commercial fisheries).

Biodiversity of benthic invertebrates is higher in the northern offshore waters (north of the Frisian Front). Density and biomass are higher in the coastal waters and in the Frisian Front area. No clear trends have been observed in macrobenthic communities.

Phyto- and zooplankton composition shows long-term changes, primarily related to natural oscillations (meteorology, transport patterns). To some extent, nutrient enrichment plays a role in the increase in dinoflagellates and diatoms.

Habitat level
Several habitat types can be distinguished in the Dutch part of the North Sea, differing in depth, grain size, silt content and biological diversity. Some of these habitats, “shallow banks” and “reefs”, are designated as Natura 2000 sites, and have been labelled ”unfavourable – inadequate” in terms of their conservation status. Information is available about the spatial distribution of benthic habitats outside Natura 2000 sites, but less information is available on quality aspects, if at all.

Ecosystem level
At an ecosystem level, there is general agreement that global biodiversity faces unprecedented threats as a result of human activities in the marine environment, land-based inputs to the sea and climate change. According to an assessment by Wortelboer the current biodiversity of the Dutch North Sea is only 40% of its natural state. Fish and mammals have relatively low nature value scores, whereas macrobenthos and birds have relatively high scores. Although the trend in average biodiversity since 1990 is negligible, phytoplankton and mammals show an overall positive trend, whereas macrobenthos and fish show an overall negative trend. The nature value indicator for mammals is improving slightly.

- **Descriptor 2: Non-indigenous species**

Pressures:
The main pressure comes from intentional or unintentional introduction resulting from human activities, or species that have arrived without human help from an area where they are alien. Commercial shipping and aquaculture are currently the most important activity for the introduction of non-indigenous species, through ballast water and fouling organisms on ships’ hulls. Non-indigenous species can cause considerable adverse and/or harmful change in the North Sea ecosystem potentially leading to the disappearance of habitats, extinction of species and changes in the food web. At present, however, no such changes are known to have occurred in the Dutch part of the North Sea.

Abundance and status:
There are no specific monitoring programmes for the introduction and establishment of non-indigenous species. The American jackknife clam has successfully established itself in the Dutch coastal zone. It is suspected that this species might have caused the decrease of some indigenous bivalve species, though no causal relationship could be established. The Pacific oyster has established itself in the South-west Delta area and the Wadden Sea, possibly facilitated by climate change. This species poses a high risk in terms of competition with other bivalves and habitat modification.

The risk of impact from non-indigenous species increases as the intensity of related activities increases, though the actual risk might not be equivalent due to the implementation of measures. Furthermore, the magnitude of the actual ecological impact of invasion cannot be predicted.

- **Descriptor 3: Commercially exploited fish and shellfish**

Pressures:
The main pressure on commercial fish and shellfish stocks is the extraction of species by fisheries, including extraction as a consequence of incidental by-catch of non-target species.

Abundance and status:
Fishing mortality and reproductive capacity of fish stocks
Although fishing mortality has decreased in recent years, spawning stock biomass (SSB) has barely recovered. Currently, most commercial stocks in the North Sea cannot be considered to be sustainably exploited.

Population age and size distribution of fish stocks
There was a decline in the size distribution of demersal fish in the North Sea over the period 1975-2005. This probably also applies to commercial species. There has been some improvement on the OSPAR EcoQO for the proportion of large fish, but it has not been met yet.

At least two commercial species (plaice, sole) are maturing at a younger age and smaller size. This is attributed to intensive exploitation and caused evolutionary changes in age and length at maturation in these species.

Status of commercial shellfish stocks
During the 1990s, the cut trough shell *Spisula subtruncata* was commercially exploited. Over the last decade, its abundance has shown a major and unexplained decline. Nowadays, some fisheries exploit the American jackknife clam, mussels and cockles in the coastal zone.

- **Descriptor 4: Food webs**

Pressures:
As with biological diversity (descriptor 1), many activities and the associated pressures in the Dutch part of the North Sea impact on food webs by affecting species distribution or abundance. The most important activities in this respect are commercial fishing and land-based emissions.

Abundance and status:
The actual design and implementation of indicators for this descriptor is the subject of debate, both nationally and internationally. Current information needs to be complemented by information on other key species or trophic groups in future.

Productivity of key species or trophic groups
The current conservation status of grey seals under the Habitat Directive is “unfavourable-inadequate”. The current conservation status of harbour seals under the Habitat Directive is “favourable”.

The current conservation status of harbour porpoises under the Habitat Directive is “unfavourable-inadequate”. However, the Conservation Plan for the Harbour Porpoises in the Netherlands suggests that a conservation status of “favourable” or “last concern” would be more suitable for the southern North Sea.

The OSPAR EcoQO for proportion of large fish (>40 cm) has declined from more than 30% before 1980 to 10% in 2007, a decline that justifies concern. However, numbers do seem to be increasing again.

Abundance/distribution of key trophic groups/species
The monitoring of by-catch and population estimates of harbour porpoise in the North Sea is inadequate for assessing whether the OSPAR EcoQO for harbour porpoise by-catch is being met.

- **Descriptor 5: Human-induced eutrophication.**

Pressures:
The predominant pressure is the riverine discharge of nutrient-enriched freshwater into the coastal zone.

Abundance and status:
Concentrations of nitrogen and phosphorus in coastal waters have decreased since the 1980s. However, the targets for nitrogen concentrations in coastal waters have not yet been met. This is reflected in biological indicators. Chlorophyll concentrations in coastal waters do not show a clear trend over the period 1990-2009 and the number of blooms of the indicator species *Phaeocystis* is still higher than target levels. As nutrients can be released from enriched soils and sediments for decades, reducing eutrophication is a long-term process.

The effect of eutrophication on the marine ecosystems is that it generally favours opportunistic algae and animals and thus changes species composition. Algal blooms generally decrease light attendance, but this has minimal effects in the relatively turbid North Sea. Oxygen depletion and shifts in phytoplankton composition, with risk of toxic algal blooms are prospected and observed due to changing N/P ratios, but more research is needed to underpin a causal relationship with eutrophication.

- **Descriptor 6: Seafloor integrity**

Pressures:

The main pressures affecting the integrity of the seafloor are related to physical disturbance and extraction of species. Bottom trawling fishing gear (e.g. beam trawls, otter trawls, shrimp trawls) are a dominant source of disturbance. Other activities with strong, but more localized, impacts on the seafloor are the extraction of sand and coastal nourishments. These activities are expected to increase.

Abundance and status:
Physical damage
Physical disturbance of the seabed is keeping benthic communities in an early successional state, indirectly affecting seabed stability, species diversity and associated food webs. Large, long-lived, superficially living species are most vulnerable to physical disturbance. Beam trawling in particular is widespread and intensive in a large part of the Dutch North Sea. It is however expected that fishing methods will become more sustainable, potentially leading to a lower impact on benthic habitats.

Condition of the benthic community
Biogenic substrates are generally sensitive to physical disturbance. Beds of long-lived shellfish or reefs of *Sabellaria* rarely occur. The population of long-lived species, as exemplified by the ocean quahog *Arctica islandica*, is declining in comparison to the 1980s. The tube dwelling polychaete *Lanice conchilega* can be considered a reef-building ecosystem engineer that is relatively resistant to physical disturbance. The impact of physical

disturbance on the associated fauna is more pronounced, but the recovery rate of this species is considered rapid.

- **Descriptor 7: Hydrographical changes**

Pressures:
The dominant pressures relate to large-scale construction activities that result in hydrographical changes, such as altered erosion and sedimentation processes (erosion, sedimentation and physical disturbance of ecosystem).

Abundance and status:
It is certain that past building activities have led to hydrographical changes, especially in estuaries. Evaluating these changes in environmental quality is impossible as no monitoring data are available from before construction began. Possible effects include loss of or damage to coastal habitats and changes to the physical nature of the seabed.

Presently, the extension of the Port of Rotterdam in the Maasvlakte 2 project and the Sand Engine pilot project are both relevant to this descriptor. National regulations for coastal defence often prioritise natural and soft techniques. Compensation measures are consequently taken.

- **Descriptor 8: Contaminants**

Pressures:
Elevated concentrations of contaminants are caused by land-based anthropogenic inputs via rivers, the atmosphere, shipping and oil and gas exploitation.

Abundance and status:
<u>Concentrations of contaminants</u>
Concentrations of chemical substances (excluding nutrients) in water are decreasing and seldom exceed the WFD standards in the North Sea. Only concentrations of TBT are too high in coastal areas, according to the WFD and OSPAR standards. If current efforts continue it is likely that standards for chemical substances will be achieved by 2020. Doses of radioactivity in marine seafood are below the limit value.

In the OSPAR assessments of concentrations in sediments and biota, concentrations of several metals, PCBs and PAHs have a potential for significant adverse effects on the ecosystem. Another list of “substances of special attention” describes substances with potential adverse effects, pending proper assessment. These priority chemicals are pesticides, short-chained chlorinated paraffins (SCCPs), nonylphenol/ethoxylates, TBT, and brominated flame retardants (BDEs).

The discharge of pharmaceuticals and personal care products to the marine environment is increasing. The ecotoxicological risks of these highly biologically active compounds are largely unknown.

<u>Effects of contaminants</u>
Contaminants can affect processes from molecular to ecosystem level by altering the reproduction and survival of organisms (e.g. imposex and fish diseases). The OSPAR assessment criteria set for the EcoQO oiled guillemots and imposex have not yet been met, but if trends continue the goal for oiled guillemots may be achieved by 2020. The TBT problem in sediments will continue for many years due to its persistence, and the assessment criteria set for imposex will not be met by 2020.

- **Descriptor 9: Contaminants in fish and other seafood**

Pressures:
Elevated concentrations of contaminants are caused by land-based anthropogenic inputs via rivers, the atmosphere and by shipping and oil and gas exploitation.

Abundance and status: In both the Dutch Monitoring Programme and the Joint Assessment Programme, none of the maximum permissible levels for food safety is currently being exceeded. Fish and shellfish from relatively contaminated coastal areas show elevated levels, yet all clearly fall below the maximum levels. Some contaminants have no legal limit, but analysis indicates there is no reason for concern.

- **Descriptor 10: Litter**

Pressures:
The main sources of marine litter are shipping, recreation and river discharges.

Abundance and status:
Marine litter affects the seabed, the water column, coastlines and the organisms inhabiting the Dutch part of the North Sea. There is little quantitative information about the weight of litter, nor about its presence in the water column and on the seabed. The data available show that numbers of waste items on the beach have stabilised since 2002. Microscopic plastic particles may be of concern as these are found in the stomachs of organisms. 90% of the fulmar population have these particles in their stomach, exceeding the OSPAR EcoQO for the amount of plastic in fulmars.

- **Descriptor 11: Energy, including underwater noise**

Pressures:
Sources of particularly loud underwater sound include explosive sources (pile driving activities) associated with the installation of offshore windfarms, underwater explosions (nuclear and otherwise, including detonation of old ammunition) and seismic exploration, mainly by the oil and gas industries, echo sounders, shipping and naval sonar operations.

Abundance and status:
Generic guidelines/procedures for the measurement and quantification of underwater sound are lacking at present. It is the extent of the effects from electromagnetic fields and underwater noise that is unknown.

Conclusion

In this report, the environmental status of the Dutch part of the North Sea is presented through an overview of current human activities and associated pressures. “Status”-related descriptors (1) biodiversity, (4) food webs and (6) seafloor integrity are impacted by human activities and related pressures, namely physical damage to habitats, biological disturbance through extraction of species (target and non-target) and enrichment by nutrients. There is a lack of information on any quantitative relationship between human activities, environmental pressures and the current status of the North Sea. Substantial information is lacking for descriptors (10) litter and (11) underwater noise. The related pressures are expected to increase.

More specifically, future knowledge gathering should focus on:

- Biodiversity: Presence and distribution of organisms
- Food web: A description of key species and trophic groups and their interrelationship
- Quantitative relationships between pressures and state descriptors (1) biodiversity, (4) food webs and (6) seafloor integrity e.g.:
    - -Physical damage and benthic communities
    - -Extraction of species and related impact
    - -Amount of litter and impact
    - -Underwater noise and impact
- Assessment of cumulative impact of pressures in time and space.

1 Introduction

1.1 Background

The European Marine Strategy Framework Directive (MSFD) (EC, 2008) 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 (Min. IenM) and the Ministry of Economic Affairs, Agriculture and Innovation (Min. 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 Indicators and Environmental 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 report on the Initial Assessment (this report) gives a description of the current status 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, gives recommendations on the characteristics of Good Environmental Status (Prins et al., 2011). 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.

The report on the establishment of indicators and environmental targets presents a proposal for environmental indicators and targets (Boon et al., 2011). The proposal is based on an elaboration of the criteria and indicators in the Commission decision on criteria and methodological standards for GES in marine waters (EC, 2010) The GES definition 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 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 (anonymus, 2011).

1.2 The Marine Strategy Framework Directive

The European Marine Strategy Framework Directive (MSFD) (EC, 2008) entered into force on 15 July 2008. 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, every 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.

In the Directive it is also stated tha 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,
- introducing the programme of measures, by 2016 at the latest,
- 2020: GES,
- Every six years: update.

1.3 Requirements of the Initial Assessment

Article 8, the MSFD describes the requirements for the Initial Assessment:
Member states must produce:

- an analysis of the essential features and characteristics, and the current environmental status of their marine waters
  - this analysis should be based on an indicative list of elements from Table 1 in Annex III of the MSFD,
- an analysis of the human activities and the predominant pressures and impacts on the environmental status of their marine waters
  - based on an indicative list from Table 2 in Annex II,I
  - dealing with qualitative and quantitative aspects of the various pressures and trends,
  - covering the main cumulative and synergetic effects,
  - taking into account relevant assessments made for existing Community legislation,

- o an economic and social analysis of the use of their marine waters and of the cost of degradation of the marine environment,

The analyses must also take into account other relevant assessments, such as those produced for other EC legislation (e.g. Water Framework Directive) or Regional Sea Conventions (i.e. in the case of Dutch marine waters: OSPAR). Coordination is required to ensure consistency between member states within a marine (sub)region, and to ensure that transboundary impacts are taken into account.

1.4 Approach to the Initial Assessment

The MSFD entered into force on 15 July 2008. Many of the concepts behind the MSFD still need further elaboration. As part of this process, the European Commission asked Joint Research Centre (JRC) and International Council for the Exporation of the Sea (ICES) to provide scientific support and put forward a comparable and consistent interpretation of the concept of GES. This eventually resulted in reports from ten Task Groups, published in April 2010, for each of the qualitative descriptors of Good Environmental Status in Annex I of the MSFD, with the exception of descriptor 7 (Hydrographical conditions). A Commission Decision on criteria and indicators for assessing GES was published on 1 September 2010 (EC, 2010).

Within OSPAR, several working groups are working on recommendations for the implementation of the MSFD in the OSPAR area by means of a harmonised approach. Possible approaches are still in development. There is still a need for further elaboration of the concepts behind the MSFD. It is therefore conceivable that the initial assessment, the set of GES characteristics, the environmental targets and associated indicators produced by 2012 will be nothing more than a first attempt. Much of the required information is still unavailable, and a pragmatic approach is advisable. Further development and refinement will be necessary in the subsequent six-year reporting period.

Given the ongoing process described above, a pragmatic approach has been taken in compiling this report. Extensive analysis of data was not possible within the timeframe available for this report, and the report therefore relies on readily available information and expert knowledge. The OSPAR Quality Status Report was published in 2010 (OSPAR, 2010). This report and the background documentation to the QSR provided valuable information. In addition, information was collected from scientific publications, reports and unpublished material. Although Article 8 of the MSFD does not make reference to Annex I of the MSFD, the assessment of current environmental status focused on the 11 qualitative descriptors for GES from Annex I. This approach was taken to enable a more direct comparison between the present status as described in the Initial Assessment, and GES and the environmental targets and indicators. The description of current environmental status presents the information currently available that is in line with the characteristics of GES and the criteria and indicators mentioned in the Commission Decision (EC, 2010).

The eleven descriptors of the MSFD comprise a system for describing marine ecosystem status. Although not stated in the MSFD, 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 interlinkages between descriptors and pressures. This hierarchy is based on their discrimination between pressures, and the isolated position of descriptors 1 and 4 (biological diversity and food webs, respectively). Borja et al. (2010) suggest that descriptors 1 and 4 should be given greater weight. All other descriptors relate more or less to identifiable pressures, with descriptors 2, 5, 8, 9, 10 and 11 concerning inputs and descriptors 3 and 6 concerning physical and biological extraction from the system. The conceptual model of Borja et al. (2010) emphasizes 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 high-level biological integration.

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) 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 1.1. A few other descriptors (3, 6, 7) are mainly related to physical or biological disturbance, by extraction of species or disturbance of habitats (shown on the left-hand side of Figure 1.1). As suggested by Borja et al. (2010), the descriptors Biological diversity and Food webs are more indirectly influenced by pressures and could be considered to integrate the effects of human pressures on the other descriptors.

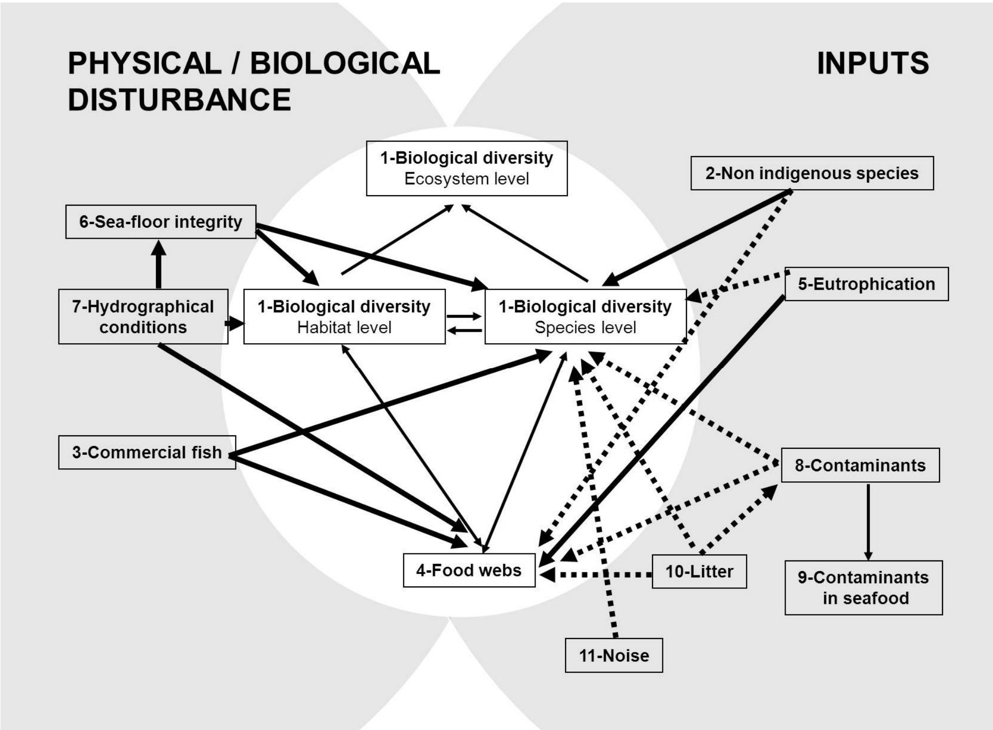


Figure 1.1 Conceptual model showing how the 11 qualitative descriptors are linked. Continuous lines indicate strong links, dotted lines indicate weaker links (adapted from Borja et al., 2010).

1.5 Outline of the report

Chapter 2 gives a general description of the characteristics of the Dutch part of the North Sea, as determined by the physical conditions. An overview of the present human activities in the North Sea, and the predominant pressures caused by these activities is given in Chapter 3. The current environmental status is the result of the conditions determined by the physical environment and the pressures due to human activities. The current environmental status of the Dutch part of the North Sea is specified in Chapter 4. The chapter gives a description of each of the eleven qualitative descriptors for determining GES mentioned in Annex I of the MSFD. Several Annexes at the end of the report provide more detailed information.

2 Description of the Dutch part of the North Sea

2.1 Physical description

The total area of the Greater North Sea is approximately 575,000 km$^{2.}$ Seven countries directly border the North Sea (United Kingdom, France, Belgium, The Netherlands, Germany, Denmark, Sweden and Norway). Two further countries (Luxemburg, Switzerland) partly cover watersheds of rivers that discharge into the North Sea. The Dutch part of the North Sea is situated in the Southern Bight and is approximately 58,000 km^2 (Figure 2.1).

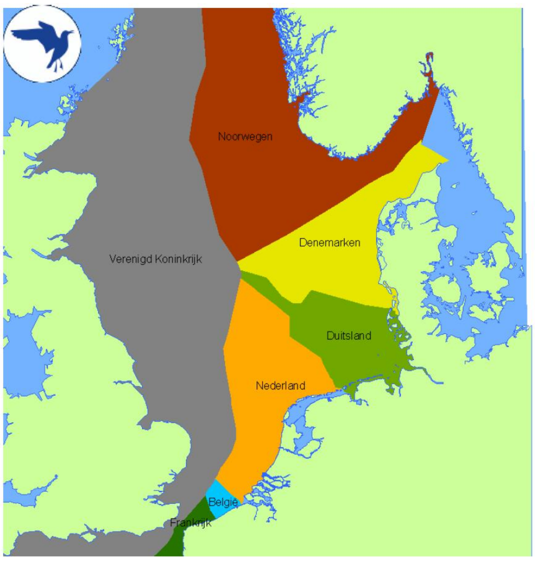


Figure 2.1 The Greater North Sea (www.noordzeeatlas.nl)

Bathymetry

The depth of the Dutch Continental Shelf (DCS) increases from the south and from the coastal waters (< 30m) towards the north (60 – 70m), but on the scale of the greater North Sea (depths up to 200 m on the northern shelf with the exception of some deeper channels, and up to 700 m in the Norwegian Trench) the Dutch sector is relatively shallow (Figure 2.2). The deepest areas of the Dutch EEZ are the Oyster Grounds (~50m) which lie to the north and border on the Dogger Bank in the north-west. In the west, depths of 30-40 m can occur on the Cleaver Bank. Along the southern slope of the Dogger Bank, the eastern edges of the Silver Pit are visible, extending west to the British continental shelf.

Geology and substrate

The North Sea substrate is formed by sedimentary deposits several kilometres thick, which originate from the surrounding landmasses. Some of their strata contain large amounts of liquid and gaseous hydrocarbons, which are intensively exploited. The sediment distribution pattern shows sand and gravel deposits occurring in the shallower areas, whereas fine-grained muddy sediments have accumulated in many of the depressions (e.g. Oyster Grounds, Elbe valley, NW of the Dogger Bank, Devil's Hole and the Fladen Grounds, Figure 2.3). Tidal flats like the Wadden Sea (NL) and the Wash (UK) receive their sediments directly or indirectly from rivers and from adjacent North Sea areas. The suspended particulate matter settles to form either sandy or muddy sediments according to its composition and the predominant local hydrodynamic conditions.

In the Dutch Continental Shelf, different habitat types have been distinguished based on depth and substrate (Figure 2.3). Shallower coastal areas are mainly sandy, whereas the substrate in the northern parts is much finer and muddier. The exception here is the sandy Dogger Bank. In the south, sandbanks are present in the Voordelta, and the Zeeland, Hinder and Flemish Banks are found further off the coast of Zeeland. These are landscapes of sand waves that spread across several kilometres in the direction of the tide. Coarse sand is found on the outside of the Wadden islands, with the coarsest areas situated to the north-west of Texel and Vlieland. The Texel Rocks – relics of the Ice Age – are found in this same area (Leopold and Dankers 1997). Similar rocks have also been found in the “Borkumse Stenen” (Borkum Stones) area near the German border. Away from the coast, the coarsest area is found on the Cleaver Bank. A mosaic of sediment types is found here, consisting of stones, gravel and different sands, as well as old shell material (Laban, 2004).

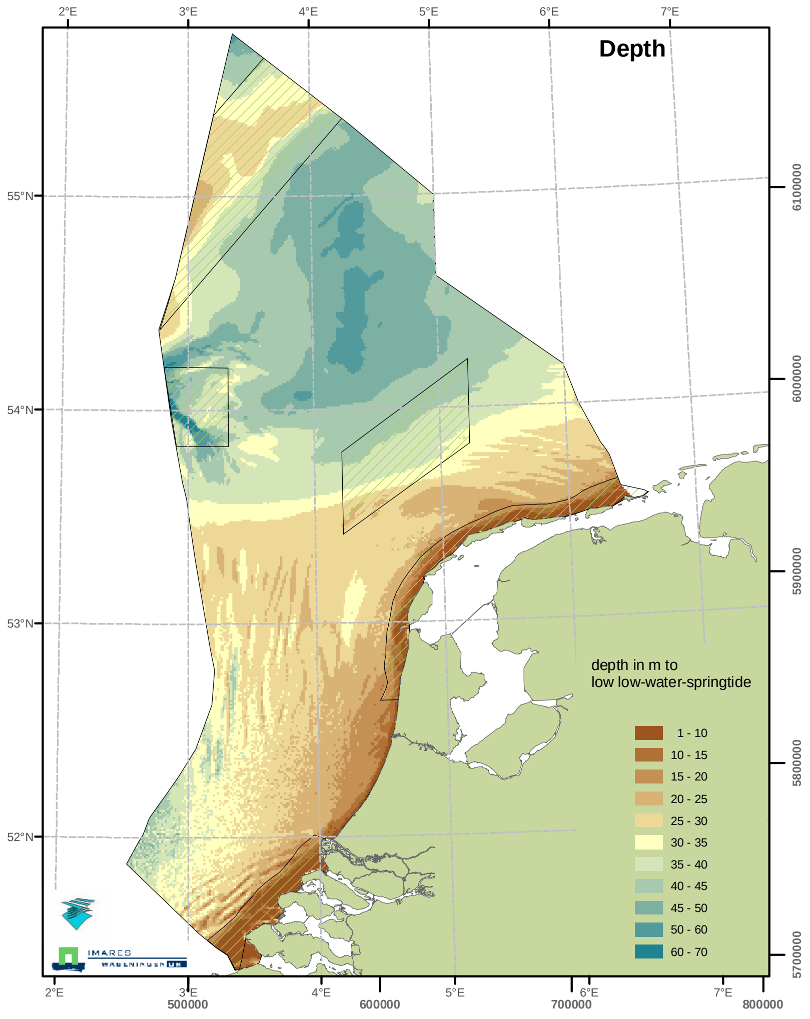


Figure 2.2 Map of bathymetry of the Dutch sector of the North Sea (from Lindeboom et al. 2008)

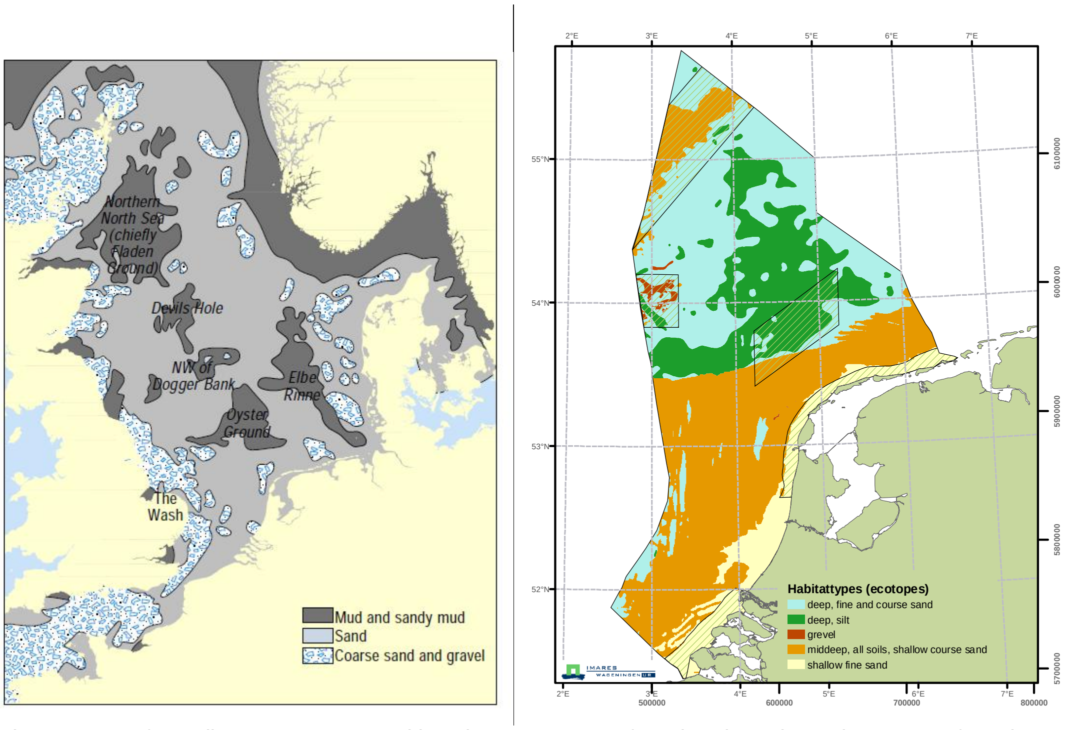


Figure 2.3 Left: Sediment types. Named locations are areas of mud and sandy mud. Source: after Eisma (1981), from OSPAR 2000. Right: habitat types in the Dutch sector of the North Sea (from Lindeboom et al. 2008)

Water masses and circulation

The general circulation pattern in the North Sea is an anticlockwise gyre mainly driven by tidal forcing (Figure 2.4), although the pattern might be reversed or might cease for limited times as a result of wind forcing. Along the Dutch coast, circulation is affected by the inflow of rivers resulting in a northerly oriented residual flow (OSPAR, 2000).

The oceanographic conditions in the North Sea are determined by the inflow of saline Atlantic water through the northern entrances and to a lesser extent through the English Channel, as well as input from rivers (Figure 2.4). Every year, 300 – 350 km^3 of freshwater flow into the North Sea via rivers, most of it originating in Scandinavia. The river Rhine also contributes a large input of freshwater and 92-97 km^3 of freshwater input comes from the Netherlands and Belgium. The water of the shallow North Sea consists of a varying mixture of North Atlantic water and freshwater run-off, whereas the deeper waters of the North Sea consist of relatively pure water of Atlantic origin. Along the continental coast, a coastal river with lower salinity and increased turbidity, strongly influenced by river discharges and freshwater run-off, extends several tens of kilometres offshore (Figure 2.5).

The salinity and temperature characteristics of shallow areas are strongly influenced by heat exchange with the atmosphere and local freshwater supply. Deeper areas are also partly influenced by surface heat exchange (especially winter cooling) and, in certain areas, are slightly modified through mixing with less saline surface water. The inflow of Atlantic water, both from the north and through the Channel, shows large seasonal and inter-annual variability, driven by the North Atlantic Oscillation (NAO) (Pingree, 2005). The NAO winter index, a measure of the atmospheric pressure gradient between the Azores and Iceland, has undergone long-term and short-term fluctuations. High (positive) NAO index values are associated with strong inflow and transport of Atlantic water through the North Sea (Reid et al., 2003). The NAO index shifted to high values from the late 1980s into the early 1990s, followed by a marked drop to a strong negative anomaly in the winter of 1995/96. These were very marked climatic events that have been associated with changes in plankton composition (Planque and Batten, 2000; Beaugrand et al., 2002; Beaugrand, 2003; Reid et al., 2003), fish populations and other biota in the North Sea (Reid and Edwards, 2001, Reid et al., 2001, Edwards et al., 2002, Reid and Beaugrand, 2002). An analysis of data from Dutch and other monitoring programmes in the North Sea also indicates regime shifts in 1979 and 1988 and possibly also in 1998. These regime shifts are evident among various biological data series, and were probably triggered by environmental factors such as salinity, temperature and weather conditions (Weijerman et al., 2005).

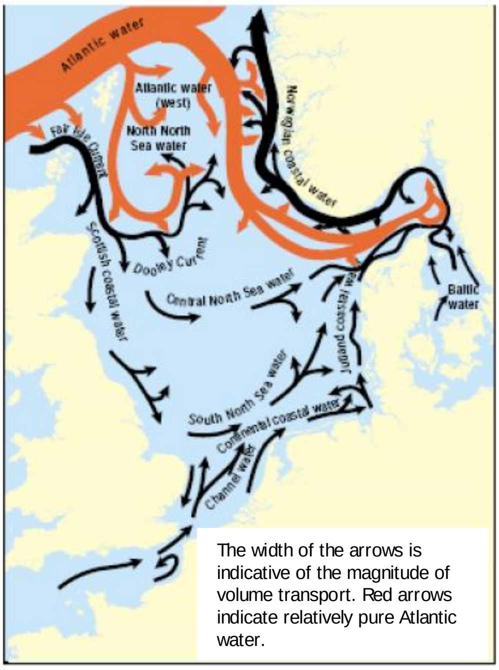


Figure 2.4 General hydrodynamic transport pattern in the Greater North Sea (ICES, 2008)

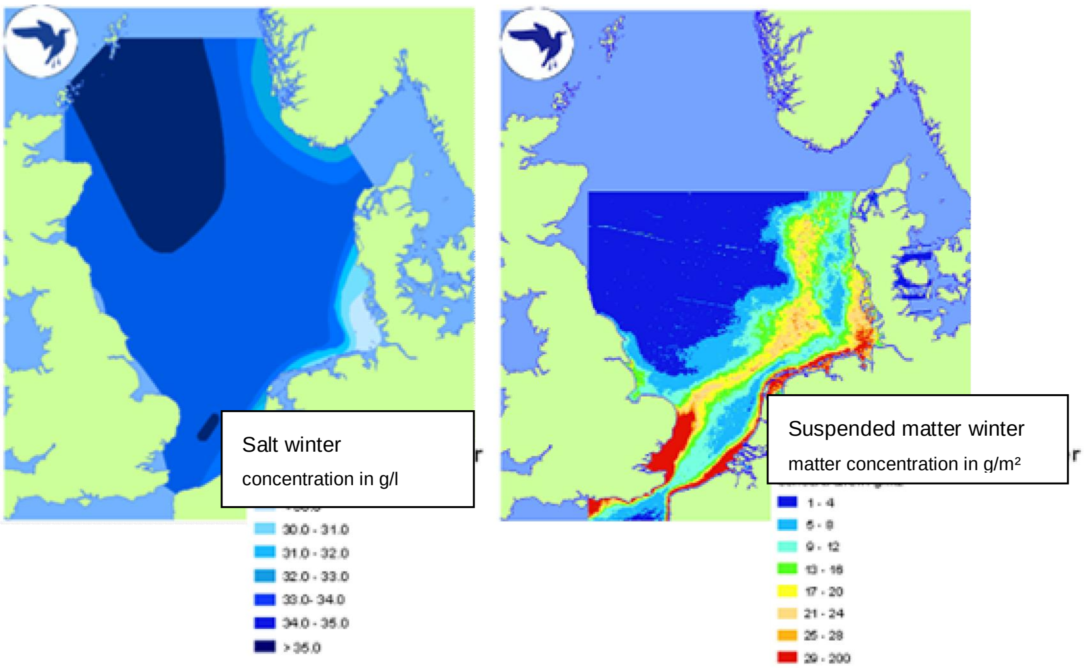


Figure 2.5: Winter mean salinity (left) and suspended matter concentrations (right) in the North Sea (www.noordzeeatlas.nl)

Physical parameters – salinity
In Dutch coastal waters, typical salinity ranges are 27 to 34 although lower salinities occasionally occur in periods with high river discharges. In the open waters, and especially in the western parts of the North Sea, seasonal changes in sea surface salinity (around 35) are comparatively small. However, large inter-annual variability can be seen in the regional distribution of sea surface salinity (SSS) (Figure 2.6), and long-term salinity records of the North Sea also show significant variability (Becker, 1990). High salinities are primarily caused by a combination of reduced freshwater input and vertical mixing, as well as increased influx of Atlantic water. The waters in the Dutch Continental Shelf can vary considerably in salinity due to the different water masses flowing through and the influence of river input, which affect the coastal areas.

Physical parameters – temperature
The temperature of the North Sea is governed by the local effects of solar heating and heat exchange with the atmosphere (ICES, 2005) and through the influx of Atlantic water (Corten and Van de Kamp, 1996). North Sea surface temperatures (SST) show a strong yearly cycle, with amplitudes ranging from 8°C in the Wadden Sea to less than 2 °C at the northern entrances (Figure 2.7-a). The increasing amplitude towards the south-east is related to the greater proportion of low-salinity coastal water and the reduced depth. The long-term annual mean (Figure 2.7-b) shows small differences in the North Sea area with a mean value of about 9.5°C. The shape of the 11°C isotherm indicates the inflow of warmer water from the English Channel into the North Sea. The lowest temperatures (Figure 2.7-c) in the northern Atlantic inflow area decreased over a 25-year period (from 1969 to 1993) by about 1°C. The highest temperatures (Figure 2.7-d) increased in that area by about 1°C, and in the northern North Sea by about 2°C (Becker and Schulz, 2000). Van Aken (2010) has shown that there has been an increase in seawater temperatures since the 1980s. However, this increase is not necessarily caused by global warming but may be due to weather patterns (Van Aken, 2010).

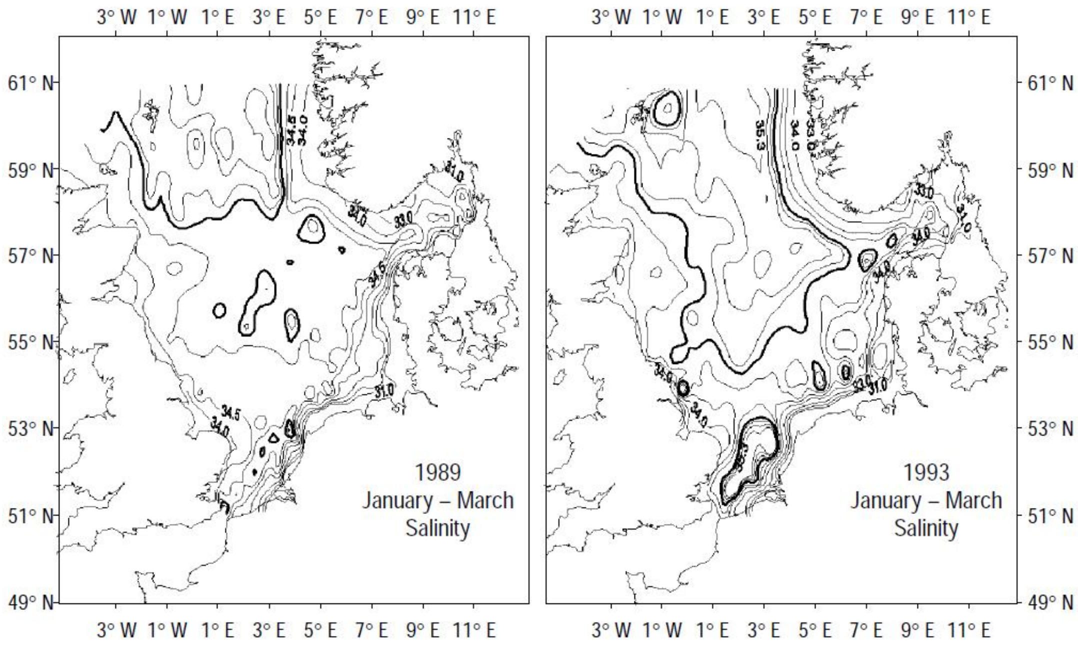


Figure 2.6 Surface salinity distribution for the winters of 1989 and 1993 as an example of interannual variability. Source of data: ICES, from OSPAR 2000.

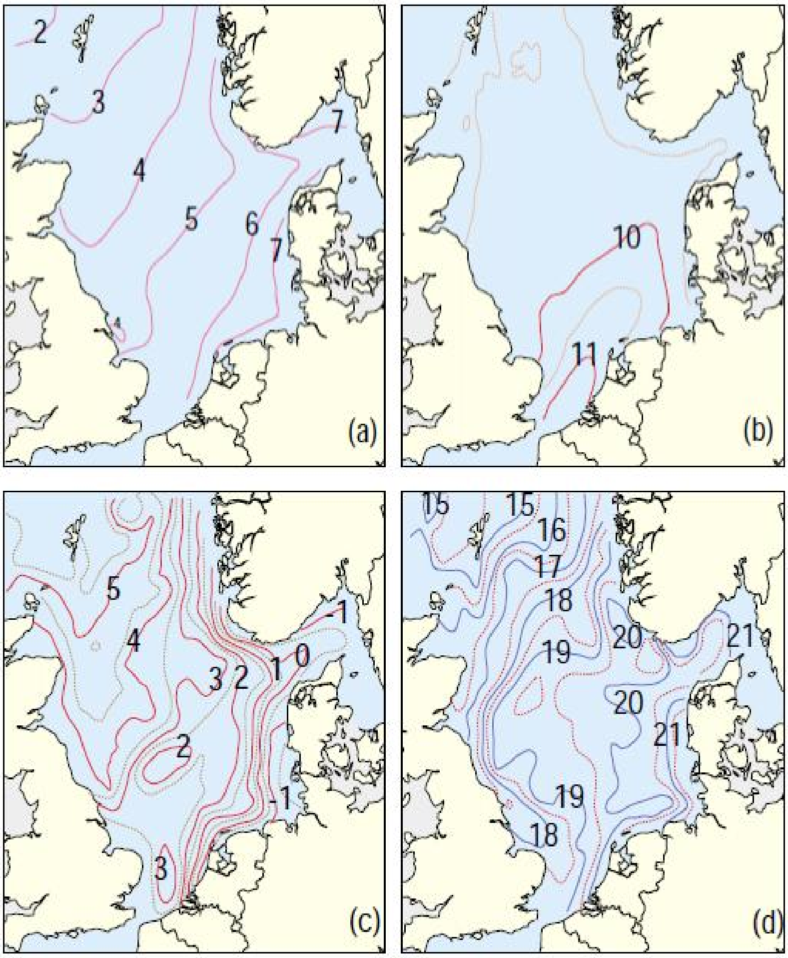


Figure 2.7 The North Sea sea surface temperature distribution in °C (1969–93): (a) amplitude of the yearly cycle; (b) mean; (c) minimum values; (d) maximum values. Source of data: Becker and Schulz (2000), from OSPAR 2000.

Physical parameters – suspended particulate matter concentrations and light transmission

Suspended particulate matter (SPM) concentrations are relative high along the coast, with large natural variability (Figure 2.8). There is a strong cross-shore gradient, and SPM concentrations decrease rapidly to values around 5 mg/l in offshore waters (>20-30 km off the coast). In coastal waters annual average values can reach 30-100 mg/l. Concentrations are higher in winter, and during and after storms SPM levels can be 2-3 times higher than average values in coastal waters. Long-term variability up to a factor 2 occurs under the influence of weather conditions and climatic events like NAO (Suijlen & Duin, 2002).

The light climate in the water column is strongly influenced by local SPM concentrations. In spring the phytoplankton bloom has a relatively small effect (<10-20%) on light attenuation. Due to the high SPM levels near the coast, the average euphotic depth (the depth of the water column where enough light penetrates for photosynthesis) is typically 5-10 m near the coast, and up to 20 m further offshore. Near the coast water depths are approximately twice the euphotic depth, whereas in the relatively shallow offshore areas (<20 m) the euphotic depth approaches water depth (Suijlen & Duin, 2001).

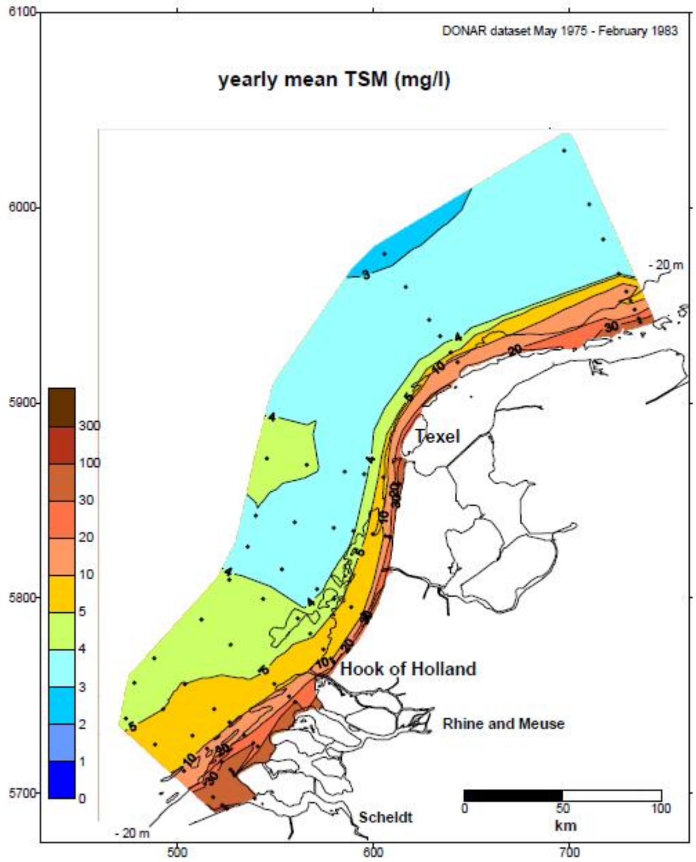


Figure 2.8 Yearly mean near-surface total suspended matter concentrations in the Dutch coastal zone for the period 1975-1983 (Suilen & Duin, 2002).

Fronts

Fronts or frontal zones mark the boundaries between water masses of different physical characteristics and are a common feature in the North Sea (Figure 2.9). Fronts are important because they can restrict horizontal dispersion (e.g. of plankton) and because there is enhanced biological activity in these regions (Becker, 1990). They can also mark areas where surface water is subducted to form deeper water. Three types of front are present in the North Sea: tidal fronts, which mark the offshore limit of regions where tide-induced mixing is sufficient to keep the water column mixed in competition with the heating of the surface layer; upwelling fronts, which form along coasts in stratified areas when the wind forces the surface water away from the coast, thus allowing deep water to surface along the coast; and salinity fronts, which form where low-salinity water meets water of a higher salinity. Tidal fronts develop in summer in the western and southern parts of the North Sea where tidal currents are sufficiently strong. Upwelling fronts are common in the Kattegat, Skagerrak and along the Norwegian coast. Prominent salinity fronts are the Belt front which separates the outflowing Baltic surface water from the Kattegat surface water, the Skagerrak front separating the Kattegat surface water from the Skagerrak surface water and the front on the offshore side of the Norwegian coastal current.

One of the large fronts encountered in the Dutch Continental Shelf is the Frisian front north of the coast of the Dutch Wadden Islands, which forms a boundary between the Atlantic water mass and the freshwater run-off from the Dutch coast. Furthermore, fronts can have currents, meanders and eddies associated with them, which results in strong tidal currents oriented parallel to the coast. In areas such as the Rhine/Meuse outflow, for example, river water spreads along the Dutch coastline. This water overlies the denser, more saline seawater, and a pattern of estuarine circulation is established perpendicular to the coast. Such currents are important to consider for the transport of any contaminants contained in riverine waters, which can be significantly higher close to the coast, even at some distance from the estuary concerned. Abrupt changes in topography as well as unusual weather conditions can cause currents to deviate from this long shore alignment.

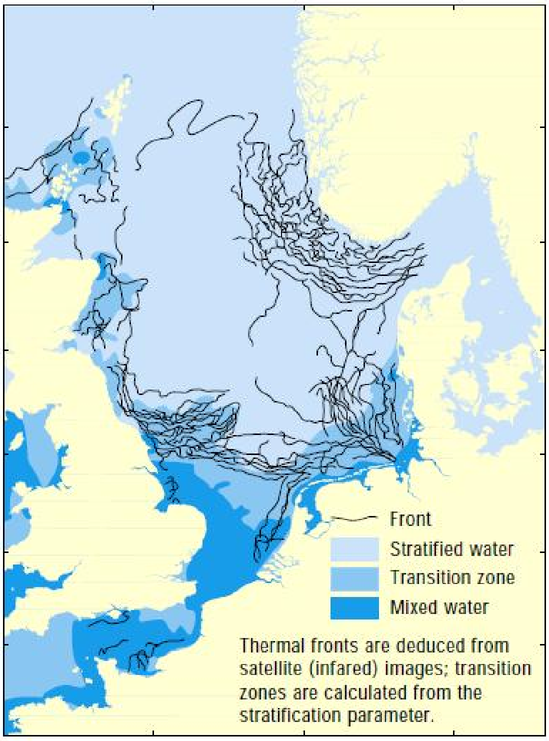


Figure 2.9 Transition zones between mixed and stratified water in the North Sea. Source: Becker (1990).

Stratification and mixing

Stratification occurs when two water masses differ in temperature (thermocline), salinity (halocline), density (pycnocline) and/or oxygen (chemocline) to the extent that mixing between water masses does not occur. Strong haloclines can occur, for example, between inflowing river water and more saline seawater. Thermoclines may occur in deeper waters during the summer when the surface waters are heated by solar radiation. The influence of wind and storms increases mixing between water masses and in winter most areas of the North Sea are well mixed (exceptions are the deep areas of the Norwegian Trench and also the Kattegat and Skagerrak). In late spring, as solar heat input increases, a thermocline (a pronounced vertical temperature gradient) is established over large areas of the North Sea. The thermocline separates a heated and less dense surface layer from the rest of the water column where the winter temperature remains. The strength of the thermocline depends on the heat input and the turbulence generated by the tides and the wind.

Stratification has important effects on the growth of phytoplankton during the summer. Due to the lack of exchange between water masses above and below a thermocline, phytoplankton blooms can deplete the nutrients in the surface layer and nutrients therefore limit further phytoplankton growth.

Figure 2.10 shows a temperature section taken during July 1989 across the Dogger Bank from the island of Terschelling (Dutch Wadden Sea) showing stratification in the deeper areas (Oyster Grounds) but not necessarily above the Dogger Bank or the shallower coastal areas.

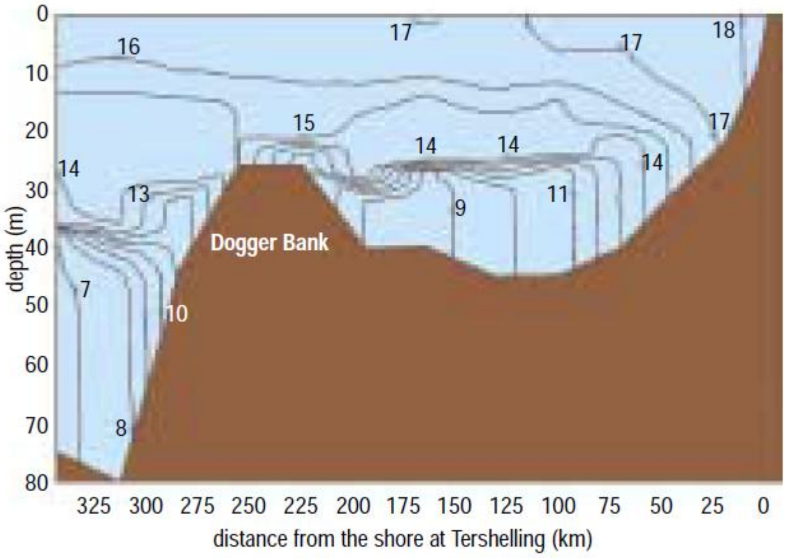


Figure 2.10 Vertical temperature section in °C north-north-west from Terschelling (the Netherlands) taken on 26 July 1989 and showing vertical stratification, from OSPAR (2000).

Nutrients

Key nutrients in the North Sea are nitrogen, phosphorus and silicate. These show strong seasonal patterns with a distinct peak in December/January and a strong decline following the spring phytoplankton bloom. In June/July nutrients can limit primary production, particularly in stratified waters. Nutrients originate from sources on land which are input into the North Sea via rivers and atmospheric deposition (in the case of nitrogen), but also through inputs from the Atlantic Ocean water masses via the north or through the English Channel (Table 2.1). River inputs are the main anthropogenic source of nutrients. In the southern North Sea, the Rhine/Meuse, Seine, Elbe, Weser, Humber and Thames discharge >70% of the total riverine nitrogen and phosphorus loads. Channel water is the source of approximately 40% of the total N load and 70% of the total P load in the southern North Sea (Blauw et al., 2006). Due to the much higher nutrient concentrations in freshwater compared to oceanic water, nutrient concentrations are high near the coast and decrease strongly offshore, in line with the salinity gradient.

Table 2.1 Summary of characteristic values for physico-chemical parameters. Values are ranges or 90th percentile values, based on results from routine monitoring in the MWTL programme for 1990-2009.

	Coastal waters	Offshore waters
Salinity	20-34	34-35.5
Temperature (ºC)	2-21	5-19
Oxygen (mg/l)	6-10	6-10
pH	7.7-8.7	7.7-8.4
SPM (mg/l)	2-100	1-18
Total nitrogen (µM)	80	16
Total phosphorus (µM)	3.1	0.9

2.2 Ecological functions and subdivisions

The North Sea is a highly productive sea, with strong interaction between benthic and pelagic processes. With the exception of the deeper waters along the Norwegian coast the North Sea belongs to the cool-temperate, boreal biogeographical zone.

In the Dutch part of the North Sea, a distinction is generally drawn between the coastal waters, the offshore waters of the Southern Bight, the Frisian Front and the area north of the Frisian Front, which differ in both abiotic conditions and biological characteristics. Several areas are distinguished that are considered to be ecologically valuable (Figure 2.11) Table 2.2 is an overall profile of these areas (VenW, 2009):

Table 2.2 Areas that are considered to be ecologically valuable

Dogger Bank: The Dogger Bank is the area where the northern and southern fauna in the North Sea meet. The Dutch part of this sandbank is located at a depth of more than 20 metres. The most typical sandbank community is found in the shallowest part of the sandbank. It is a spawning ground for various species of fish, which draws seabirds to the area to forage.
Cleaver Bank (Klaver Bank): This is a reef area transected by a deep trough rich in fish. There is a wide variety of benthic life, including dead man's fingers, a type of coral. There are many sea birds and sea mammals.
Frisian Front (Friese Front): This front is the transition between shallow sandy soils and deeper silty soils. Rich in nutrients, the area attracts benthic life, fish, marine mammals and sea birds such as the guillemot and the great skua.
Brown Ridge (Bruine Bank): Not particularly rich in benthic fauna, but there are many fish on this high sand bank surrounded by deep sea. It is a spawning ground for flatfish. There are many porpoises in the area. In winter, there are many sea birds (including guillemots), particularly in the south-eastern part.
Central Oyster Grounds (Centrale Oestergronden): The silty soil holds a variety of benthic life. In summer, large numbers of fulmar come here to forage. It is also home to the long-lived ocean quahog, although this shellfish species appears in larger numbers to the north-west of the area.
Gas Seeps (Gasfonteinen): While gas fountains have been found in this area, the hard substrate that can form and the associated typical benthic life have not been demonstrated. Gas is also bubbling up in various locations on the Dogger Bank. Methane-loving bacteria have been found near these seeps.
Borkum Stones (Borkumse Stenen): Ongoing research should demonstrate the presence of reef structures in this area. Several boulders have been found recently. The area is used as a feeding ground by seals, and porpoises have been sighted.
Zeeuwse Banks: Landward, these sandbanks merge into the coastal zone. Shell deposits are typical of the area. Red-throated divers have also been seen here.

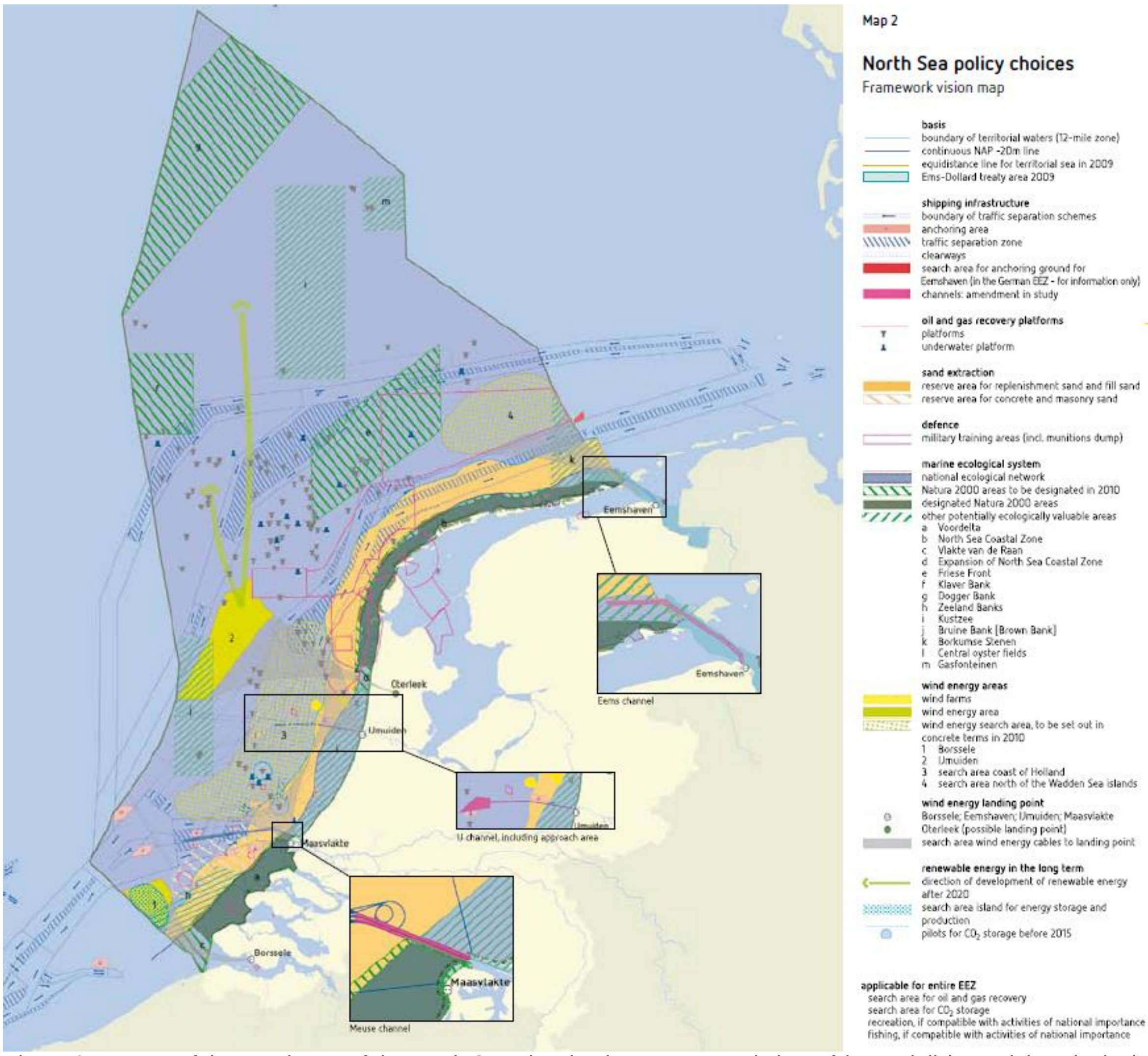


Figure 2.11 Map of the Dutch part of the North Sea showing human use and sites of (potentially) special ecological importance (VenW, 2009).

2.3 Climate change

This general description of the effects of climate change in the North East Atlantic is based on the effects of climate change in the North East Atlantic identified in the OSPAR Quality Status report (OSPAR, 2010), with some specific additional information pertaining to the Netherlands.

Continued emissions of greenhouse gasses at or above current levels are expected to cause further warming and to cause further changes in the global climate system during the 21st century. The changing climate has been linked to a wide range of impacts on marine ecosystems, both directly (through changes in sea temperatures) and indirectly (through impacts on the seasonality, distribution and abundance of species). There are many uncertainties in the scenarios for future greenhouse gas emissions and in model forecasts. This, together with the need to better understand how marine ecosystems respond to change, makes it difficult to predict impacts of future climate change on marine ecosystems.

A range of potential climate change impacts are predicted for the various components of the marine ecosystem (OSPAR, 2010) in Table 2.3:

Table 2.3 Potential climate change impacts for the various components of the marine ecosystem

Increased sea temperatures*: Since 1994 the seawater has warmed at a greater rate in the North Sea than the global mean and an increase in sea surface temperature of 1-2 ºC has been observed since the 1980s. Further warming is expected.
Increased freshwater input (specifically near the poles).
Shelf sea stratification*: In recent years there has been evidence of earlier stratification and onset of the associated microalgal bloom. In the future, the shelf seas may thermally stratify more strongly and for longer.
Increased storms*: Severe winds and mean wave heights increased over the past 50 years, but similar wind strengths also occurred in previous decades. Projections of storms in the future climate are very low-confidence.
Sea-level rise: The global sea level rose on average by 1.7mm/yr throughout the 20th century. A faster rate of sea-level rise was evident in the 1990s. For the Netherlands, scenarios for coastal protection assume a maximum sea level rise of 1.3 metres by 2100 (VenW, 2009).
Reduced CO_2 uptake: In the North-Atlantic a reduced flux of CO_2 into surface waters was observed in 2002-2005 compared to 1994. CO_2 uptake is dependent on water temperature, stratification and circulation.
Acidification*: Since the start of the industrial revolution, a global average decrease in pH of 0.1 units has occurred. During the 21st century ocean acidity could reach levels unprecedented in the last few million years, with potentially severe effects on calcareous organisms.
Coastal erosion: In many areas the combined effects of coastal erosion, infrastructure and sea defence development have led to a narrow coastal zone. Predictions of what might happen in the future are very uncertain and highly location-specific.
Nutrient enrichment: Drier summers may already be contributing to a decrease in nutrient inputs. Higher nutrient input in wet years has caused harmful algal blooms. Predictions are linked to a number of factors.
Reduced Atlantic overturning circulation. Is very likely.
Reduced sea ice. At the poles.

*topics with additional information given below

Temperature

One of the longest time series of temperature measurements in the North Sea consists of the data from Helgoland in the inner German Bight. Observations began in the 1870s and have continued until the present day. Data gaps, especially between 1945 and 1960, were filled with corrected data from nearby Light Vessel. The time series shows a remarkable annual, inter-annual and decadal variability (Figure 2.12). The SST series shows a weak positive trend which is in agreement with the global temperature increase of about 0.6°C/100 yrs. The positive trend can be largely related to a more step-wise increase between 1989 and 1994, which was due mainly to milder winters. Average winter temperatures increased by approximately 1.6°C between 1980 and 2004, and the majority of this increase occurred from 1988 to 1989, when a rise of 1°C was observed (Figure 2.13; Dulvy et al. 2008). Since then temperatures have remained at this higher level and continued to rise. Cold years (e.g. 1963, 1996) are related to extremely cold winters.

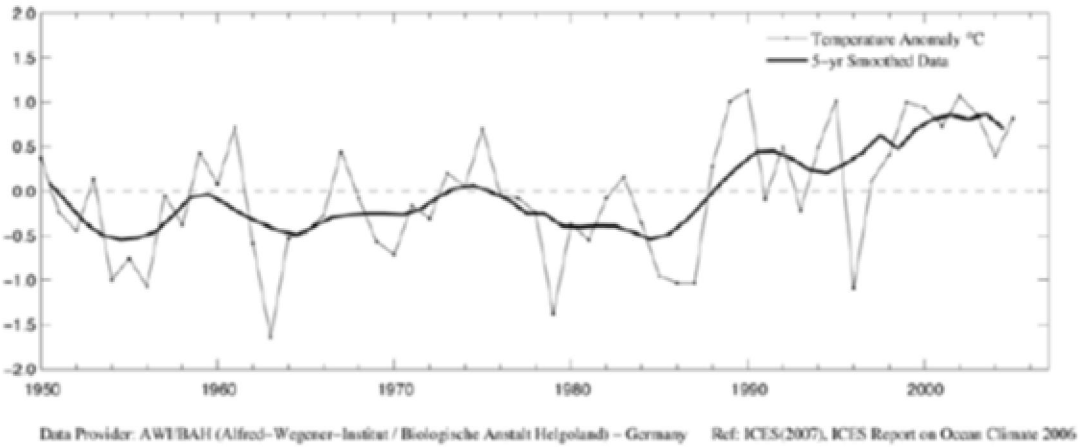


Figure 2.12 Annual mean surface temperature anomaly at Helgoland Roads Station as representative of the southern North Sea (from ICES, 2008).

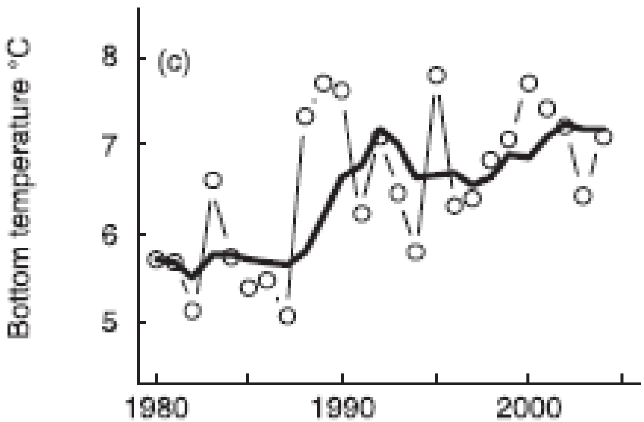


Figure 2.13 Average winter bottom temperature (from Dulvy et al. , 2008).

Stratification

Changes in stratification can be expected if changes in temperature, wind and circulation patterns occur. Higher temperatures can increase the area and/or the duration of stratification. The extent and duration of stratification can have profound impacts on the biology due to its effects on nutrient flux and oxygen concentrations in the bottom layer.

Increased storms

Storm surges can occur in the North Sea, especially along the Belgian, Dutch, German and Danish coasts during severe storms. They sometimes cause extremely high water levels, especially when they coincide with spring tides. The Royal Netherlands Meteorological Institute (KNMI) website reports an increase in the number of days per year on which the wind comes from the south-west, raising air temperatures across the Netherlands, as well as a decrease in the number of storms over the period 1962 – 2002 (Smits et al., 2005). Long-term trends in wind are however difficult to determine due to the large daily and seasonal variability, as well as spatial differences inherent in wind data.

Acidification
Since the industrial revolution, atmospheric carbon dioxide levels have risen by nearly 40% from pre-industrial levels (Doney et al., 2009). The oceans are a huge carbon sink, absorbing up to 30% of this carbon dioxide (Sabine & Feely, 2004). The dissolved carbon dioxide reacts with the seawater and forms carbonic acid, decreasing carbonate ions and increasing hydrogen (H+) concentration, thus making the water more acidic (Caldeira & Wickett, 2003). The reduced pH alters important chemical balances within the ocean. The average global ocean pH declined by 0.1 units in the 20th century, and is expected to continue to decrease by up to 0.5 units by the end of the 21st century (Caldeira & Wickett, 2005). Note that the acidity of the oceans is measured in pH, which is presented on a logarithmic scale. Small changes in reported pH values therefore represent considerable changes in ocean acidity.

Since 1975, the routine Dutch monitoring programme has included systematic measurement of pH in the North Sea and adjacent estuarine and coastal waters. A number of methodological problems (to which pH measurements are very sensitive) and missing data make it difficult to interpret the trends directly (Provoost et al. 2010). Provoost et al. (2010) therefore came up with a method of analysing these data and looking at seasonal and inter-annual variability. They found that the amplitude of the seasonal signal varies between 0 and 0.6 pH units, and clearly correlates with system productivity (Figure 2.14); (Provoost et al. 2010).

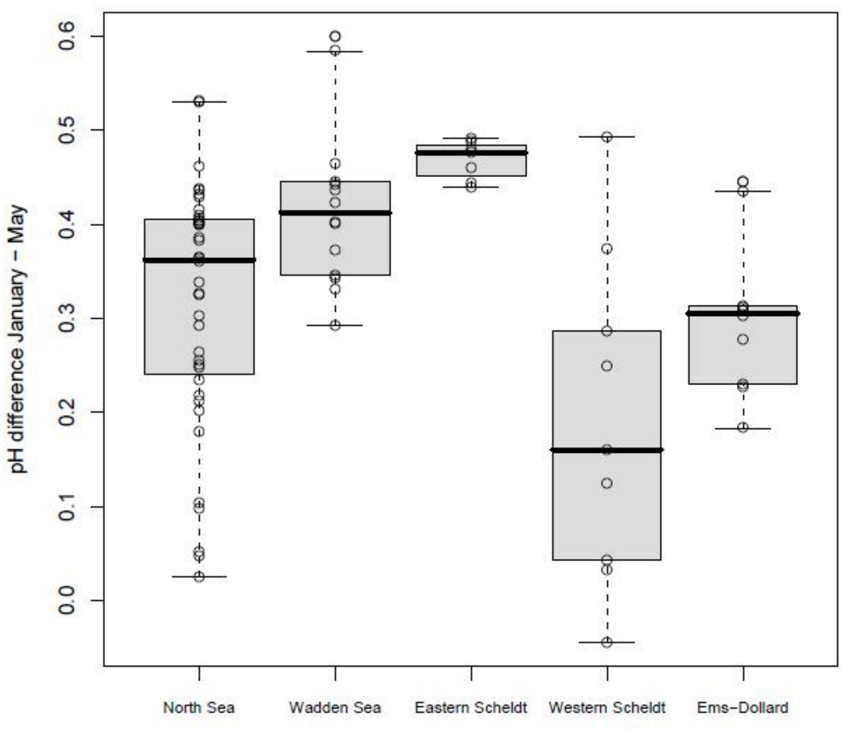


Figure 2.14 Per station seasonal amplitudes for the different geographical areas (from Provoost et al., 2010).

Accordingly, seasonal pH differences can be primarily attributed to the shifting balance of production and respiration processes over the season, with pH increases in spring when production increases faster than respiration and, conversely, pH decreases in summer and autumn when respiration processes are more important than primary production. Long-term trends were also found to be system-dependent (Figure 2.15; Provoost et al., 2010) and observed rates of change differed in sign and magnitude from those calculated from atmospheric CO_2 projections (declines of 0.0013–0.0020 unit per year). This shows the importance of other processes that are at play which may be more important than CO_2 uptake, at least in coastal systems.

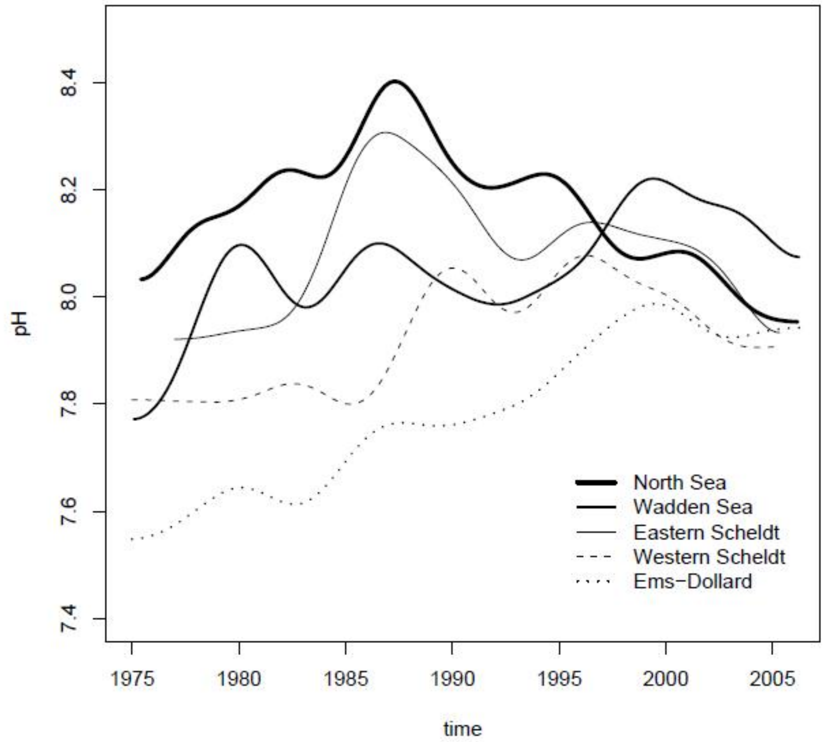


Figure 2.15 Summary of the long-term signals from selected stations on the Dutch Continental Shelf (from Provoost et al. 2010).

Primary production, for example, will increase the pH value by about 1.3×10^{-3} per μM carbon at pH~8 (Soetaert et al., 2007). Nitrification, on the other hand, decreases pH by about 2.5×10^{-3} per μM carbon under the same conditions. Aerobic respiration tends to lower pH, while denitrification and sulphate reduction in the sediment increase pH. Outgassing of CO_2 in estuaries and river mouths results in an increase in pH (1.5×10^{-3} per μM carbon). Calcification and carbonate dissolution lead to a lowering and an increase in pH, respectively. The coastal systems on the Dutch Continental Shelf have experienced major changes in their biogeochemical functioning and this seems to be reflected in their long-term pH evolution. The drop in pH in the North Sea appeared to be greater (0.3 units) than the expected 0.1 pH unit which has been caused by acidification in the last two decades. The additional 0.2 pH unit is probably caused by major changes in the production-mineralisation cycle due to lower nitrogen inputs from rivers. The potential effects of ocean acidification on marine ecosystems are still the subject of intense scientific scrutiny, but these effects appear to be predominantly negative. Much of the research focuses on the effects of ocean acidification on calcifying organisms, such as shellfish, corals and echinoderms. Acidification reduces the $CaCO_3$ (calcium carbonate) saturation state, making it difficult for calcifying organisms to build and maintain their skeletons and shells (Doney et al., 2009). In addition to affecting calcification, ocean acidification is likely to affect the larval and juvenile stages of many marine invertebrates (Dupont et al., 2008), with reverberating effects through trophic levels, indirectly affecting non-calcifying organisms. Furthermore, even when long-term averages do not appear to show dramatic changes, the seasonality of ocean pH and the effects of local and temporal extreme values need to be considered.

Nutrient enrichment
The input of nutrients is related to the input of water, either through oceanic water masses or freshwater input from rivers. Changes in circulation patterns and river-run off will therefore impact on nutrient concentrations in the North Sea.

Many of the observed physical and chemical changes are consistent with increasing atmospheric CO_2 and a warming climate (rising sea temperature, reduced sea ice and acidification) but many of the causative links to climate change are still not well understood. It is therefore difficult to predict the precise rate and magnitude of change, as well as the direction of change in, for example, ocean uptake of CO_2, salinity, storminess and nutrient enrichment, and to map impacts at local level. Physical and chemical changes have been directly linked to impacts on marine organisms (range shifts in plankton, fish and intertidal species communities) and are suggested to have important secondary effects on factors such as prey availability for seabirds. Uncertainties about the physical changes that will occur makes it difficult however, to predict things like the effects of stratification on primary production, storminess on seabird nesting sites or nutrient enrichment on harmful algae blooms. The understanding of the links between climate change and impacts on marine ecosystems also remains limited due to a lack of data (e.g. marine mammals; benthic ecology; intertidal communities) and difficulties in establishing local effects. The possible impacts of climate change on the biological marine environment are summarized in Table 2.4 (OSPAR, 2010):

Table 2.4 Impacts of climate change on the biological marine environment

Plankton: Over the last 50 years a 1000 km northward shift of many plankton species has been observed. The timing of seasonal plankton blooms is changing.
Harmful algal blooms: In areas affected by lower salinities and higher temperature, harmful algal blooms have occurred. Increasing incidence is the result of changes in sea temperature, salinity and stratification.
Fish: Northward shifts of both bottom-dwelling and pelagic fish have occurred. A lack of knowledge of the underlying mechanisms of these shifts makes projections uncertain. Increased temperatures could increase the incidence of disease in farmed species of fish and shellfish
Marine mammals: The impact mainly concerns more northerly regions, where the loss of sea ice can result in a loss of habitat and might change the availability of prey species.
Seabirds: Impacts on seabirds are likely to be caused more by changes in their food supply than by loss of nesting sites due to changed weather.
Non-indigenous species: Increased invasions and establishment may be facilitated by climate change and pose a high risk to existing ecosystems. The establishment of the Pacific oyster (*Crassostrea gigas*) has been linked to climate change.
Intertidal communities: Warm water intertidal species might expand their distribution range, as already observed in the UK.
Benthic ecology: Benthic sessile organisms are largely tolerant to moderate environmental changes over reasonable adaptive time scales, but are very vulnerable to abrupt and extreme events.

3 Human activities and pressures on the ecosystem

3.1 Introduction

The Dutch part of the North Sea is one of the most intensively exploited seas in the world (VenW, 2009). In addition to the exploitation of living resources (shrimp trawling, demersal and pelagic fisheries) the area is used for several other human activities. It is used for maritime transportation to and from several large ports in Belgium and the Netherlands, and busy shipping lanes to the Atlantic, northern Germany and the Baltic cross the area. Other human activities are oil and gas exploitation, tourism and recreation, cables and pipelines, sand and gravel extraction, coastal nourishments, dredging and relocation of dredged materials, military activities, and the construction and use of wind farms for renewable energy. Several areas have been designated protected areas under the Birds and Habitat Directives (Figure 3.1). In some cases the human activities concern cross-border activities that are not restricted to the Dutch part of the North Sea, as in the case of maritime transport or networks of cables and pipelines.

In the past, infrastructural works for coastal defences have altered the exchange between the North Sea and estuaries in the SW Netherlands. At present, a land reclamation project is underway for the extension of the Port of Rotterdam (the Maasvlakte 2 project), and along the entire coastline coastal nourishments are being carried out to protect the sandy coast from erosion.

These human activities exert biological, physical and chemical pressures on the marine ecosystem. Some of these activities in the Dutch part of the North Sea, like the construction of offshore windfarms and sand extraction for coastal protection, are expected to intensify over the coming decades.

In addition to activities at sea, some land-based activities also impact on the marine environment. Emissions from point and diffuse sources on land can reach the sea, either through the inland water system, resulting in river discharges of substances, or through the atmosphere, resulting in atmospheric deposition at sea.

Finally, the Dutch part of the North Sea is an open ecosystem, forming part of a highly dynamic shelf sea where transport processes and migration of animals connect the various parts of the North Sea and connect it with the North East Atlantic Ocean. The environmental status of the Dutch part of the North Sea is influenced by activities in the various river basins discharging into the North Sea and in other parts of the North Sea. Activities in the Dutch part of the North Sea can also influence the environmental status of other parts of the North Sea.

The following sections describe current human activities in the Dutch part of the North Sea, the expected developments in these activities until 2020, and the associated pressures on the environment. The descriptions are based on general information from various sources (Voet & Budding, 2008; VenW, 2009; www.noordzeeloket.nl) and additional references cited in the text.

The final two sections of this chapter describe the links between human activities, pressures and the potential effects on the environmental status, and present a preliminary assessment of cumulative effects in the Dutch part of the North Sea.

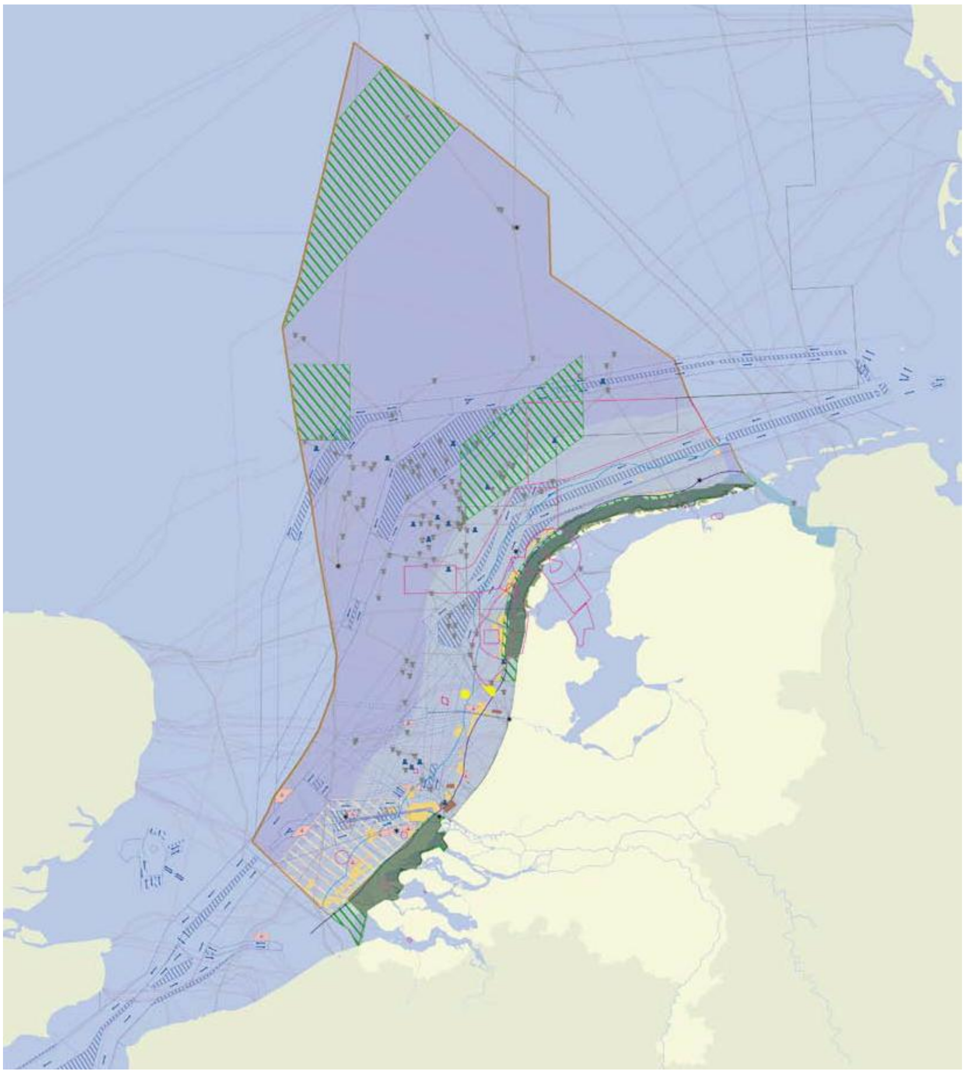


Figure 3.1 Map of the current human activity in the Dutch part of the North Sea (VenW, 2009).

3.2 Aggregate and shell extraction

3.2.1 Current situation

The Netherlands extracts large volumes of sand from the North Sea – currently in excess of 25 million m^3 every year, more than any other country around the North Sea. Some 12 million m^3 per year is extracted for coastal nourishment. Marine sand is also used on land at construction sites (approx. 13 million m^3/year). Sand extraction generally occurs offshore from the 20 m depth contour (Figure 3.2). The sand pits that are created are relatively shallow (no deeper than 2 metres). Though the licensed extraction area is much larger (approx. 450-600 km^2), 90% of the material extracted in the Netherlands was taken from 7.5 km^2 in 2006, 9.2 km^2 in 2007, 8.3km^2 in 2008 and 23 km^2 in 2009 (ICES, 2010).
Since 2009, much higher volumes have been extracted. 30 million m3 was extracted in 2009 for large projects to nourish beaches at potential future risk due to sea-level rise. In addition, a large increase in extraction levels has resulted from the Maasvlakte 2 port development project, which will require 210 million m3 in its first phase (V&W, 2009). The sand needed for the land reclamation project to extend the Port of Rotterdam (the Maasvlakte 2 project) is

being extracted from one site. The project will require an extremely large-scale extraction of marine sand (up to 365 million m^3). For this purpose, a sand pit with a maximum depth of 20 m will be created. The total surface area of the extraction site will be approximately 15 km^2. Significant coastal defence works, such as the Sand Engine project (approximately 20 million m^3 in 2011), are likely to keep demand for Dutch marine sand high for some time (ICES, 2010).
Only minor amounts of coarse sand for industrial use are extracted from the Dutch part of the North Sea. Gravel is extracted in only small volumes as a by-product of sand extraction.
Potential extraction sites for concrete and masonry sand are found in the area off the coast of the SW Netherlands (Figure 3.2). As this sand is located some metres below the seabed, large quantities of sand would also have to be removed from the top layer before the concrete and masonry sand could be extracted. No extraction is expected at these sites in the short term.

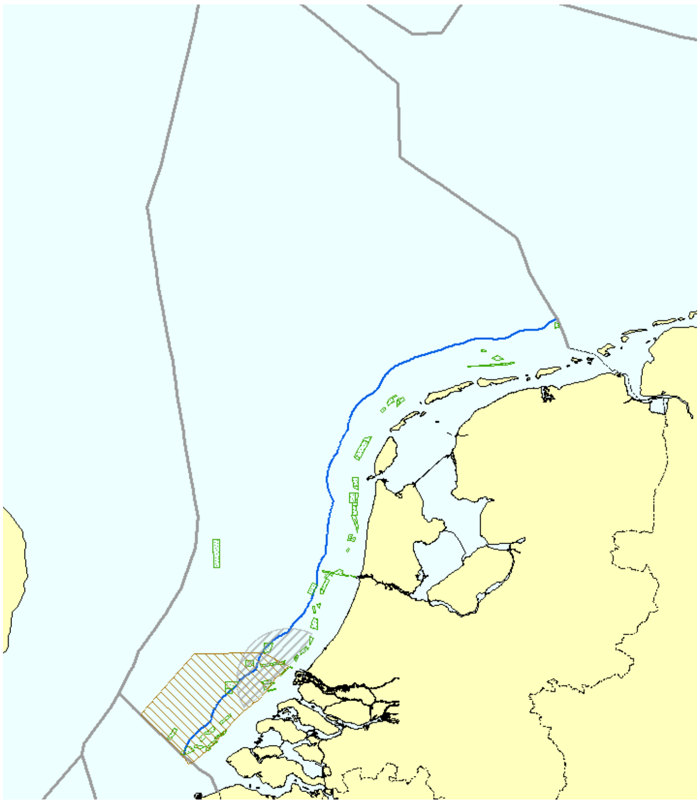


Figure 3.2 Map showing the sites where sand extraction is permitted (green areas), the site used for sand extraction for the Maasvlakte2 project (right-hatched area) and the site reserved for the extraction of concrete and masonry sand (left-hatched area) (www.noordzeeloket.nl). Note that actual extraction occurs over a much smaller area.

In addition to sand, fossil shells are also extracted at sea. The maximum permissible amounts for extraction are approx. 26 million m^3 in the Voordelta and 81 million m^3 in other parts of the North Sea. The shells are sold for a variety of purposes, such as paving, drainage and farming. The majority are cockles Cerastoderma edula, which occur in high densities in the Wadden Sea.

3.2.2 Future developments

The Netherlands is prone to flooding by the sea. To protect this low-lying country, the coastline is maintained and defended. Coastal nourishments to maintain the sandy coasts have been carried out since 1990, using sand extracted further offshore (on the seaward side of the 20 m depth contour).

An increase in sand extraction is expected over the coming decades. To compensate for the present rate of sea-level rise the amount of sand extracted for coastal nourishments will increase from 12 to 20 million m^3 per year. Any acceleration in sea-level rise will increase this amount further. In the extreme scenario of a sea-level rise of 130 cm by the year 2100, 85 million m^3 per year will be needed by the end of the century.

An increase in sand extraction for use at construction sites on land of up to 25 million m^3 per year is considered a possibility.

Apart from the above-mentioned volumes of sand extraction, sand may also be needed for large infrastructural projects. 20 million m^3 would for example be needed for the construction of the Western Scheldt Container Terminal in the port of Vlissingen. A seaward extension of the coastline by one kilometre has also been suggested. This would result in an additional demand of up to 40 million m^3 per year. The Sand Engine experiment requires ~25 million m3, which will be extracted in 2011. This should last for approx. 5 years, after which a further suppletion may be required if the experiment is to be continued.

The above-mentioned increases in sand extraction are expected to occur over the long term. Little or no increase is expected in the period to 2020.

3.2.3 Pressures

The main pressure related to sand extraction is physical damage (selective extraction, abrasion and changes in siltation). Sand extraction is a source of underwater noise, and also results in biological disturbance of the benthic community at the site of extraction (V&W, 2009). Recolonization of extraction sites takes 4-6 years. Minor effects include the release of substances from the sediment (e.g. organic matter, sulphides, ammonium, metals) to the water column. The chemical effects of aggregate dredging are however likely to be minor due to the very low organic and clay mineral content of most commercial aggregate deposits in tidal environments. The impacts of sand extraction are mainly local.

The duration of the extraction of marine aggregates at a specific site depends on several factors: the volume of dredged material, the type of material, the equipment used and environmental factors as wind, waves, etc. Dredging can last from months to years.

The pressures are summarised in Table 3.3.

3.3 Coastal defence

3.3.1 Current situation

To protect this low-lying country, the sandy coastline of the Netherlands is maintained and defended. Since 1990, management of the coastline has focused on dynamically maintaining the coastline at its present position. Since 2001, the total volume of sand present in the coastal area between the dunes and the 20 m depth contour (known as the “Kustfundament”) have been maintained. This is done by means of coastal nourishments, using sand extracted from sites further offshore to nourish beaches or the littoral zone (up to a depth of approx. 8 m). The nourishments are increasingly being carried out in the littoral zone, while beach nourishments are decreasing (Figure 3.3). Each year a decision is made on the nourishments that are needed that year. The nourishments aim to ensure that the coast is protected for at least the next 50 years. The total volume of nourishments is approximately 12 million m^3 per year, the total length is 18 km per year on average (Figure 3.4).

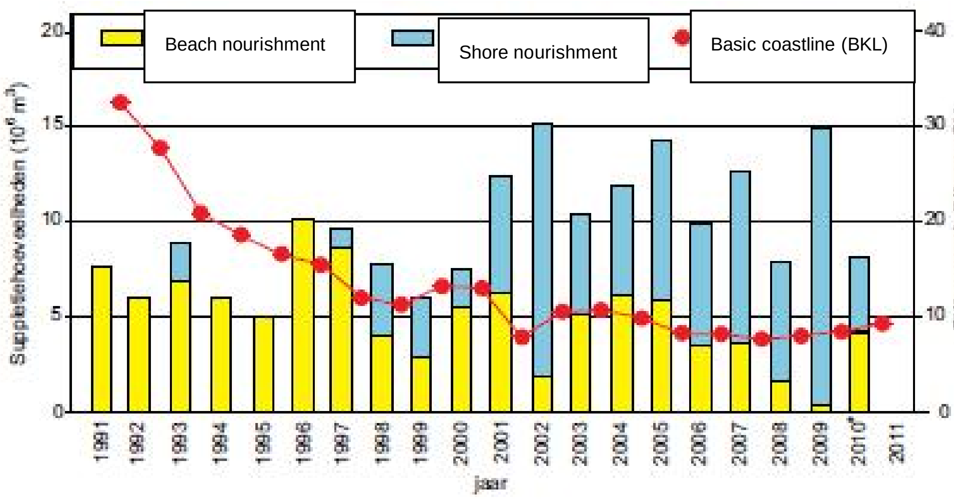


Figure 3.3 Total volume of coastal nourishments carried out since 1991, on beaches (yellow) and in the littoral zone (blue) (RWS, 2011).

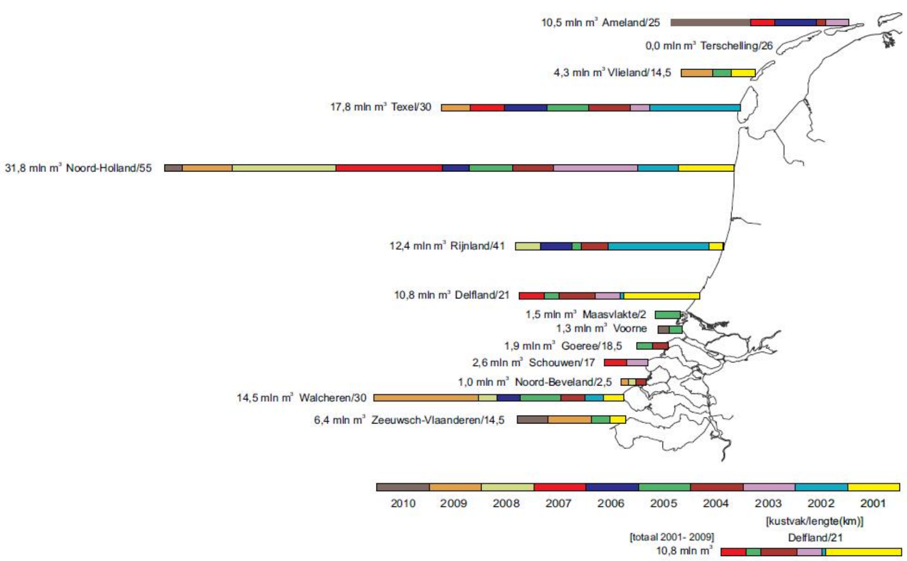


Figure 3.4 Total volume (million m^3) and length (km) of nourishments carried out along various stretches of the Dutch coast in the period 2001-2010 (RWS, 2011).

3.3.2 Future developments

The volume of coastal nourishments is forecast to increase to 20 million m^3 per year, to keep up with the present rate of sea-level rise. If there is an acceleration in sea-level rise the amount will increase further, and in the extreme scenario of a sea-level rise of 130 cm by the year 2100, 85 million m^3 per year will be needed by the end of the century.

3.3.3 Pressures

The main pressure caused by coastal nourishments is temporary or permanent physical loss of habitat through the smothering of the benthic ecosystem at the sites where the nourishments are carried out. Nourishments also have an effect on sediment transport along the coast. The pressures are summarised in Table 3.3.

3.4 Oil and gas activities

3.4.1 Current situation

At present, there are about 143 production facilities at sea, >90% of them for gas extraction and the rest for oil. Assuming that the average platform area that touches the seabed is 250 m^2, the total surface area covered by platform structures is approximately 0.036 km^2. These facilities are linked to an extensive network of pipelines for the distribution of oil and gas (Figure 3.5). The total length of pipelines is approx. 3700 km, 200 km of which are out of use.

3.4.2 Future developments

Expectations are that in this decade only a limited number of new oil and/or gas fields will be developed in the North Sea (two to four per year). The rate at which existing sites are decommissioned depends, among other things, on the oil price. Most exploitation sites are expected to be closed down between 2020 and 2030 because of depletion of the oil and gas fields. The policy to promote the exploitation of smaller fields is expected to bring about a further extension of the network of pipelines.

3.4.3 Pressures

The pressures related to oil and gas activities differ during the different phases – exploration, drilling, construction, operation and decommissioning. The main pressure caused by seismic exploration for oil and gas is underwater noise. Underwater noise is also caused by drilling activities and, to a lesser extent, during the production phase. Drilling activities also cause changes in siltation, mainly through the discharge of cuttings (most of which are deposited in close proximity – within 100 metres – to the platform). During production, the legs of a platform usually cause a physical loss of around 250 m^2 per platform (Karman, 2008). After approximately 10 to 25 years, this physical loss will be reversed when the platform is removed (decommissioning). Installation - and removal - of pipelines causes abrasion (i.e. physical disturbance of the seafloor) up to approximately 10 m on each side of the pipeline. Disturbed surface is local. Hazardous substances may be released into the environment by drilling and production activities, but use and discharge of offshore chemicals are subject to strict mining/licensing rules and subsequent inspections. In most cases the produced water (process water), containing hydrocarbons (≤ 30 mg/l dispersed oil in OSPAR area), metal salts and mining chemicals (additives) (OSPAR, 2009c). With the ageing of oil and gas fields, the volumes of process water increase (OSPAR, 2009c). Reduction measures have decreased the concentration of dispersed oil in process water over the last decade and an overall reduction in the total discharge of chemicals has been achieved. In some cases process water is re-injected into the reservoir for pressure maintenance, but also to avoid discharges to the sea.

Offshore exploration and production of oil and gas is not subject to seasonal variation, and once a platform is taken into production, exploitation can last for approximately 25 years.

The pressures are summarised in Table 3.3.

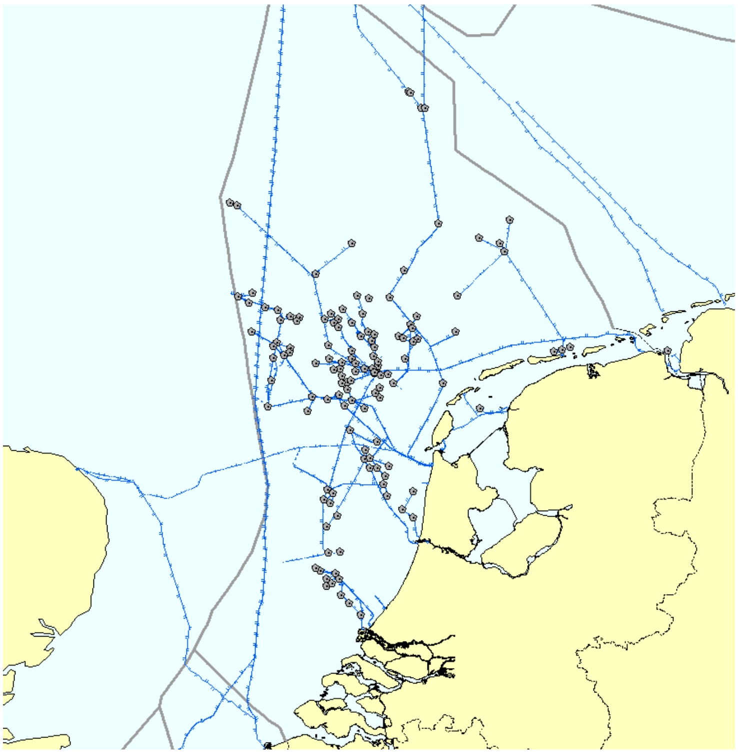


Figure 3.5 Map showing platforms and pipelines for the exploitation of oil and gas (noordzeeloket.nl).

3.5 Wind energy

3.5.1 Current situation

Two windfarms have been built off the Noord-Holland coast, with a total capacity of 228 MW and a total surface area of approximately 45 km^2. Operations at the Egmond aan Zee Offshore Windpark (OWEZ) commenced in 2006, followed in 2008 by the Princess Amalia Windpark (Figure 3.1). An additional capacity of approximately 700 MW of wind energy is to be commissioned by 2012, probably at sites to the north of the island of Schiermonnikoog.

3.5.2 Future developments

Of all renewable energy resources, wind energy is expected to experience the largest expansion at sea this decade. Present plans aim for a total capacity of 6000 MW in the Dutch part of the North Sea by 2020. This is equivalent to a total surface area occupied by offshore windfarms of approximately 1000 km^2.

There are less advanced plans for the construction of an island at sea, to be used for the temporary storage of energy. The rationale behind this is the need to counteract the imbalance between electricity supply by wind energy and the daily demand for electricity. Storage of energy might be combined with forms of sustainable energy. Construction of such an island is not expected in the short term.

3.5.3 Pressures

The pressures related to wind energy differ during the construction phase, the operational phase and the decommissioning phase. Nedwell & Howell (2004) used four phases to assess the acoustic implications of offshore windfarms:

Pre-construction
Include geophysical and geotechnical survey, meteorological mast installation and an increase in vessel traffic. Vessel traffic will increase in the vicinity of a windfarm before its construction and continue through to decommissioning.

Construction
One of the most significant activities during windfarm construction is foundation installation. Dredging and rock laying may be undertaken during windfarm construction. Other construction activities include cable laying, turbine and turbine tower installation, and ancillary structure (e.g. offshore transformers) installation. In addition to this, divers will be used throughout windfarm construction to carry out underwater activities, and they may use a variety of tools.

Operation
By far the longest phase of a windfarm's life cycle is the operational phase. Low-frequency sound levels can be expected from the turbines.

Decommissioning
The final stage of a windfarm's life cycle, the majority of which may be a reflection of the installation process. However, the wind turbine foundation decommissioning process is unclear. Options for pile foundation removal include jet and explosive cutting below the seabed. While the process for concrete foundation decommissioning is not known, it may include explosive break-up followed by dredging.

The potential impact of cables is described in a separate section.
Windfarms, and the associated banning of fisheries from these areas, are suggested to have positive ecological impacts as well, as a consequence of the creation of new habitats and a refuge for species.

The pressures are summarised in Table 3.3.

3.6 Carbon capture and storage

3.6.1 Current situation

At present, no capture and storage of CO_2 occurs in the Dutch part of the North Sea.

3.6.2 Future developments

Over the coming decades, capturing CO_2 at source and transporting it to deep underground storage facilities is seen as an interim step in the transition to sustainable energy management. Depleted gas fields and their associated pipelines at sea offer a potential future infrastructure for CO_2 storage, and the area to the north-west of Texel is a site of particular interest for large-scale storage. Locations of certain underground water-retentive soil strata (aquifers) might also be used for CO_2 storage. However, application of storage techniques at this scale is not expected before 2020.

The four most attractive CO_2 storage options have been assessed. This included a feasibility level analysis of the technical viability, availability and cost of using each site for CO_2 injection from 2015. This included a site development plan for each site, outlining the timeline for actions to bring each site into operation as well as the cost of those actions and key risks. Fields have been identified (P18, Q1, P6 and K12-B) as the most attractive CO_2

storage options for 2015, and others (P15 and Q1B) identified as attractive CO_2 storage options on slightly longer time horizons.

3.7 Cables and pipelines

3.7.1 Current situation

The first cables laid on the seabed, several decades ago, were transatlantic telecommunications cables between Europe and North America. The number of telecom cables then grew steadily but has since stabilised (Figure 3.6). The total length of the cable network is 4000 km; 2100 km of the cables are no longer in use (Aegidius P. Kap, 2005).

An extensive network of pipelines has been laid in the North Sea since the development of oil and gas fields. The total length of the present network of pipelines is about 3700 km.

3.7.2 Future developments

The opening up of the European electricity market has caused an increase in the demand for international power supply links (interconnectors). At present, the Netherlands has an interconnector across the sea, a cable between the Netherlands and Norway (NorNedkabel), and one is under construction between the Netherlands and the United Kingdom (BritNedkabel). No further major expansion is expected in the network of interconnectors across the North Sea between the Netherlands and other countries.

The European Commission has awarded a grant for COBRA, the undersea electricity cable to be installed on the seabed between the Netherlands and Denmark. The objective of the COBRA project is to advance the integration of more sustainable energy (particularly wind energy) into the Dutch and Danish electricity supply.

The construction of windfarms at sea will generate an additional need for power cables between the windfarms and the Dutch coast. The government is exploring possibilities for ‘power points at sea’ for the benefit of large-scale offshore windfarms.

As no expansion of oil and gas exploitation is expected in the future, no major extension of the existing network is likely. However, the laying of new pipelines for international connections must be taken into account, as well as an extension of the network due to increasing exploitation of small oil and gas fields.

3.7.3 Pressures

Sealing of habitats occurs when artificial hard substrates are laid. However, these effects of cables and pipelines on the marine environment are small and very localised. Abrasion resulting from placement of cables and pipelines can affect the seafloor. The impact of this disturbance is not long-lasting, however (1 – 8 years). Local changes in the thermal regime might occur due to heat dissipation from the power cables. Disturbance due to electromagnetic fields is also a possibility, and may have a potential impact on the orientation ability of sharks and skates.

The pressures are summarised in Table 3.3.

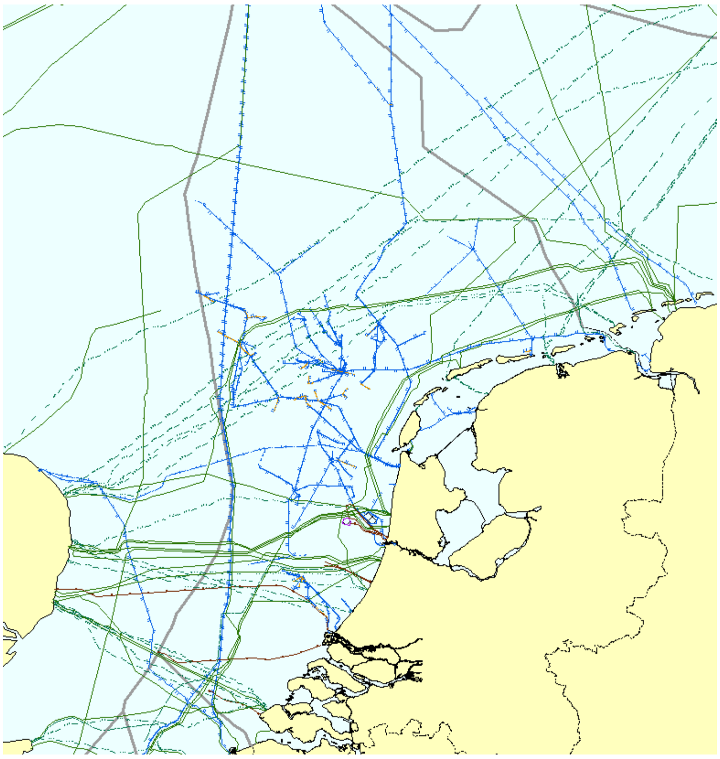


Figure 3.6 Map showing the network of cables (green) and pipelines (blue) in the North Sea (noordzeeloket.nl).

3.8 Martime transportation

3.8.1 Current situation

The intensity of maritime transportation makes the North Sea one of the busiest seas in the world. The Dutch part of the North Sea sees approximately 260,000 ship movements a year. Over 110,000 of these movements are to and from Dutch seaports. The main shipping lanes are situated just across the 12 nm limit, and further offshore near the Frisian Front (Figure 3.7). More than 50% of all ship movements are associated with these shipping routes. Other ship movements involve vessels for fishing and offshore activities, and recreational boating.

Several routing measures have been established in the North Sea. First of all, traffic separation schemes adopted by the United Nations International Maritime Organization (IMO) are in place. The purpose of these schemes is to regulate traffic, to prevent the risk of collisions. The IMO has also adopted the international mandatory deep-water route that must be used by tankers in the Dutch part of the North Sea, and is part of the traffic separation schemes applying in the North Sea. The reason behind the mandatory routes for tankers is the special international status of the Wadden Sea as a Particularly Sensitive Sea Area (PSSA). The mandatory route lies further offshore, so that any oil spill resulting from an accident can be controlled before it reaches the protected area. Tankers also have to travel the shortest route between harbour access and the deep-water route and vice versa. The expansion of the Ports of Rotterdam will lead to extra activities in the port area and in harbours where the fishing vessels are registered.

Finally, clearways have been assigned, routes defined on the basis of normal traffic flows in which no mining installations may be built. Ships are not obliged to use these routes, however. These clearways are given the status of “recognised sea lane essential for navigation” (UNCLOS) meaning that they must, in principle, be kept free of all obstacles, including windfarms.

Special shipping lanes connect the main ports with the shipping lanes. Special anchoring areas have been designated near the main ports.

The total surface area of the ship traffic infrastructure is approximately 3600 km^2.

3.8.2 Future developments

An increase in the number of shipping movements is expected, as described by Voet & Budding (2008). Factors behind this development are:

1. An increase in shipping movements due to growing transport volumes
2. A decrease in shipping movements due to larger ships and improved loading
3. An increase in shipping movements due to a shift from road transport to shipping
4. An increase in shipping movements due to larger seaport capacities (e.g. Maasvlakte 2)

Maritime transportation on the North Sea will not only become busier, but also more diverse. In addition to merchant shipping, sea towage and hydraulic engineering work, it will also include fishing and increased pleasure boating.

Since global oil production is set to drop, the transportation of oil by sea will decrease in the long term. This may be offset in part by the transportation of biofuel. The transportation of LNG is expected to grow in the future.

The volume of container transport and transhipment is rising sharply. By 2040, the current volume will have increased by 50-300%, with the Maasvlakte 2 area playing a key role in accommodating this growth. The increase in the scale of ships is a significant development. Due to draught restrictions, a number of ports in the region will become less suitable for landing containers. Rotterdam, Antwerp, Hamburg, Bremerhaven and Willemshaven are expected to be the main ports for container transport.

An increase in ship movements to and from Dutch ports and total ship movements in the Dutch part of the North Sea in the order of 15-30%, relative to 2004, is expected by 2015.

3.8.3 Pressures

Shipping is a source of underwater noise. Shipping noise may affect mammals, birds and fish. It is also assumed that shipping is a major source of pollution at sea caused by the discharge of waste and loss of cargo. The IMO has assumed responsibility for pollution issues and, over many years, has adopted a wide range of measures to prevent and control pollution caused by ships and to mitigate the effects of any damage that may occur as a result of maritime operations and accidents. In accordance with MARPOL 73/78, far-reaching prohibitions and restrictions on spills and waste at sea are in force. Nevertheless, illegal discharges of oil and toxic or hazardous substances still occur. Maritime transportation can impact on the marine environment through hazardous substances in various ways, including the introduction of oil or other noxious substances (e.g. antifouling), operational discharges, or the loss of vessels and/or cargo.

Non-indigenous species can be transferred in ballast water, associated sediments, and by fouling on ships' hulls.

The pressures are summarised in Table 3.3.

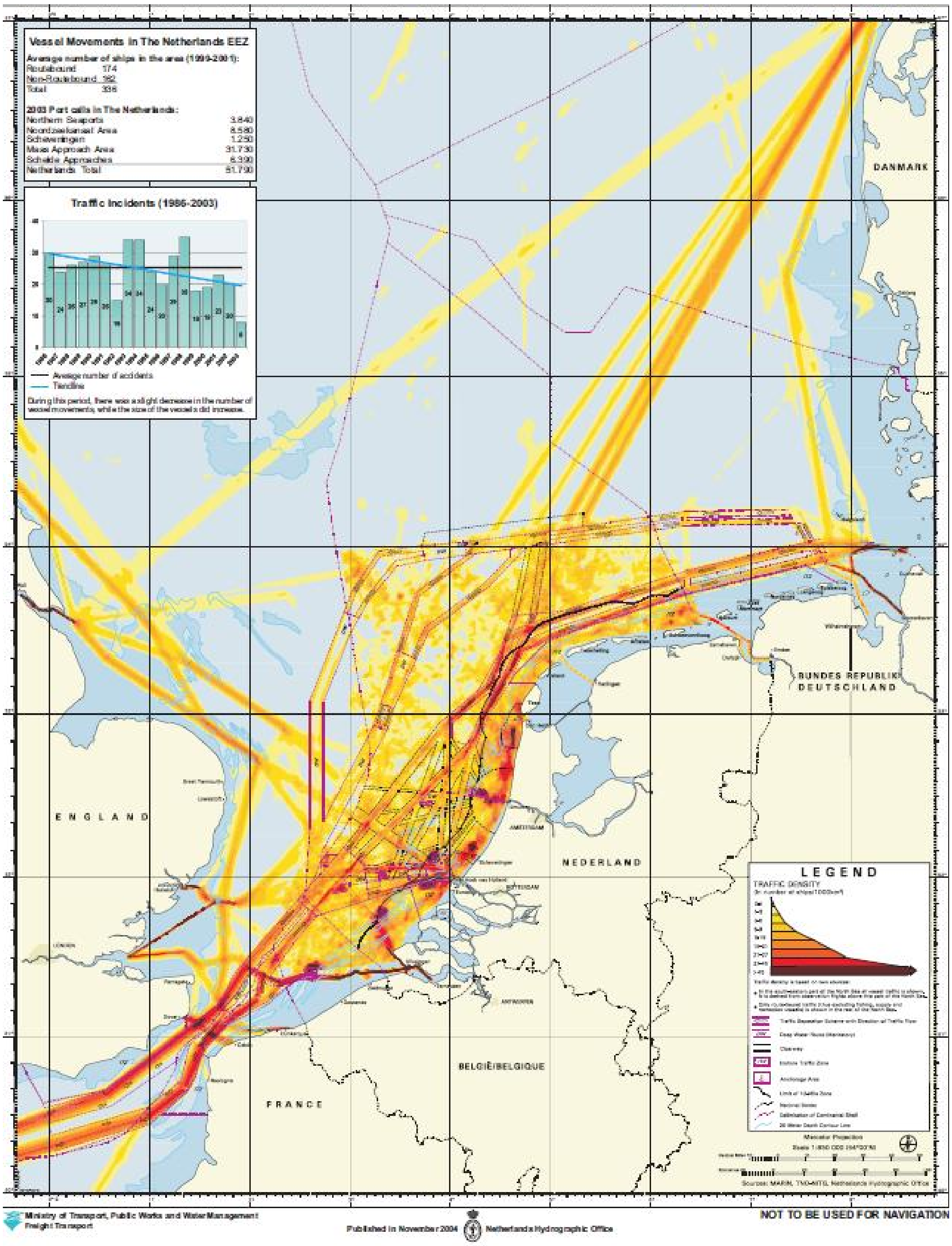


Figure 3.7 Map showing vessel traffic density in the southern North Sea (www.noordzeeloket.nl).

3.9 Dredging

3.9.1 Current situation

Sand and silt are transported along the Dutch coast. Rivers also transport sand and silt downstream. This material settles in areas with lower turbulence, like ports and shipping channels. To maintain the depth of this infrastructure, maintenance dredging of shipping channels and ports is carried out. Less contaminated sediment can be relocated and is disposed of at sites near the ports of Rotterdam, Scheveningen and IJmuiden. The annual amount of dredged sediment is approximately 30 million m^3. About 2 million m^3 is so polluted that it has to be dumped at a special storage site on land. The remainder of the material is redistributed.

3.9.2 Future developments

Maintenance dredging may increase to accommodate larger ships.

3.9.3 Pressures

Dredging and relocation of the dredged material leads to physical damage to the seafloor at dredging and deposition sites and have effects on benthic communities (Stutterheim, 2002). Dredging can release substances from the sediment (Schipper et al., 2010).

The pressures are summarised in Table 3.3.

3.10 Fishing

3.10.1 Current situation

The North Sea is a productive continental shelf sea, with high yields of commercially exploited fish stocks. The 1960s saw unprecedented growth in fisheries and yields, with the highest fish catches ever extracted from the North Sea around 1970. Since then, total yields have steadily fallen, to approximately 50% of the 1970 level. The greatest decreases have occurred in demersal fish, with yields now back at levels similar to 1955-1965.
The Dutch fishing sector mainly targets demersal fish (roundfish like cod, and flatfish like sole and plaice) and pelagic fish (mainly herring and mackerel). Shrimp fishing occurs in coastal waters, and shellfish are dredged at some sites in coastal waters (Figure 3.8).

In 2009, the Dutch fishing sector had 430 vessels operational in marine waters (Taal et al. 2010). However, data on the number of vessels give little information as to actual fishing pressure, since other aspects play a role in determining this, such as type of fishing, actual amount of time fished, etc. Fishing for pelagic fish mainly occurs outside the North Sea. Demersal fishing (mainly beam trawling) is concentrated in the southern North Sea (Figure 3.9 and Figure 3.10) The number of large trawlers (>300 hp) in the Netherlands has steadily decreased since 1985, with a number of the larger vessels being decommissioned in 2008. In 2009 the largest vessels (>2000 hp) reduced their engine power. The number of Dutch “Euro cutters” (225-300 hp) has increased since 1985, but has remained stable over the past few years (Taal et al. 2010). In addition to fishing by the Dutch fishing fleet, vessels from several neighbouring countries (Belgium, France, United Kingdom, Germany, Denmark) are allowed to fish in parts of Dutch territorial waters.

Other fishing activities like gill and trammel net fishing (59 vessels in 2009), fyke and angling (103 vessels in 2009), mussel and oyster (75 vessels in 2009) and other shellfish fisheries (7 vessels in 2009) occur in the coastal and estuarine areas (Taal et al. 2010).

3.10.2 Future developments

The Dutch North Sea fishing sector is a highly specialised entrepreneurial industry that is under increasing pressure due to a number of developments:

- Beam trawling is very energy-intensive, and fuel prices are rising
- The catch yields are restricted by the Common Fisheries Policy
- Growing public pressure on the sector to produce in a more eco- and animal-friendly way
- The space available for fishing in the North Sea is decreasing

Changes to the Common Fisheries Policy, market prices for fish and climate change will also affect the sector. Downsizing and structural change in the sector are expected as a consequence of management actions aiming at reducing fishing pressure, and due to reduced economic profitability, which is increasingly determined by rising oil prices (Van Densen & Overzee, 2008), and also by other factors like the international market and the competition with fish from aquaculture. A significant decrease is expected in the economic value of fishing on the Dutch Continental Shelf between 2005 and 2015 (Voet & Budding, 2008; Ecorys, 2010). There are various initiatives to develop fishing techniques with lower impacts (less bottom disturbance, fewer discards, and lower fuel consumption). Overall, changes in intensity and spatial distribution of fishing activity and a decrease in the impacts of fisheries (bottom disturbance, discards) can be expected.

3.10.3 Pressures

The physical impact of bottom tending gear on the benthos results in damage to the physical habitat, which in turn has the potential to cause substantial and long-term changes to benthic ecosystems. Actual changes to different types of benthic ecosystem depend on their intrinsic vulnerability and recovery from the impact, and thus vary among benthic habitat types. Lost fishing nets constitute marine litter. Noise produced by the boats can affect mammals and birds. Non-selective extraction occurs for target as well as non-target species. A general trend towards smaller fish in the fish community over the past few decades is likely to have been caused by fisheries. The pressures are summarised in Table 3.3.

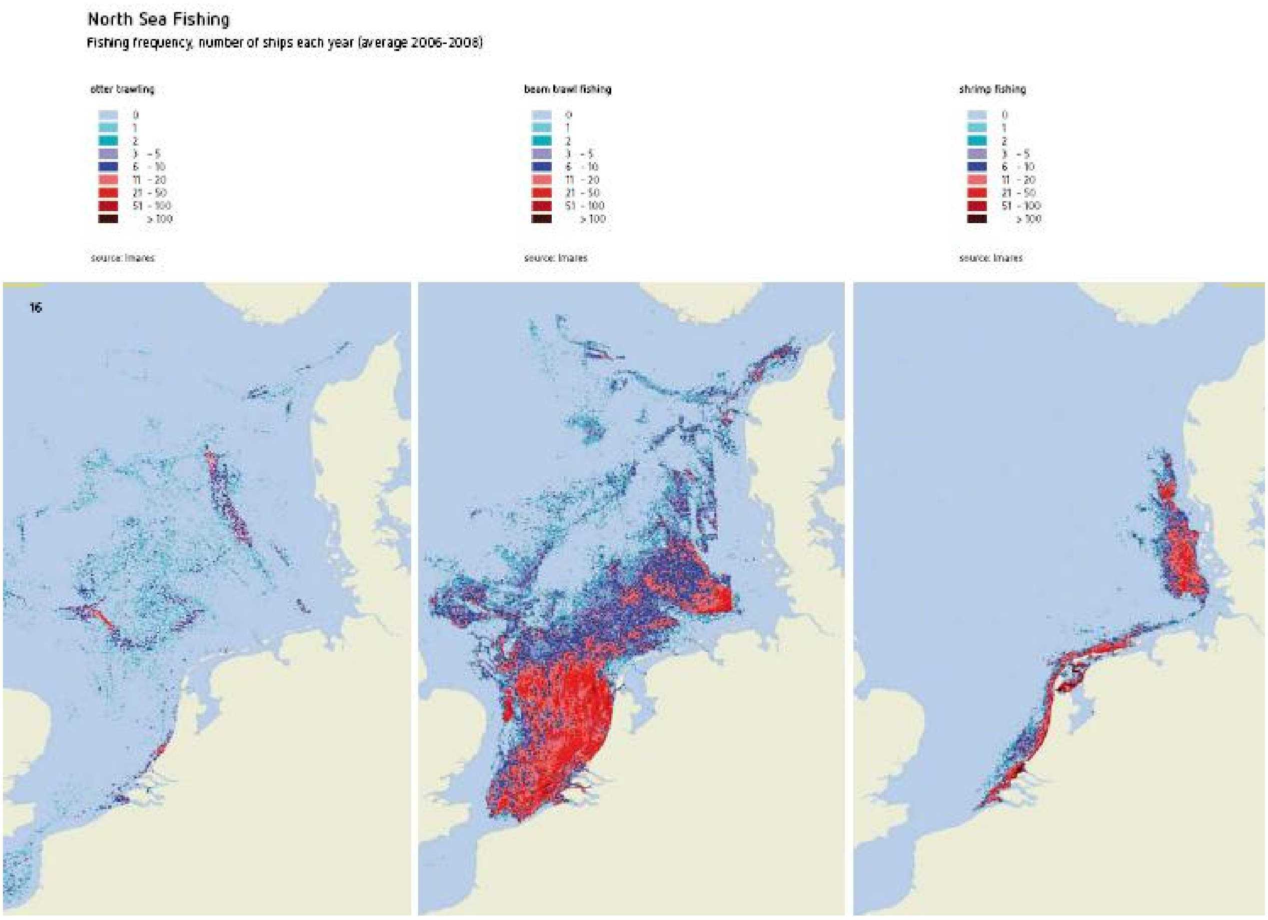


Figure 3.8 Fishing frequency for otter trawling (left panel), beam trawling (centre panel), shrimp trawling (right panel). Number of ships each year (average 2006-2008) (VenW, 2009).

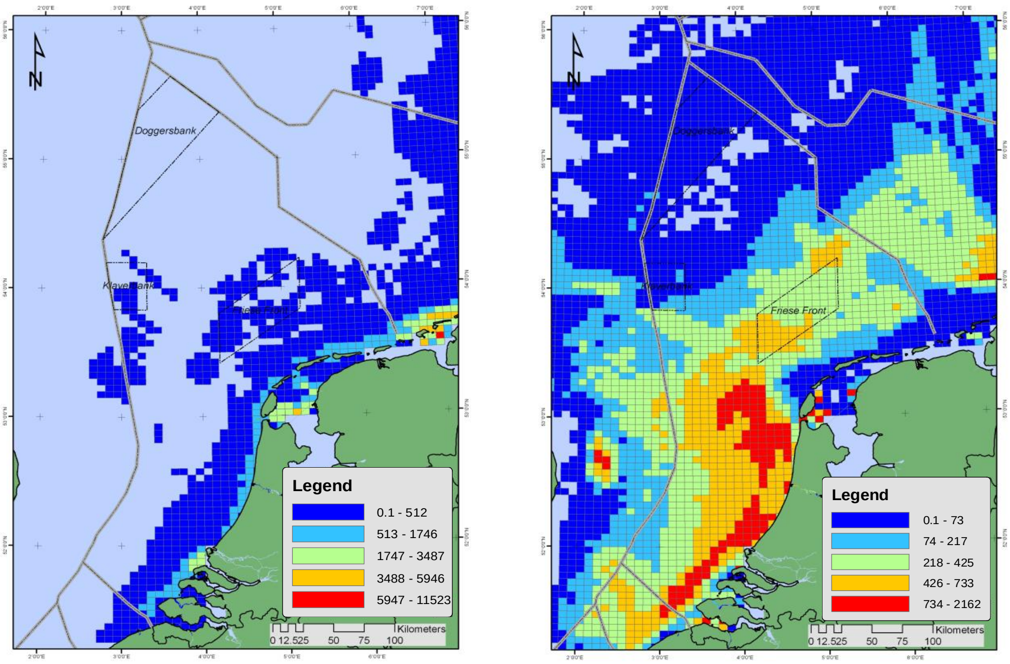


Figure 3.9 International beam trawl effort on the Dutch Continental Shelf (DCS), the total sum in hours fished during 2006-2008. A) small beam trawl including shrimp fisheries (<300hp) and B) large beam trawl (>300hp) based on data gathered for FIMPAS (international = Dutch, Danish and German fleet. Earlier studies showed that these three fleets are most representative for the DCS.

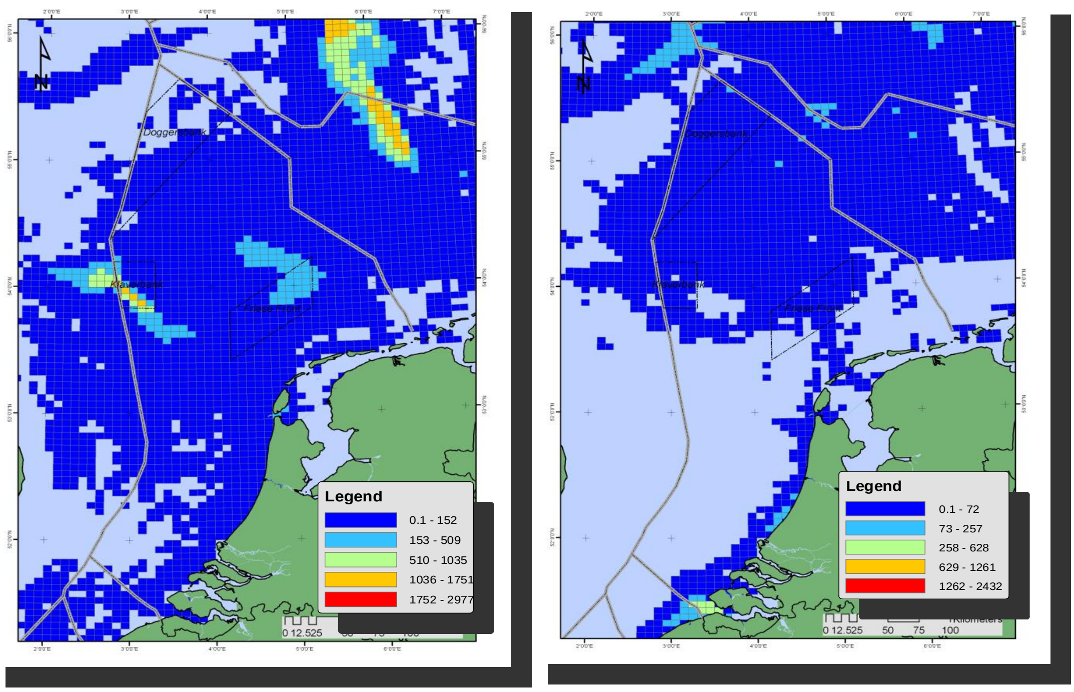


Figure 3.10 International otter trawl effort on the Dutch Continental Shelf (DCS) total sum in hours fished during 2006-2008. A) small otter trawl (<300hp) and B) large otter trawl (>300hp) based on data gathered for FIMPAS. (international = Dutch, Danish and German fleet. Earlier studies showed that these three fleets are most representative for the DCS).

3.11 Military activities

3.11.1 Current situation

Some 7% of the Dutch Continental Shelf (4200 km^2) is used for military purposes. These areas are used as shooting ranges, flying zones or mine testing areas (Figure 3.11). In addition, there are sites where munitions have been dumped in the past (Figure 3.12). Old munitions, generally dating back to WWII, are often encountered by fishermen. These explosives are dismantled and blown up at sea.

3.11.2 Future developments

No changes in military activities are expected.

3.11.3 Pressures

The main pressure associated with military activities is the production of underwater noise, due to the destruction at sea of WWII munitions. The pressures are summarised in Table 3.3.

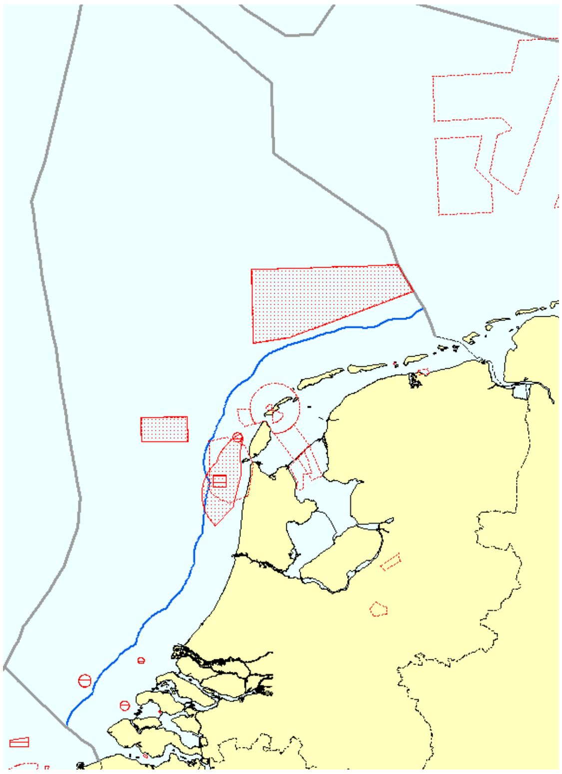


Figure 3.11 Map of areas used for military purposes (www.noordzeeatlas.nl).

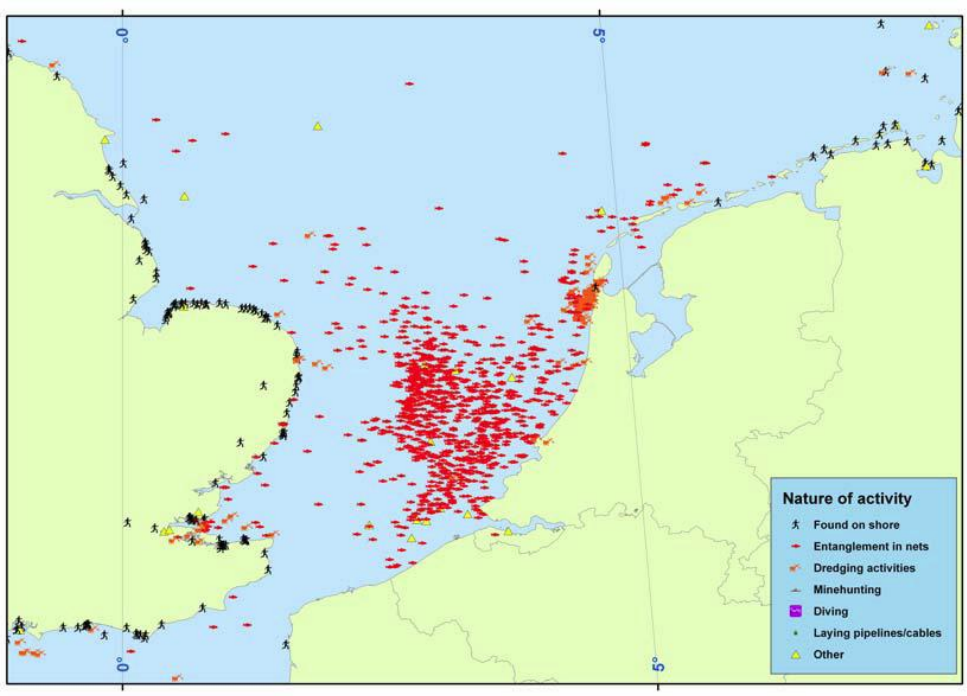


Figure 3.12 Location and nature of munitions encounters in the southern North Sea (OSPAR, 2009b).

3.12 Tourism and leisure activities

3.12.1 Current situation

The Dutch coast is a national and international tourist attraction, where both near-shore activities (e.g. wind- and kite surfing, swimming, fishing) and offshore activities (e.g. recreational boating, diving and fishing) occur.

3.12.2 Future developments

The sector is expected to experience an average annual growth of 2.6% up to 2015. There is a demand for the extension of marinas. The intensity of navigation along the coast and across the North Sea to and from the United Kingdom is increasing.

3.12.3 Pressures

For wildlife with visual and auditory senses (seabirds, marine mammals) disturbance is an important pressure. It is not always possible to separate visual and auditory stimuli that cause disturbance. Animals might shy away from areas with frequent disturbance, such as kite-surfing and wind-surfing sites in the Voordelta. Another important pressure associated with maritime tourism in the Dutch part of the North Sea is the introduction of litter. Other, minor, pressures include the introduction of synthetic and non-synthetic substances and compounds by ships and yachts, and physical loss and damage.
The pressures are summarised in Table 3.3.

3.13 Emissions

3.13.1 Current situation

River discharges are the major anthropogenic source of many non-synthetic substances and synthetic compounds in the Dutch part of the North Sea (OSPAR, 2009c). Dutch coastal waters are strongly influenced by riverine discharges from the Scheldt, Rhine, Meuse and Ems. The catchment areas of these four rivers (>400,000 km^2, population approx. 80 million) cover some 30% of the total drainage basin of the Greater North Sea. Discharges from other rivers (e.g. the Seine, Thames, Humber) also influence water quality to some extent in the offshore part of the Dutch North Sea. The Dogger Bank is mainly influenced by Atlantic Ocean water, imported into the North Sea from the north.

In addition to river loads, other sources include:

- atmospheric deposition,
- emissions from shipping and offshore installations,
- disposal of dredged material,
- Channel water and water from the northern Atlantic Ocean,

It should be noted that only emissions from shipping and offshore installations can be considered direct sources. The other sources mentioned above are actually pathways for emissions that to a large extent occur on land (namely point or diffuse discharges to surface waters or air which are subsequently transported to the sea).

WFD priority substances

Van Gils (2007) collected information on the loads of 31 priority substances of the Water Framework Directive (Directive 2000/60/EC) from the above-mentioned sources. A more or less complete dataset of the contribution from various sources could be established for 15 of these substances. In a follow-up to this study model simulations were carried out to establish the effect of emission reductions on water quality targets.

Estimates were made of the contribution from the various sources and the expected trends in concentrations of a selection of substances (TBT, cadmium, copper, zinc) and five PAHs (benzo[a]pyrene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[g,h,i]perylene and indeno[1,2,3-cd]pyrene) (Van Gils, 2008; Van Gils & Friocourt, 2008).

Metals and POPs

The analysis shows that, in the case of metals, loads are dominated by the input from rivers and by loads related to dredged material disposal. Emissions from combustion in power plants, industry and industrial processes were the largest contributor to atmospheric deposition of lead, cadmium and mercury in the Greater North Sea. For POPs, atmospheric deposition is also a major source, in addition to river loads. Annual atmospheric emissions of POPs decreased in the period 1990 – 2005. TBT levels are almost completely determined by emissions related to shipping (Table 3.1).

Concentrations of the non-synthetic substances (metals) are also to a large extent determined by loads from the Channel, which include natural background concentrations.

Nutrients

River discharges are the source of approximately 50% of the total nitrogen input into the southern North Sea. The other major source is the Atlantic Ocean (through the Channel). In the Dutch part of the North Sea the relative contribution of rivers to anthropogenic nitrogen loads is even greater. Riverine nitrogen loads have decreased by 20-30% since the 1980s, and phosphorus loads from rivers have decreased by more than 50% since 1985.

In 2001 to 2004 an average 15% (range 12-18%) of the total nitrogen input to the Dutch Continental Shelf originated from atmospheric deposition (Table 3.2).

3.13.2 Future developments

Riverine loads of most substances are expected to decrease as a consequence of measures to reduce emissions from point and diffuse sources.

Measures targeting the use of TBT as antifouling are expected to result in a sharp fall in TBT concentrations (also see §5.9). PAHs are not expected to show significant changes in concentrations up to 2015.

Further decreases in loads of other natural substances, particularly nitrogen, are expected as a result of measures related to the implementation of the Water Framework Directive.

3.13.3 Pressures

Emissions result in the introduction of nutrients and other natural substances, and in the introduction of synthetic compounds, causing eutrophication and harmful effects associated with toxic and hazardous substances.

The pressures are summarised in Table 3.3.

Table 3.1 Summary of loads (kg/year) to Dutch coastal waters (12 nautical mile zone) in 2005. From: Van Gils (2008).

	Cd	Cu	Zn	BaP	BbF	BghiPe	BkF	InP	TBT
Atmosphere	417	12870	50403	429	1546	185	566	350	0
Shipping	19	13224	38764	2	1	0	1	2	883
Off-shore	6	0	4006	0	1	0	0	0	0
Dredging sludge	2792	21685	123285	256	303	235	117	224	8
Other	142	4915	23808	2	0	1	41	1	0
Ems	165	7650	33500	21	25	21	14	19	6
IJsselmeer	618	33803	99449	30	41	34	18	32	9
Rotterdam Waterway	2802	102778	295810	161	191	132	90	137	49
Haringvliet	1696	54762	259123	50	66	53	32	49	12
Scheldt	1727	29769	155540	124	155	100	76	102	21
Noordzeekanaal	203	8491	26725	41	45	27	21	27	8
Kanaal Gent-Tern.	32	1216	7648	10	11	8	5	7	1
Small inflows	584	28253	116078	65	71	61	35	54	
Total	11202	319415	1234138	1192	2457	858	1017	1002	997

Table 3.2 Estimated total nitrogen load to the Dutch Continental Shelf from river inputs and atmospheric deposition (from: Baretta-Bekker et al., 2008).

Year	**Estimated total-N deposition in Dutch Continental Shelf (kt/year)**	**River input on Dutch Continental Shelf (kt/year)**	**Contribution of atmospheric deposition (%)**
2001	61.0	382	14
2002	56.2	429	12
2003	49.3	219	18
2004	50.5	265	16
Average	54.2	324	15

3.14 Nature conservation

3.14.1 Current situation

Several areas in the Dutch North Sea are characterized by a high level of diversity or special ecological features. Several international treaties (Ramsar, Bern Convention, UNCLOS, CBD, World Heritage Convention, CMS, OSPAR) and pieces of EU legislation (Birds and Habitats Directives) provide a framework for establishing Marine Protected Areas (MPAs).[1] Various areas in the Dutch part of the North Sea have recently been designated or are to be designated Natura 2000 sites (http://www.noordzeenatura2000.nl/ (Jak et al., 2009).

In 2008 the Netherlands designated the *Voordelta* a Special Protection Area (SPA) under the Birds Directive and a Special Protection Zone (SAC) under the Habitats Directive. The Voordelta occupies an area of the North Sea of more than 900 km^2. At the site, conservation objectives are in place for 'sandbanks which are slightly covered by seawater all the time, subtype North Sea Coastal Zone' (Habitat type 1110_B). Habitat Directive species in the Voordelta are grey seal and harbour seal and the fish species sea lamprey, river lamprey, allis shad and twaite shad. Thirty Birds Directive species are found in the Voordelta: cormorant, shelduck, ringed plover, dunlin, goldeneye, sanderling, little gull, eider, great crested grebe, greylag goose, sandwich tern, avocet, gadwall, horned grebe, spoonbill, red-breasted merganser, pintail, red-throated diver, bar-tailed godwit, oystercatcher, shoveler, wigeon, turnstone, scaup, redshank, common tern, teal, curlew, grey plover and common scoter.

In 2009 the Netherlands designated the North Sea Coastal Zone a Special Protection Area (SPA) under the Birds Directive and a Special Area of Conservation (SAC) under the Habitats Directive. An additional area of approximately 1,240 km^2 was designated a Natura 2000 site in February 2011. The entire area of 1,445 km^2 is situated between the Ems and Bergen aan Zee. It extends from the low water line, or the foot of the dunes on the islands (which are inhabited), to a water depth of NAP -20 m. The North Sea Coastal Zone consists of "sandbanks which are slightly covered by seawater all the time, subtype North Sea Coastal Zone" (Habitat type 1110_B), and "mudflats and sandflats not covered by seawater at low tide, subtype North Sea Coastal Zone" (Habitat type 1140_B). Areas with embryonic shifting dunes (H2110) and small areas with salt marsh type vegetation occur on the beaches (habitat types H1310, H1330, H2190). The Habitat Directive species are harbour porpoise, grey seal and harbour seal and the fish species sea lamprey, river lamprey, allis shad and twaite shad.

The "Vlakte van de Raan" in the mouth of the Western Scheldt estuary was designated a SAC in February 2011. The Vlakte van de Raan is a Habitat Directive site or SAC of approximately 190 km^2 that consists of "sandbanks which are slightly covered by seawater all the time, subtype North Sea Coastal Zone" (Habitat type 1110_B). The Habitat Directive species are harbour porpoise, grey seal, harbour seal and the fish species river lamprey, sea lamprey and twaite shad.

Three marine sites (Dogger Bank, Cleaver Bank, Frisian Front) are expected to be designated Natura 2000 sites as soon as the Nature Protection Act is applicable to the entire Dutch Continental Shelf. The Dogger Bank and Cleaver Bank areas were nominated for SAC status in December 2008 and were adopted by the EC in December 2009. The Frisian Front will be designated as SPA and as such needs no prior submission to the EC.

The Dogger Bank is a shallow area that extends across the UK, Dutch, German and Danish sectors of the North Sea, and the Dutch SAC is a marine site of approximately 4,715

[1] *A Marine Protected Area (MPA) is a protected area whose boundaries include some area of ocean. MPA is often used as an umbrella term covering a wide range of marine areas with some level of restriction to protect living, non-living, cultural, and/or historic resources.*

km^2. The Dogger Bank consists of “sandbanks which are slightly covered by seawater all the time, subtype Dogger Bank” (Habitat type H1110_C (Jak et al., 2009)). The relevant Habitat Directive species are harbour porpoise, grey seal and harbour seal.

The Cleaver Bank is a Habitat Directive site or SAC in the category ”reefs” (Habitat type 1170 (Jak et al., 2009). It is a marine site of approximately 1,235 km^2. The Cleaver Bank is the only site in the Dutch North Sea where considerable quantities of gravel on the sediment surface and larger cobbles and stones with a specific covering of calcareous red algae and sedentary species also occur. The Habitat Directive species are harbour porpoise, grey seal and harbour seal.

The Frisian Front is to be designated a SPA. It covers an area of 2880 km^2. Four Birds Directive species are found on the Frisian Front: great skua, great black-backed gull, guillemot and lesser black-backed gull.

3.14.2 Future developments

A research project is being carried out in other ecologically important areas (Borkum Stones, Brown Ridge, Gas Seeps, Zeeuwse Banks) to ascertain whether these or other areas qualify for specific protection under the BHD or in the context of the MSFD (Van Bemmelen & Bos 2010, Bos et al. 2011, Goudswaard et al. 2011). The final results are expected to be available in 2012. The Oyster Grounds qualify as OSPAR MPA because of the high degree of biodiversity in the benthic community (Lindeboom et al. 2005). However, the Dutch government only nominates Natura 2000 areas (SPAs and SACs) as OSPAR MPAs, so the Oyster Grounds are not on the list.

3.15 Transboundary effects of human activities

The Dutch part of the North Sea is an open ecosystem, forming part of a highly dynamic shelf sea where transport processes and migration of animals connect the various parts of the North Sea and connect the North Sea with the north-east Atlantic Ocean. The environmental status of the Dutch part of the North Sea is influenced by activities in various continental and British river basins discharging into the North Sea, and by activities in other parts of the North Sea. Similarly, activities in the Dutch part of the North Sea can influence the environmental status of other parts of the North Sea. Some human activities are transboundary by nature, such as maritime transportation and fishing.

One example of transboundary effects is the transport of substances discharged into the North Sea to other parts of the North Sea. Nutrient-rich water enters the North Sea from the Atlantic, and is transported with residual currents southward along the east coast of the UK, and northward along the continental West European coast. Models have shown that the German Bight receives nutrients via coastal currents that originate in the Atlantic and which become progressively enriched by nutrients from river inputs and atmospheric deposition (OSPAR, 2010). Model studies to quantify the contribution of the various natural and anthropogenic sources are part of an ongoing OSPAR activity (Lenhart et al., 2010).

3.16 Linking human activities and pressures to GES descriptors

An indication of the expected change in drivers and pressures for the period up to 2020, and the relevance of those pressures in terms of the 11 qualitative descriptors of Good Environmental Status (Annex I of the Directive) is given in Table 3.3. The table presents a qualitative assessment of the relative importance of the pressures, based on the results of an expert workshop in preparation for the OSPAR QSR 2010 (Karman, 2008; OSPAR, 2009c), recently updated on the basis of expert judgment. It should be noted that this table presents an initial, qualitative, assessment of the predominant pressures in the Dutch part of the North Sea. This approach for the purposes of the Initial Assessment is probably sufficient for identifying the predominant pressures. Further studies will be required for a more detailed evaluation of the relative importance of human activities and associated pressures, to develop programmes of measures, for example.

The table indicates that the most dominant activities affecting the Dutch part of the North Sea are aggregate extraction, oil and gas exploration, maritime transport, coastal defence, fisheries and land-based emissions. Renewable energy is an activity that is expected to become important in the near future. The main pressures associated with these activities are physical loss and physical damage, underwater noise and marine litter, contamination and nutrient enrichment, introduction of non-indigenous species and selective extraction of species. These pressures affect nearly all GES descriptors, with descriptors D1 (Biological diversity), D4 (Marine food webs) and D6 (Seafloor integrity) being influenced by the biggest range of pressures.

Pressures that are considered to be unimportant at the scale of the Dutch part of the North Sea are interference with hydrological processes, and inputs of organic matter and microbial pathoGES.

An increase in pressures can be expected for GES descriptors 1 (biological diversity), 2 (non-indigenous species), 4 (food webs), 6 (seafloor integrity), 10 (litter) and 11 (underwater noise). Pressures for GES descriptors 3 (commercially exploited fish), 5 (human-induced eutrophication), 8 (contaminants) and 9 (contaminants in seafood) are expected to decrease.

Table 3.3 A qualitative indication of links between human activities, pressures and relationship with GES descriptors for the Dutch part of the North Sea. See legend for an explanation of arrows and colours. For a description of the pressures see Appendix C; pressures are also defined in EC, 2008

** no mariculture occurs at present*

Pressure	Physical loss		Physical damage			Other physical disturbance		Interference with hydrological processes		Contamination by hazardous substances		Nutrient and organic matter enrichment		Biological disturbance			
Activity	Smothering	Sealing	Changes in siltation	Abrasion	Selective extraction of sediment	Underwater noise	Marine litter	Significant changes in thermal regime	Significant changes in salinity regime	Introduction of substances and compounds	Introduction of radio-nuclides.	Inputs of fertilisers and other nitrogen- and phosphorus-rich substances	Inputs of organic matter	Introduction of microbial pathogens	Introduction of non-indigenous species and translocations	Selective extraction of species (incl. incidental non-target catches)	Introduction of new habitats
Extraction of marine aggregates	←		←	←	←	←						←	←			←	
Dredging for navigational purposes	←		←	←	←	←				←		←	←			←	
Dumping of w astes and other material	→	→	→			→	→			→	→	→	→	→	→		
Exploration for oil and gas (incl seismic exploration and placement or removal of structures for exploration)		↑	↑	↑		↑		↑	↑	↑	↑						↑
Placement, maintenance and presence of cables and pipelines		←		←		←		←									
Maritime transportation				←		←	←			←		←		←	←		
Renew able energy (incl w ind farms)		←				←		←	←	←					←	←	←
Coastal defence (incl land reclamation)	←	←	←		←	←			←								
Maritime tourism				←		←	←			←		←	←	←	←		
Mariculture *	↑	↑		↑		↑	↑			↑		↑	↑	↑	↑		
Marine commercial fisheries				→		→	→			→						→	→
Land-based emissions (river discharges, atmospheric deposition) or transboundary transport							↑			→		→	→	→			
Military activities						↑											
GES descriptors																	
1. Biological diversity																	
2. Non-indigenous species																	
3. Commercially exploited fish																	
4. Marine food chains																	
5. Human induced eutrophication																	
6. Sea floor integrity																	
7. Hydrographical conditions																	
8. Contaminants																	
9. Contaminants in sea food																	
10. Litter																	
11. Energy, incl. underw ater noise																	

Driver-pressure table		**Expected trend until 2020**	
	high		
	moderate	↑	increase
	moderate-high, but local	→	no change
	negligible or non-existent	↓	decrease
Relevance of pressure based on Karman et al. (2008) and expert judgment		Trends based on information presented in this chapter	

Pressure - GES descriptor table	
	Pressure of primary importance in Dutch marine w aters
	Pressure of secondary importance
(adapted from Cardoso et al., 2010)	

3.17 Cumulative effects and risks

Clearly, the human activities in the North Sea described in the previous sections and their impacts do not stand in isolation. Some activities are related to similar impacts on a specific ecosystem component, while other activities may only have an impact on a specific organism. Furthermore, some may overlap in time and/or space. In order to be able to apply the Ecosystem Approach to the management of human activities, a thorough understanding of the cumulative effects of these activities on the marine environment is needed. Cumulative effects can be defined as "All effects on the environment which result from the impacts of a plan or project in combination with those overlapping effects from other past, existing and (reasonably foreseeable) future projects or activities" (Karman & Jongbloed, 2008).

Different types of cumulative effects interaction exist (OSPAR, 2009c):
- Effects of multiple instances of the same activity (for example multiple windfarms in a coastal area)
- Effects of more than one activity leading to the same disturbances (for example accumulation of noise emissions caused by shipping, exploration drilling and construction of windfarms)
- Effects of more than one activity leading to multiple disturbances (for example accumulation of the effects of noise of windfarm construction and the effects of fisheries).

Although some examples of cumulative effects assessments (CEA) exist (e.g. Halpern et al., 2008), there are still considerable gaps in the knowledge that hamper quantitative assessment. To date, no common methodology or understanding of CEA has been agreed (OSPAR, 2009c).

Besides clear and direct effects, indirect effects should also be considered. Indirect effects refer to effects on the environment which are not a direct result of the activity but are often the result of a complex pathway.

3.17.1 Case studies as an example of cumulative effect assessments for the Dutch part of the North Sea

During an expert workshop in 2008 (Karman et al., 2008), relevant ecosystem elements, pressures and activities in the Dutch part of the North Sea were discussed and prioritized. The intensity of the pressures and the vulnerability of ecosystem elements for these pressures were assessed by experts using a classification system (none, marginal, limited, considerable, large). A model approach was applied to these results, integrating the pressures to give a cumulative effect on ecosystem elements (Karman et al., 2008). The workshop resulted in a relative ranking of pressures in terms of their importance and the effects of activities upon the ecosystem. Benthic trawling was estimated to make the most significant contribution to pressures, followed by land-based discharge of chemical compounds and shipping.

Other measures of the relative importance of activities have been proposed. Lindeboom (2005) proposed a relative benthos damaging index for different human activities at sea, and concluded that fisheries have the largest impact on the benthos, followed by sand extraction. Other current activities were considered to be of minor importance.

The difference between the impact assessments by Lindeboom (2005) and Karman et al. (2008) can be attributed to the scope of the study. Lindeboom's index (2005) solely considers benthic life and thus ignores pressures related to other aspects of the environment. It might therefore be more suitable than the one proposed by Karman et al. (2008) for some specific descriptors or elements of descriptors, e.g. Biodiversity (benthic species and habitats), Food webs and Seafloor integrity. Karman et al. (2008) give a more generic impact assessment, covering more aspects of the ecosystem, and more pressures.

A cumulative effects assessment (CEA) methodology was developed for the Dutch part of the North Sea, as a case study for the OSPAR Intersessional Correspondence Group for the BA6 Assessment and the Cumulative Effects Assessment (OSPAR, 2009c). The assessment methodology developed for the Dutch case study assumes that effects are a function of the intensity of pressures caused by activities and of the sensitivity of ecosystem components to those pressures (Karman et al. 2008; OSPAR, 2009c). A tiered approach was used for the CEA:
1 Scoping, scoring and cumulating,
2 Geographical distribution,
3 Temporal variability,

Extent and frequency are combined to produce a generic qualitative assessment that can be applied to all pressures (Table 3.4).

Table 3.4 Combined Frequency and Extent categories in a cumulative assessment.

		Frequency			
		Rare	**Occasional**	**Regular**	**Persistent**
	Site				
	Local patchy				
	Local even				
	Widespread patchy				
Extent	**Widespread even**				

The first tier results in a Cumulative Effect Score (CES) per ecosystem component or activity (Figure 3.13). A second tier involves geographical distribution with a subset of data to focus on the main issues. A third-tier assessment would account for time-dependent variability.
The results presented in this case study were only intended to demonstrate the method. The assessment was based on subsets of pressures and the quality of the data was considered no more than reasonable because of the limited number of experts participating in the workshop, and a lack of clear definitions. Validation of the results, including a sensitivity analysis, is needed. All pressures/ecosystem elements should be included and time-dependent variability should be taken into account (OSPAR, 2009c). In addition, it should be noted that the results of these studies tend to focus on established knowledge. Uncertainties and lack of knowledge about some activities, pressures and impacts may lead to biased results.
However, validation of the results using an earlier assessment based on literature (Karman et al., 2001) showed that the ranking of the most important activities was similar in both assessments. It can therefore be concluded that the case study, using a semi-quantitative approach based on expert judgment, complies in general with the knowledge available in the literature.

Results show that the southern part of the Dutch North Sea has the highest collective pressure. Abrasion (and other physical damage to the seabed) has the highest intensity, mainly caused by beam trawling. The cumulative effect of pressures has been assessed for benthos, fish, birds, cetaceans and pinnipeds, identifying abrasion, removal of non-target species and noise as important pressures.

Since the assessment is based only on a subset of pressures and ecosystem components, which easily leads to misinterpretation of the results, it is recommended that a follow-up to this case study should include all relevant pressures and ecosystem components (OSPAR, 2009c). It should also include temporal distribution of activities and ecosystem components, the recovery of ecosystem components, and the spatial and temporal distribution of pressures.

While this approach has shown that it is possible to establish a semi-quantitative relationship between human activities and pressures, it has also become apparent that a thorough knowledge of human activities (intensity, location) and ecosystem components (i.e. vulnerability, resilience) is needed to assess impacts. This type of information is often unavailable.

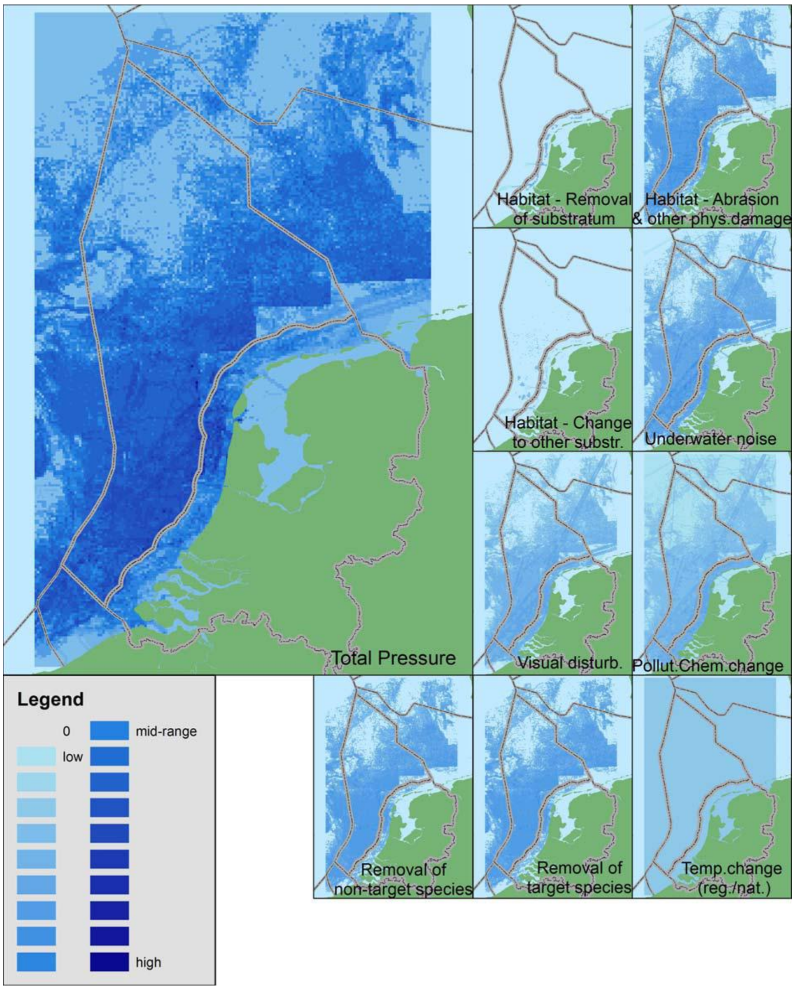


Figure 3.13 Intensity of pressures from selected activities, presented for individual pressures (small pictures) and cumulative pressure (total impact) (OSPAR, 2009).

4 Current environmental status

This chapter gives an overview of the current status of each of the 11 GES descriptors in Annex I of the MSFD, in separate sections. Each section starts with an overview of the description in Annex I of the MSFD and an overview of the criteria and indicators for the descriptor in the Commission Decision (EC, 2010), as well as general information relating to this descriptor from the Quality Status Report 2010 (OSPAR, 2010). Where available specific information for the North Sea is summarised in an overview. This general introduction is followed by a summary of the most relevant pressures for the descriptor, based on Table 3.3, and a description of the information available on the current environmental status of this descriptor. This chapter will be based on the currently available knowledge laid down in scientific (grey) background reports, the scientific literature, and in unpublished material. It describes the environmental conditions in the Dutch part of the North Sea, the current human activities and associated predominant pressures on the ecosystem, and the present environmental status, in terms of eleven GES descriptors for Good Environmental Status from Annex I of the MSFD.

GES descriptor 1: Biological diversity

4.1.1 MSFD description

Annex I MSFD
Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographical, geographical and climatic conditions.
Criteria and indicators in the Commission Decision
1.1 Species distribution
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)
1.2 Population size
Population abundance and/or biomass, as appropriate (1.2.1)
1.3 Population condition
Population demographic characteristics (e.g. body size or age class structure, sex ratio, fecundity rates, survival/mortality rates) (1.3.1)
Population genetic structure, where appropriate (1.3.2).
1.4 Habitat distribution
Distributional range (1.4.1)
Distributional pattern (1.4.2)
1.5 Habitat extent
Habitat area (1.5.1)
Habitat volume, where relevant (1.5.2)
1.6 Habitat condition
Condition of the typical species and communities (1.6.1)
Relative abundance and/or biomass, as appropriate (1.6.2)
Physical, hydrological and chemical conditions (1.6.3)
1.7 Ecosystem structure
Composition and relative proportions of ecosystem components (habitats and species) (1.7.1)

4.1.2 OSPAR QSR 2010

General description for the North East Atlantic	*From: OSPAR Quality Status Report 2010*

Biologically diverse oceans and seas are important for the proper functioning of marine ecosystems. They are also of high value to man in providing services, sustainable uses and as a basis for human health and livelihoods. However, many marine species, habitats and ecosystems are sensitive to pressures from human activities and there is general agreement that marine biodiversity globally is facing unprecedented threats as a result of human activities in the marine environment, land-based inputs to the sea and climate change.

Pressures such as the removal of species (e.g. by fishing), loss of and damage to habitats, the introduction of non-indigenous species, obstacles to species migration and poor water quality are still present. All can act in synergy with each other or be exacerbated by climate change. These pressures result in loss of biodiversity, including declines in the distribution, population and condition of species and the distribution, extent and condition of habitats, and interruption of ecological processes, for example spawning, migration, and biological communication.

The most sensitive features are those that are easily damaged and slow to recover. Some ecosystems never recover. The common skate, for instance, is a long-lived species that has a slow rate of reproduction. It is particularly vulnerable to capture by bottom-trawl fisheries and is severely depleted in many areas and is close to extirpation in large parts of the Greater North Sea.

Coastal waters contain feeding grounds, spawning and nursery areas, and feature on migration routes for seabirds and some fish species. The intense and varied human activities taking place in coastal waters, such as fishing, shipping, sand and gravel extraction, construction and marine energy production, lead to a wide range of pressures on species and habitats. These can lead to the damage or loss of key habitats in estuaries and intertidal areas. Key areas of the shelf seas include offshore banks and reefs, and frontal zones between different water masses. These play important roles in pelagic productivity but knowledge about the overall structure of shelf sea ecosystems is still developing. Fishing is recognised as a key pressure on species and habitats in the shelf seas. Some key areas are now protected but, generally, there continues to be a need for information about ecologically important areas to guide improvements in management.

Region II (Greater North Sea), regional summary:
The decline in biodiversity has not halted. Ten habitats and 29 species on the OSPAR list of Threatened and Declining Species and Habitats are still being damaged. The North Sea has greater coverage by MPAs than the other OSPAR Regions, with 5,4 % of the waters and seabed protected.

4.1.3 The Dutch part of the North Sea

The biological diversity of the Dutch part of the North Sea is influenced by the high intensity of human activities. Many activities and the associated pressures have an impact on biological diversity (Table 3.3), by affecting species distribution or abundance, or by impacting on habitat condition. The most important activities in this respect are commercial fishing, aggregate extraction, oil and gas exploration, maritime transportation, and pollution via land-based emissions.

4.1.3.1 Species-level description of biological diversity: birds

The coastal and offshore areas of the Dutch part of the North Sea are periodically of great importance for marine birds (Figure 4.1). Different species use the area at different times of the year for different reasons. Nearshore waters are critically important for local breeders, such as cormorants, gulls and terns, for food supply within colony range. The same coastal sea is used by even larger numbers of wintering birds that feed on small fish (divers, grebes, gulls, auks) or on shellfish (sea duck). Finally, tens to hundreds of thousands of migrating seabirds move through the coastal sea, often feeding as they go (including highly significant numbers of vulnerable species such as terns, little gull, great skua and Arctic skua). Offshore waters are mainly used by non-breeding piscivorous seabirds. Several species use our offshore waters in significant numbers (relative to total population sizes) in the non-breeding season. These include gannet, guillemot and razorbill, while species such as kittiwake and fulmar also use the area in their tens of thousands (but have much larger populations outside Dutch waters). In the north-west of the Dutch Continental Shelf several species occur in the thousands or tens of thousands that are only rarely seen by land-based observers in the Netherlands (puffin and little auk). Several important areas have been or will be designated under the Birds Directive (Voordelta and North Sea Coastal Zone in nearshore waters and the Frisian Front further offshore). Moreover, the Cleaver Bank (Habitat Directive) holds a high diversity of seabirds year round, while the Brown Ridge area is being studied because of high densities of wintering auks (Lindeboom et al., 2005). In order to assess the international relevance of certain North Sea areas Poot et al. (2010) have suggested that a full marine important bird areas (IBA) inventory be performed. This is a vital next step for a full review of the importance of the Dutch part of the North Sea to seabirds. It will fill gaps in the independent data for some of these areas (especially Dogger Bank and the Central Oyster Grounds).

The nearshore waters are characterized by high seabird densities. Some species are particularly vulnerable to human activities. Breeding cormorants, gulls and terns need to find sufficient food within a limited range (i.e. near their colonies). Some nearshore wintering birds are equally dependent on sufficient availability of food in a narrow strip of sea (e.g. great crested grebe, red-throated diver and common scoter). These birds spend most of their time on the water and are very sensitive to disturbance, oil slicks, and underwater set-nets. Likewise, auks wintering offshore are very sensitive to oil pollution, particularly when they occur in high densities and are unable to fly. Guillemots, for instance, seek out the Frisian Front shortly after breeding, raising their chicks and moulting their flight feathers simultaneously.

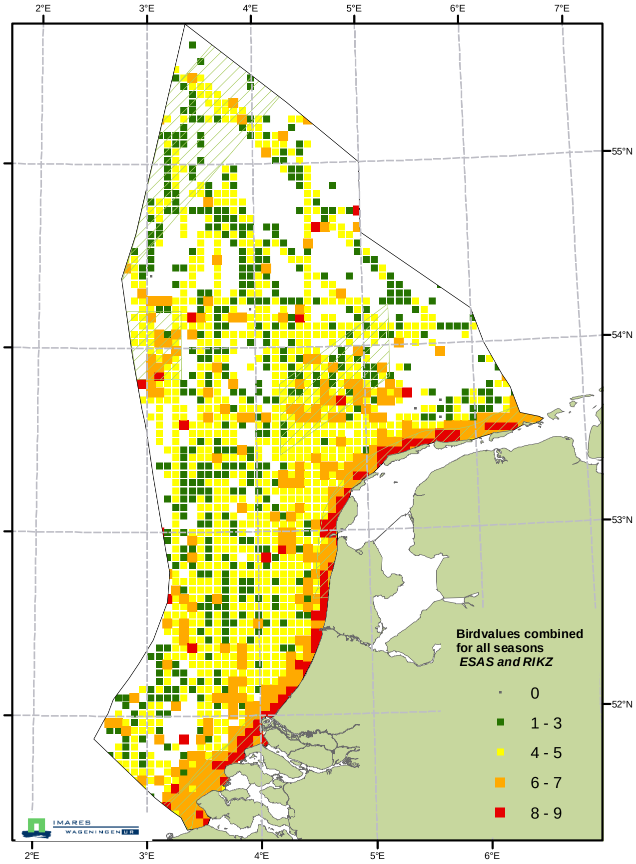


Figure 4.1 Overview of bird values in the Dutch part of the North Sea. Bird values combine densities of all relevant bird species with a bird-specific score (specific bird value) reflecting their importance to the Dutch EEZ. The specific bird values are based on the ranking of each species as a function of their biogeographical population size, potential reproductive output, dependence on the marine environment, dependence on the Dutch EEZ and dependence on the Netherlands for breeding (Bos et al., 2011).

Red-throated diver

Red-throated divers are an Annex I species under the Birds Directive. They have a rather small total population size that it is suffering under deteriorating environmental conditions, both in its breeding areas (due to lake acidification (Eriksson, 1994)) and in its winter quarters. Given these stressors, it is surprising that an increase in wintering numbers in Dutch nearshore waters has been noted over the last 25 years (Camphuysen, 2009a). The reason for this is as yet unknown. These birds feed on small and medium-sized fish that may have become more abundant with the gradual removal of large predatory fish from the system. More than 20 prey species have been identified, such as small gobiids, whiting and herring. Red-throated divers are very sensitive to disturbance and will leave preferred areas if, for example, recreational disturbance becomes too great. Groups of red-throated divers are disturbed by ships at a distance of 1000-1500m and by small airplanes at a distance of 2000m. Resting birds keep a distance of about 500m from busy beaches. Moulting birds are probably even more sensitive (Krijgsveld et al., 2004) and this may be the reason why these divers leave Dutch waters in spring to moult off NW Germany and Denmark (Skov et al., 1995).

Great crested grebe
The great crested grebe has shown a recent shift in wintering occurrence. The main wintering areas were on IJsselmeer lake and on Grevelingen Lake, but recent years have seen an enormous increase in wintering numbers just off the coast of the Dutch mainland. No conservation goals have been set for this species at sea and they winter in a fairly small marine area, situated between the Natura 2000 sites Voordelta and North Sea Coastal Zone. Some 28,000 individuals have been counted in a stretch of coast between Hook of Holland and Den Helder (Figure 4.2). These birds now winter here in both severe and mild winters. Before the 1990s, grebes only visited the North Sea in significant numbers if IJsselmeer lake froze over in severe winters, but this often coincided with high mortality (Camphuysen & Derks, 1989). In recent years, however, mortality has been low and the grebes appear to have adapted well to wintering at sea and finding sufficient food here to survive. Great crested grebes feed on small fish, but their marine diet is still largely unknown. Their food base seems to be solid in the North Sea (given the high numbers and low mortality) but the birds must be vulnerable to oil slicks and bottom set-nets.

Common scoter
Numbers of common scoter show high yearly variation (Figure 4.3). They are mainly found in shallow coastal waters rich in shellfish (Figure 4.4). In the 1980s and 1990s around 100,000 individuals were counted in the Dutch part of the North Sea. These numbers have declined drastically over the last decade. During the last survey in December 2009, only 3500 Common scoters where counted north of the Wadden Islands and just a few hundred in the Voordelta. The fall in numbers coincides with the decline in their preferred food source *Spisula subtruncata*. *Ensis directus*, which has largely replaced *S. subtruncata*, does not seem to be an appropriate source of food. The common scoter is very sensitive to disturbance, flying away when a ship approaches at a distance of about 1500m. Drifting oil slicks, typically occurring in dense concentrations on the water, are another major threat to the species.

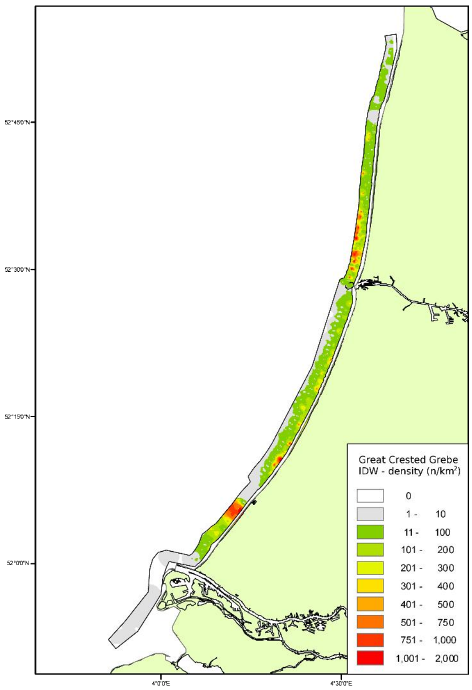


Figure 4.2 Numbers of great crested grebe between Kop van Goeree and Den Helder (2006). Source: Nederlandse Zeevogelgroep and IMARES.

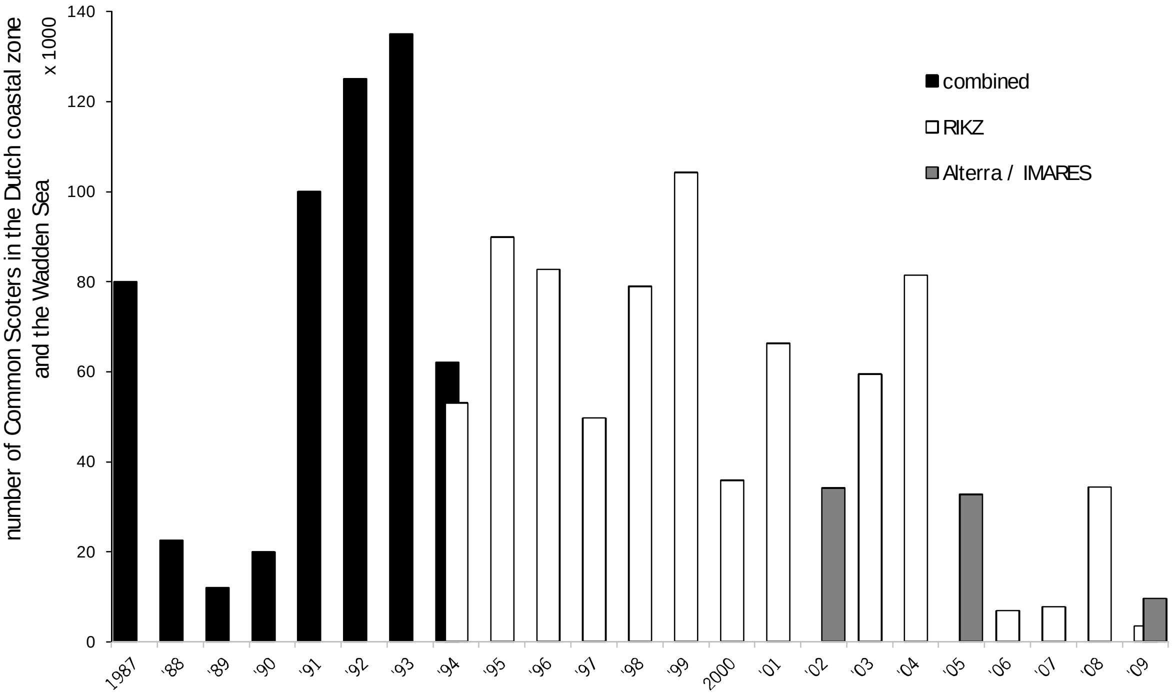


Figure 4.3 Numbers of common scoter (annual maximum) in the Dutch coastal area. Between 1987 and 1994 counts were taken from ships, planes and from land. Since 1994 only planes have been used for the count.

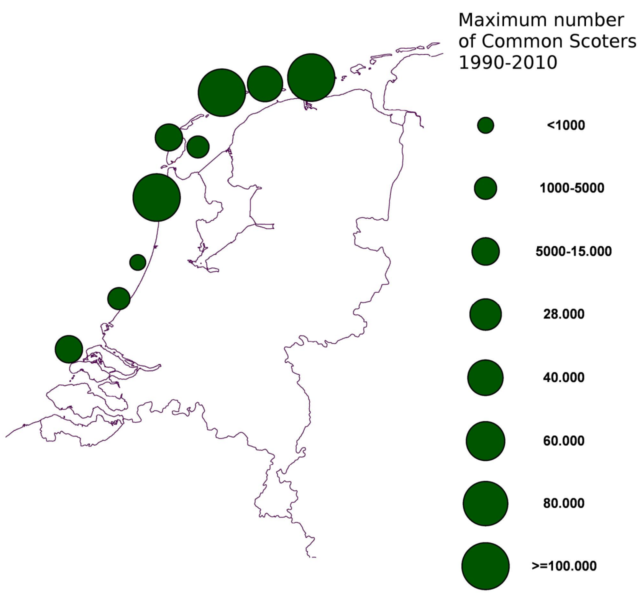


Figure 4.4 Maximum numbers of common scoter counted in the Dutch coastal area between 1990 and 2010.

Gulls, terns, cormorants: local breeders
Gulls and terns suffer from increasing recreational pressure (all beaches), development (Maasvlakte/Europoort) and predation in their breeding areas by red fox (entire Dutch mainland), a decrease in the availability of discards (gulls only) and, possibly, sub-optimal water clarity (terns). Gull numbers have soared over the past 100 years, but are now declining. Numbers of terns never fully recovered from the major setback in the 1960s caused by contamination (DDT and the like) and land reclamation in the Delta area. In contrast, cormorants have shifted from inland waters to coastal sites, founding over a dozen new, marine colonies. Feeding conditions and breeding success appear to be greater at the coast, and numbers are steadily increasing.

Kittiwake
The kittiwake is the most pelagic species of the North Sea gulls. It has a large population size, but is at risk because of drastic population declines caused by a lack of good food (sand eels). Recent trends in wintering numbers in Dutch waters are not yet known.

Auks
Guillemots and razorbills occur in significant numbers in the Cleaver Bank to Frisian Front area (and possibly also further north, and on the Oyster Grounds, where species-specific data are scarce, in summer and autumn. In late winter, large numbers of both species occur in the Southern Bight of the North Sea, roughly in the Brown Ridge area. The late-summer birds are post-breeders; the late-winter birds are pre-breeders, probably acquiring body reserves in the Southern Bight before migrating back to their (UK) colonies to breed. Little is known about numbers of puffin and little auk in the Dogger Bank area, and about their winter ecology at sea. Razorbills are year-round food specialists, feeding mainly on small sand eels and clupeids. Guillemots take the same foods when breeding, but have a much more diverse diet in winter, including some 20 fish species and a rather large prey size range (Ouwehand et al., 2004). All auks are highly vulnerable to drifting oil slicks, particularly when concentrated at preferred sites.

4.1.3.2 Species-level description of biological diversity: marine mammals

Harbour porpoises were abundant in Dutch nearshore waters in historical times, but disappeared in the late 1950s for reasons that were not studied and therefore not understood. From the mid-1990s on harbour porpoises have increased markedly in the southern North Sea, with peak abundances in nearshore sightings (to date) in 2006, 2009, and 2010 (Figure 4.6; data not shown in 2009 and 2010) (Camphuysen & Siemensma, 2011). Today, harbour porpoises appear to be common from August to May (most abundant nearshore in Feb-Mar), but scarce in mid-summer in nearshore waters, suggesting a movement away from the coast during the calving period. None of the Marine Protected Areas in Dutch waters is currently known to be of particular significance for porpoises (Figure 4.5) (Camphuysen & Siemensma, 2011).

A subdivision of the North Atlantic into 15 ‘management units’ (MU) has been suggested, two of which have relevance to the North Sea: (8) North-eastern North Sea & Skagerrak and (9) South-western North Sea & Eastern Channel. A conservative estimate for MU9, based on a single survey conducted in July 2005, would suggest a population of some 150,000 animals (one fifth of the world population). The North Sea population as a whole has been estimated at approx. 250,000 animals. Harbour porpoises in Dutch waters would be representatives of MU9, but exchanges of animals moving from east (MU8) to west (MU9) cannot be excluded. Recent aerial surveys in spring 2009 and 2010 in part of the Dutch EEZ have resulted in figures ranging from 37,000 (2009) – 56,000 (2010) individuals, or 15-23% of the North Sea population and 25-37% of MU9 (Scheidat et al., 2011; Scheidat & Verdaat, 2009).

For the southern North Sea, a strong seasonality in nearshore sightings could be indicative of seasonal movements, either from offshore areas towards the coast, or from north to south and vice versa, during which coastal habitats are frequented (Camphuysen & Siemensma, 2011).

There are published suggestions that the return of the harbour porpoise in the southern North Sea may have been triggered by a reduction in prey (sand eel) availability in the NW North Sea (Camphuysen 2004, MacLeod et al. 2007, Camphuysen et al. 2008). It is unclear whether this reduction in fish prey (if it had triggered a distribution shift) would have been some natural fluctuation or an effect of human action (climate change included). However, harbour porpoises have returned to the southern North Sea, an area where they were common for centuries (Camphuysen & Peet 2006) and where they had become virtually extinct in the 1960s to 1980s (Camphuysen & Siemensma, 2011).

Harbour porpoises are generalist feeders. However, their favourite prey items consists of gadoids, clupeids, sand eels and small demersal fish (Camphuysen & Siemensma, 2011).

The number of seals – both harbour seals and grey seals - in the Dutch part of the North Sea has increased since the mid-1980s (Figure 4.7) (Brasseur et al., 2008). Seals spend at least half of their time at sea where they feed mostly on demersal fish. Though great individual variation is observed, seals may swim about 100 km from their haul-out sites, which for most animals are the tidal sand flats in or close to the Wadden Sea. Grey seal migration from the UK was initially the major cause of the comeback of the species (Brasseur et al., 2009). However local factors also play an important. The positive trends in the number of seals may have several causes. Hunting for seals has been prohibited in the Netherlands since 1960, and was also banned in Germany and Denmark shortly after (Reijnders, 1983; Reijnders, 1992). Reduced concentrations of PCBs in the environment have had a positive impact on the fertility of seals (Reijnders, 1986; Reijnders et al., 1996). The availability of prey and the lack of other predators may have helped in the recovery of the marine mammals in the area (Reijnders et al., 2005).

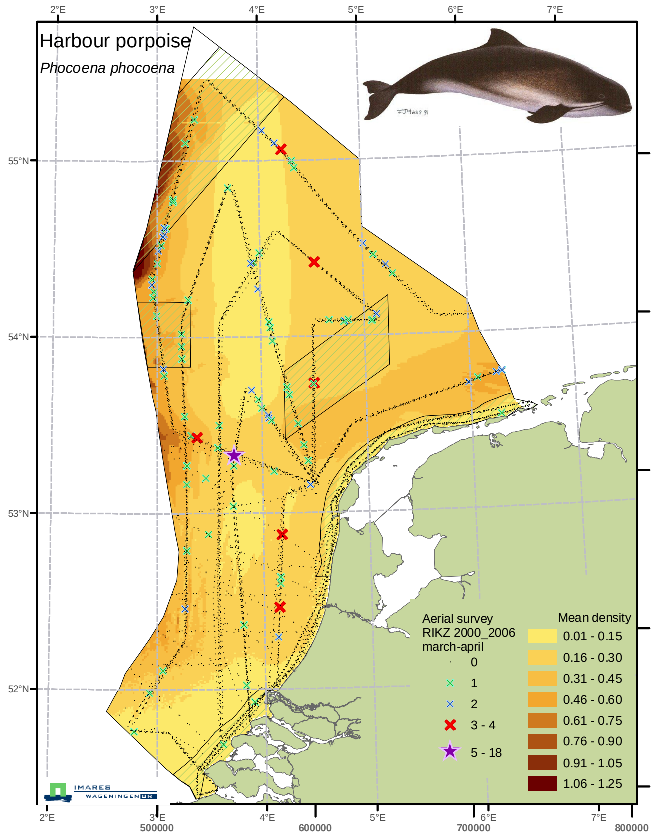


Figure 4.5 Observed animals (2000-2006, symbols,) and modelled distribution (2006, contour plot) of the harbour porpoise in the Dutch part of the North Sea in March-April. The dotted lines represent the routes flown by the plane over the period 2000 – 2006 (Lindeboom et al., 2008).

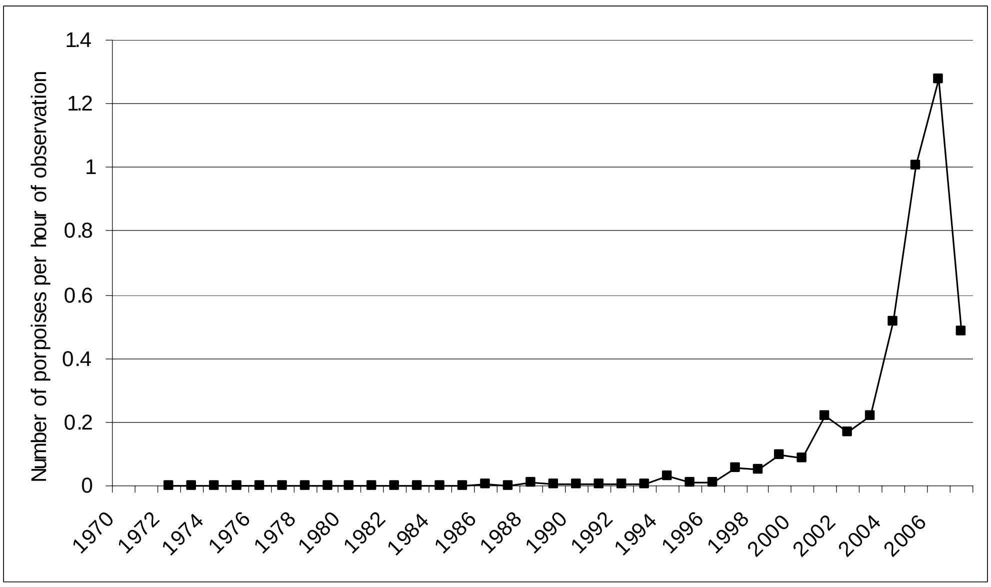


Figure 4.6 Numbers of harbour porpoise per hour of observation during seawatching (n/h), mainland coast observatories only (Scheveningen-Huiduinen, 1972-2010: from Camphuysen 2011.

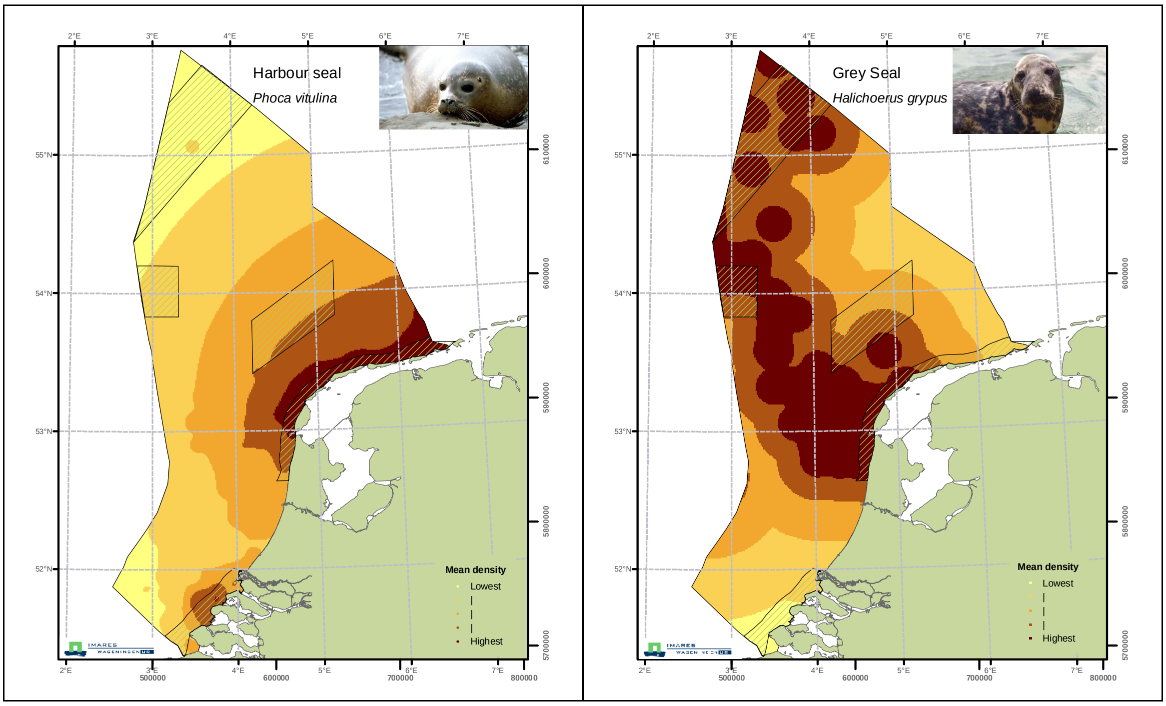


Figure 4.7 Modelled distribution based on satellite telemetry data for harbour seals (left, based on 79 individuals) and grey seals (right, 20 individuals) (Lindeboom et al., 2008).

4.1.3.3 Species-level description of biological diversity: fish

Three main fish communities have been defined in the North Sea (Callaway et al., 2002, Harding et al., 1986). The first is associated with the shelf edge and northern North Sea, the second group occurs in the central North Sea, and the third group is found in the southern and eastern North Sea. However, more discrete communities (e.g. occurring on rocky grounds or in estuaries) are also present in the region.

The fish assemblages of the central and northern North Sea are very different to those further south (Callaway et al., 2002), and the division in fish assemblages corresponds with changes in water depth and temperature. The dominant fish species include demersal species (fish that live on or near the bottom) such as whiting *Merlangius merlangus* and haddock *Melanogrammus aeglefinus*, and pelagic species including mackerel *Scomber scombrus* and horse mackerel *Trachurus trachurus*. In shallower waters (50–100m depth), populations are dominated by haddock, whiting, herring *Clupea harengus*, dab *Limanda limanda* and plaice *Pleuronectes platessa*, while at greater depth (100–200m), Norway pout *Trisopetrus esmarki* dominate (Callaway et al., 2002).

The southern North Sea is generally shallower than more northerly waters. Accordingly, the dominant fish species are those that are more characteristic of inshore waters (<50m deep). Plaice, sole *Solea vulgaris*, dab *Limanda limanda* and whiting are some of the dominant commercial species, and non-commercial species such as lesser weever *Echiichthys vipera*, grey gurnard *Eutrigla gurnardus* and solenette *Buglossidium luteum* are also an important component of the fish assemblage (Callaway et al., 2002). Species such as sand eels (Ammodytidae) and sand gobies (*Pomatoschistus* spp.) are also abundant and are important prey species for many species of demersal fish.

At total of 256 fish species have been observed in the North Sea, including part of the shelf edge (Daan 2000). Many of these are very rare or vagrant species.

In recent analyses, 95 species were selected that were considered to be caught reasonably well in local surveys (Bos et al. 2011). These analyses show a maximum of 39-50

species in 20 half-hour hauls in the area around the Cleaver bank in winter, while in summer the number falls below 30 species. In winter the Cleaver Bank seems to be the hotspot of species richness, while in summer the southern area off Zeeland is the hotspot, with 37-43 species caught in 20 hauls. The Dogger Bank area the northernmost tip of the DCS has the lowest species richness in both summer and winter (Bos et al. 2011).
Earlier North Sea-wide analyses showed that the central North Sea is an area with relatively low species richness (Figure 4.8), where it is rare to record more than 30 species in 20 half-hour hauls. The continental coast is somewhat richer, but the real hotspots of species richness lie around the borders (Figure 4.8). The reasons for these differences are still obscure, but high numbers of species may reflect regular occurrence of species that have their normal distribution largely outside the North Sea. This might explain the hotspots in Scottish waters, particularly around Shetland, and along the Norwegian Trench. Another explanation could be a higher diversity in habitat characteristics on a local scale. Similar analyses are carried out for groups of species. There is no clear explanation for this gradient.

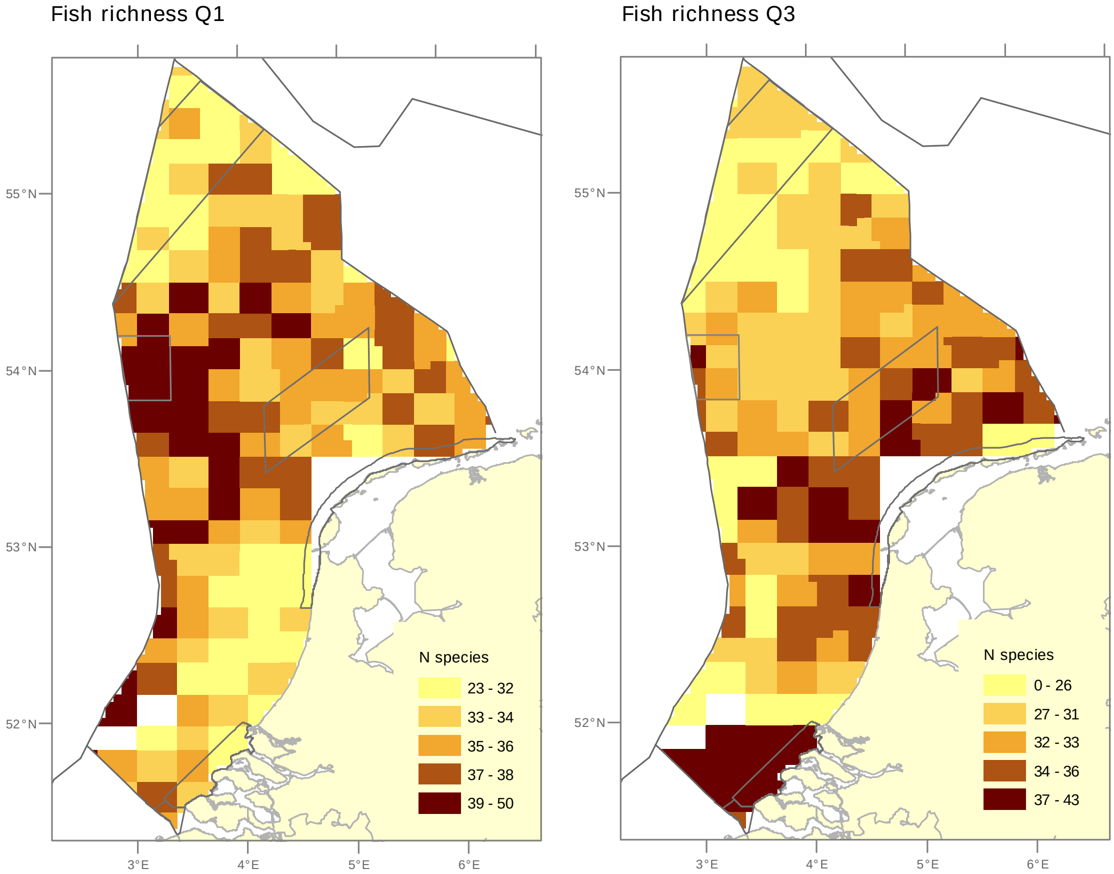


Figure 4.8 Spatial and temporal variation in fish species richness, expressed as average number of species recorded in 20 hauls out of a selection of 95 species from the IBTS. A. first quarter; B. third quarter (Bos et al. 2011).

General trends in North Sea fish species are described by Heessen and Ter Hofstede (2005) and summarised below.

1) Species that showed a considerable increase over the investigated period (1977 – 2004):

Quite a number of species showed a remarkable increase between 1977 and 2004: lesser-spotted dogfish *Scyliorhinus canicula*, 4- and 5-bearded rockling *Enchelyopus cimbrius* and *Ciliata mustela*, mackerel and horse mackerel, lesser weever, possibly spotted dragonet *Callionymus maculatus*, red and grey gurnard *Aspitrigla cuculus* and *Eutrigla gurnadus*, and the flatfish species dab, long rough dab *Hippoglossoides platessoides*, lemon sole *Microstomus kitt* and solenette. Except for mackerel and horse mackerel, these are mainly species for which no directed fishery exists.

2) Species that have shown an increase since approximately 1990 (stable between 1977-1990):

Only a few species have shown an increase since approximately 1990. These are starry smooth hound *Mustelus asterias*, twaite shad *Alosa fallax*, red mullet *Mullus surmuletus* and scaldfish *Arnoglossus laterna*. Anchovy *Engraulis encrasicolus* has increased since the mid-1990s.

3) Species that have shown a decrease since 1977:

The few species that have shown a decrease are cod *Gadus morhua*, spurdog *Squalus acanthias* and catfish *Anarhichas lupus*. All three are large species, the first being a species of major commercial importance, while the other two are landed as by-catch and have a relatively low fecundity.

Recent analysis over the period 1985-2009 showed a decreasing trend in the following species: cod, lumpsucker *Cyclopterus lumpus*, three-spined stickleback *Gasterosteus aculeatus*, whiting, pilchard *Sardina pilchardus*, spurdog, poor cod *Trisopterus minutus* and horse mackerel (Bos et al. 2011).

Temporal trends in fish diversity based on survey catches of demersal species in the south-eastern North Sea in 1906-1909 and 1990-1995 showed that more species were caught in the more recent surveys, but the diversity of the demersal fish assemblage decreased from the early to the late 20th century (Table 4.1). The analysis showed that the recent catch composition was dominated by a single species (either whiting or dab, depending on the survey gear used), which made up over 50% of the catch.

Table 4.1 Community parameters for the demersal fish species caught in the south-eastern North Sea (Rijnsdorp et al., 1996) by gear. OT = 6m Otter trawl, GOV = Grand Ouverture Vertical, BT = 8m Beam trawl (from (Rijnsdorp et al., 1996).

	1906-1909 (OT)	**1990-1995 (GOV)**	**1990-1995 (BT)**
No of species	29	48	42
SW diversity (H')	2.1	1.23	1.68
Evenness	0.62	0.32	0.45
Simpson diversity	0.83	0.58	0.67

Greenstreet and Hall (1996) performed a similar comparison of old and recent survey data for the northern North Sea groundfish assemblage (Greenstreet and Hall, 1996), using Scottish research survey data from 1929-1953 and 1980-1993. Weak evidence was found for a decline in groundfish diversity over time and *k* -dominance curves showed highly significant differences between the two time periods, whereby the community in the more recent period is dominated by a few species. However, when species targeted by a directed fishery were removed from the analysis, no change in diversity over time could be detected and the *k* -dominance curves remained similar between both periods. When analysed closely, it appears that many of the detected differences are due mainly to changes in the abundant commercially targeted species, or in the very rare species, leading to the conclusion that assemblage types are persistent in the North Sea, despite the impact of fisheries (Greenstreet and Hall, 1996).

Whilst Rijnsdorp et al. (1996) and Greenstreet at al. (1996) focus on fishery impacts on community composition, recent warming of the North Sea may also effect species diversity. Hiddink and Ter Hofstede (2008) show that the average species richness of fish in the North Sea increased from 1985 to 2006 (Hiddink and ter Hofstede, 2008). Species richness was significantly positively correlated to average winter bottom temperature over the previous five years (Figure 4.9). Fish species whose distribution range expanded contributed to the increase in local species richness. Such fish species were generally small in size and close to their northern latitudinal boundary (i.e. southerly species), while fish that decreased their range were large species and far from their northern latitudinal boundary. Over eight times more fish species displayed increased distribution ranges in the North Sea (mainly small species of southerly origin) compared with those whose range decreased (primarily large and northerly species). Only three species showed decreased range sizes: the catfish, the spurdog and the ling *Molva molva*, all three large species having a high northern latitudinal boundary. Thirty–four species displayed significant increases in distribution ranges. The five fish whose ranges expanded most were anchovy, red mullet, scaldfish, solenette and lesser weever. These are all small species with a northern latitudinal boundary at a relatively low latitude. Hiddink and Ter Hofstede (2008) conclude that the interaction between large-scale biogeographical patterns and climate change may lead to increasing species richness at temperate latitudes (Hiddink and ter Hofstede, 2008). However, they also state that species richness increased more than predicted by temperature alone, which indicates that other factors besides climate may contribute to the increase in species richness. One potential factor is improvement in the identification accuracy of the fish species during the surveys, but it is more likely that it can be attributed to an increase in small species due to a release from predation by large commercial fish, given the overexploitation of these larger species (Jennings and Blanchard, 2004).

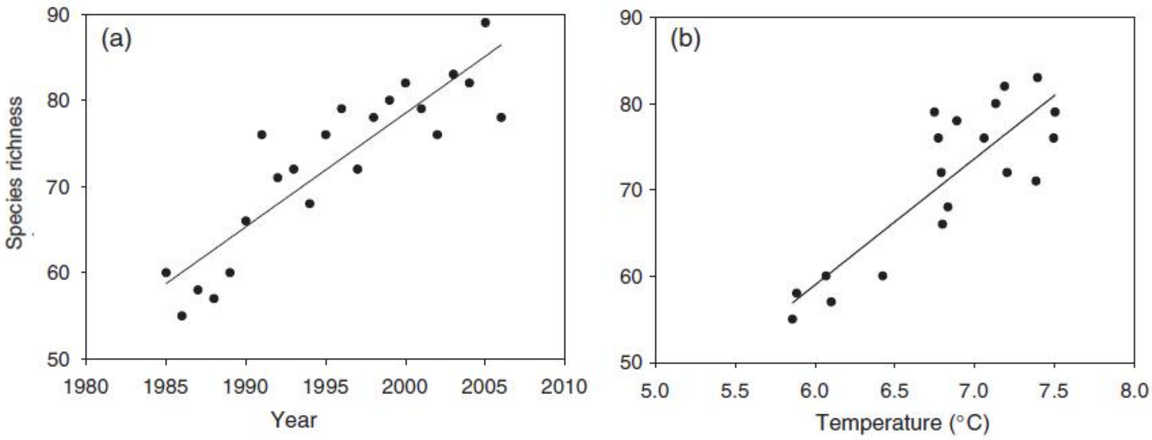


Figure 4.9 Change in North Sea fish species richness over time and with temperature. (a) Total number of species recorded per year (R^2 = 0.80, $F_{1,20}$ = 577.7, P < 0.001). (b) Total number of species recorded v. average temperature over the previous 5 years (R^2 = 0.72, $F_{1,17}$ = 44.8, P < 0.001). (Source: IBTS – data from ICES DATRAS). IBTS, International Bottom Trawl Survey (from (Hiddink and ter Hofstede, 2008).

The structure of an exploited community can change in a number of ways due to the selective removal of target species and larger size-classes of the respective species (also see §4.3 and §4.4). The number of species and their relative abundance within the community may vary. Exploited species may be replaced by ecologically similar species that are less sensitive to fishing disturbance (Pimm and Hyman, 1987), causing systems to switch between alternate stable states (e.g. (Beddington, 1984). The size composition of individuals may also change (e.g. (Pope et al., 1988), which may subsequently lead to changes in the trophic structure of the system (Greenstreet and Hall, 1996). Whilst differential effects of fishing on species with contrasting life histories can lead to gross changes in community structure (Jennings et al., 1999, Greenstreet and Rogers, 2006), environmental forces may contribute to these changes (O'Brien et al., 2000), further influencing the fish community and also mediating its response to fishing pressure. In light of recent changes in climate, it is important to consider the interactions of both anthropogenic and environmental drivers on the fish community.

4.1.3.4 Species level description of biological diversity: benthos / invertebrates

The macrobenthos (>1 mm) has been monitored annually in the Dutch part of the North Sea since 1991 (MWTL monitoring). Between 1991 and 2005 a total of 476 macrobenthic taxa were distinguished. Many of them are rare species that are found only occasionally or locally. The number of macrobenthic species is higher in the northern part of the Dutch North Sea (Dogger Bank, Frisian Front, Oyster Grounds) than in the southern part (other offshore areas and coastal zone) (Figure 4.10 and Figure 4.11) In spite of temporal changes over the period 1991-2005, the general spatial pattern remains stable. The spatial distribution of the macrobenthic diversity is in correspondence with the general trend in the North Sea (Heip et al., 1992; Rachor et al., 2007) and can be explained by the higher stability in the deeper areas in the north. In the southern area, salinity is lower, the variability in climate and hydrology is higher, and human impacts such as pollution and eutrophication (Rachor et al., 2007) and demersal fisheries are stronger. Macrobenthic biomass is generally higher in the coastal zone than in offshore areas (Fig 4.12). Based on box core data, a strong increase in biomass in the coastal area between 2002 and 2005 was observed, but in 2008 the values were back to the lower levels observed in the years preceding 2002 (Figure 4.12). This was mainly due to the patterns in biomass of *Ensis directus*. Since 2002 *Ensis directus* has accounted for more than 50% of the total biomass in the coastal area. No clear trends can be observed for macrobenthic densities (Figure 4.13).

Another part of the benthic community is the megabenthos (Figure 4.14). Megabenthos are benthic invertebrates >0.7 cm, sampled with a special benthos dredge (Triple-D; Bergman & Van Santbrink, 1994) or with a beam trawl. Royal NIOZ sampled the majority of the megabenthos in 2006, 2007 and 2008 and a smaller proportion in the 1990s at a total of 361 stations on the Dutch Continental Shelf (DCS) (see Bos et al. 2011). The special dredge cuts a square groove about 20 cm deep and 20 cm wide out of the bottom over a distance of 100 m. The data points each represent one sampling point. The density of megafauna is high along the northern and southern parts of the coastal zone, in the Frisian Front area, the Oyster Grounds and the Cleaver Bank. The highest biomasses are present in the coastal zone and the Frisian Front, again illustrating the high productivity of the area, as was shown for the macrofauna (Figure 4.14).

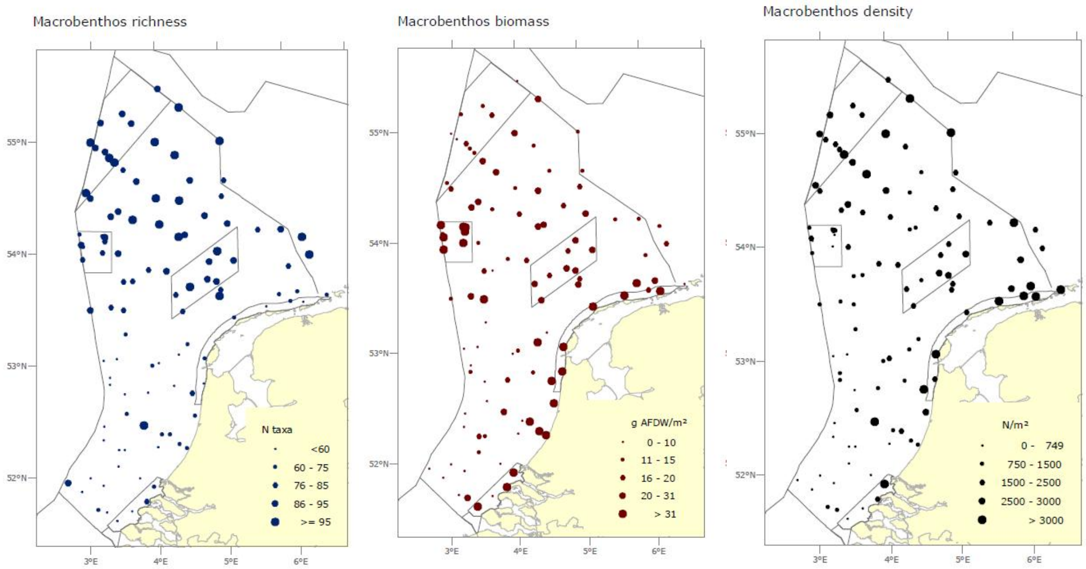


Figure 4.10 Macrobenthos (BIOMON + Cleaver Bank data; 1991-2005):species richness, biomass (g AFDW) and density (Bos et al.2011).

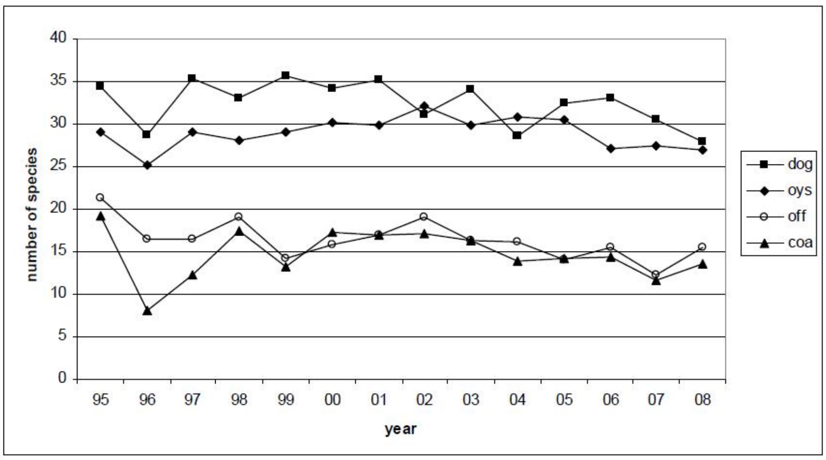


Figure 4.11 Average number of species in the coastal zone (coa), offshore (off), the Dogger Bank (Dog) and the Oyster Grounds (Oys) over the period 1995-2008 (Tempelman et al., 2008).

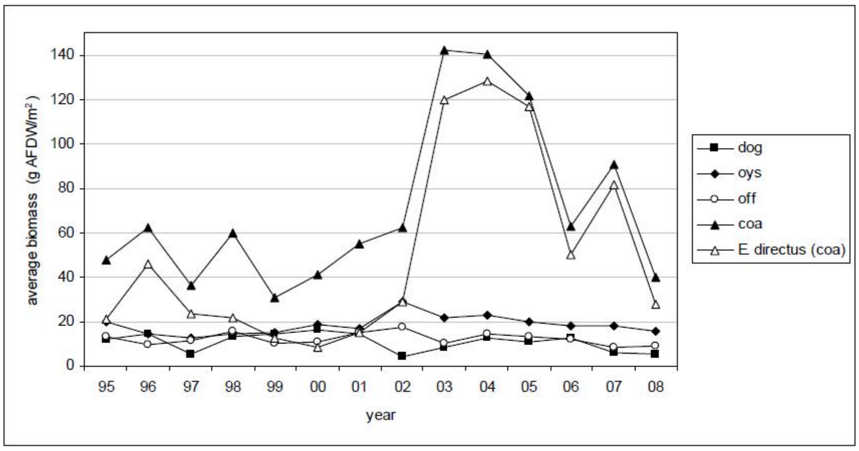


Figure 4.12 Average macrobenthos biomass in the coastal zone (coa), offshore (off), the Dogger Bank (Dog) and the Oyster Grounds (Oys), 1995 – 2008. Total biomass and the biomass of Ensis directus are shown for the coastal area (Tempelman et al., 2008).

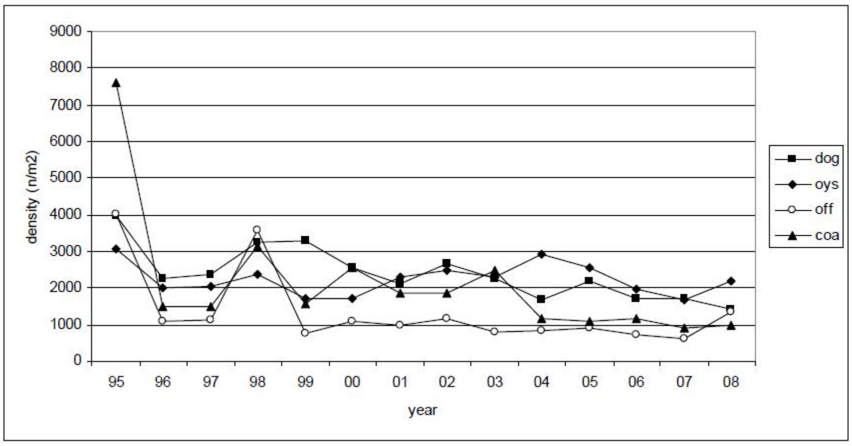


Figure 4.13 Macrobenthic densities in the coastal zone (coa), offshore (off), the Dogger Bank (Dog) and the Oyster Grounds (Oys), 1995-2008 (Tempelman et al., 2008).

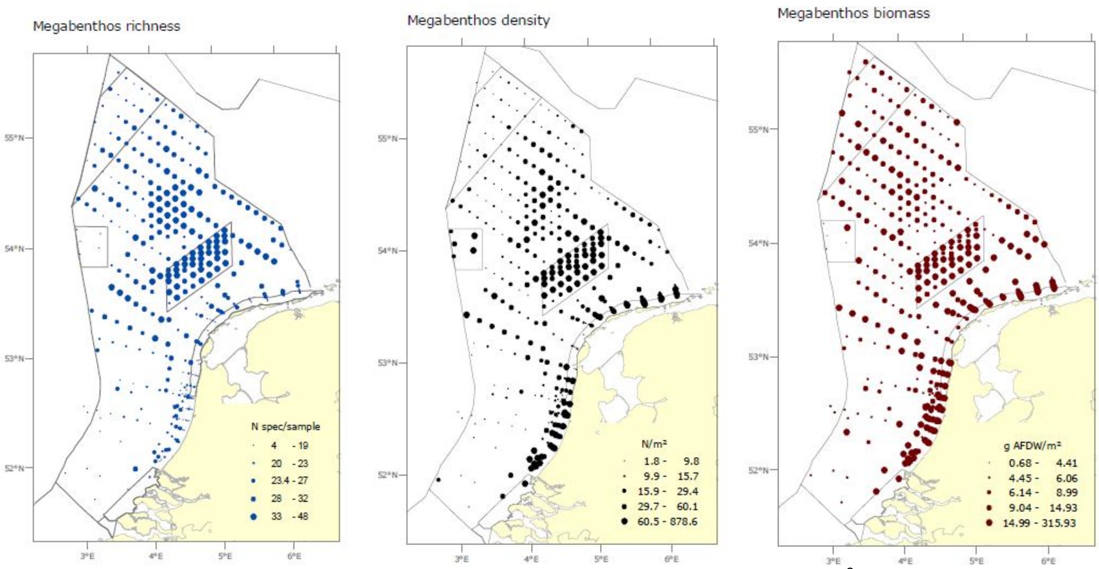


Figure 4.14 Megabenthos (Triple-D)((A) species richness per sample.(B) Density (m^{-2}) data including data from 5 Cleaver Bank stations from another sampling programme. (C) Biomass (g AFDW/m^2) data including data from 1 sampling station in the Cleaver bank. Data collected by NIOZ. For more maps of megabenthos and more information on these maps, see Bos et al. (2011).

4.1.3.5 Species-level description of biological diversity: Phyto- and zooplankton

Phytoplankton and zooplankton in the North Sea show long-term (decadal) changes in composition. These changes are to a large extent due to changes in oceanic input and water temperatures, and related to meteorological forcing caused by changes in the North-Atlantic Oscillation (Reid et al., 2001). There are indications of changes in phytoplankton composition in the Dutch part of the North Sea, with an increase in dinoflagellates and diatoms (Baretta-Bekker et al., 2009). Zuur et al. (2009) also describe an increase in small diatoms. At present, it is unclear whether these changes are a natural phenomenon or can be related to human impacts (also see §4.5). A number of authors suggest that these shifts are due to changes in nutrient concentrations, ratios and limitations (Loebl et al., 2009; McQuatters-Gollop et al., 2007; Philippart et al., 2007; Struyf et al., 2004; Van der Zee and Chou, 2004). Only data from the Continuous Plankton Survey (CPR) surveys are available for zooplankton, covering only the most offshore waters of the Dutch part of the North Sea.

4.1.3.6 Habitat level

EUNIS habitats

Habitats can be defined at different levels, depending on the level of detail of the characteristics (physical, biological) that are taken into consideration. The EUNIS map by De Jong (1999) in Lindeboom et al. (2008) distinguishes five habitat types in the Dutch part of the North Sea, most of them being characterised by fine to coarse sands. Only in the eastern part, on the Cleaver Bank, does a relatively small area with gravel occur (Figure 4.15 and Table 4.2).The habitat types were based on the physical parameters depth, grain size and silt content. At this level of the habitat typology (EUNIS level 3) the composition of the benthic community is not taken into consideration. However, the spatial distribution of macrobenthic communities is roughly comparable to the spatial variation in habitat types (Figure 4.16).

Interpolations of habitat maps and macrozoobenthos data can be used to produce a predictive habitat map (Schokker *et al.*, 2007; Van der Wal *et al.*, in prep).

At present, no information is available on trends in habitat condition, with the exception of Natura 2000 sites.

Table 4.2 Surface area of the different habitat types in the Dutch part of the North Sea

Ecotope	Surface (km^2)	Relative (%)
Deep, silty	11721	20
Deep, fine and coarse sand	18850	32
Medium depth, mixed sand	23195	39
Shallow, fine sand	5362	9
Gravel	411	<1

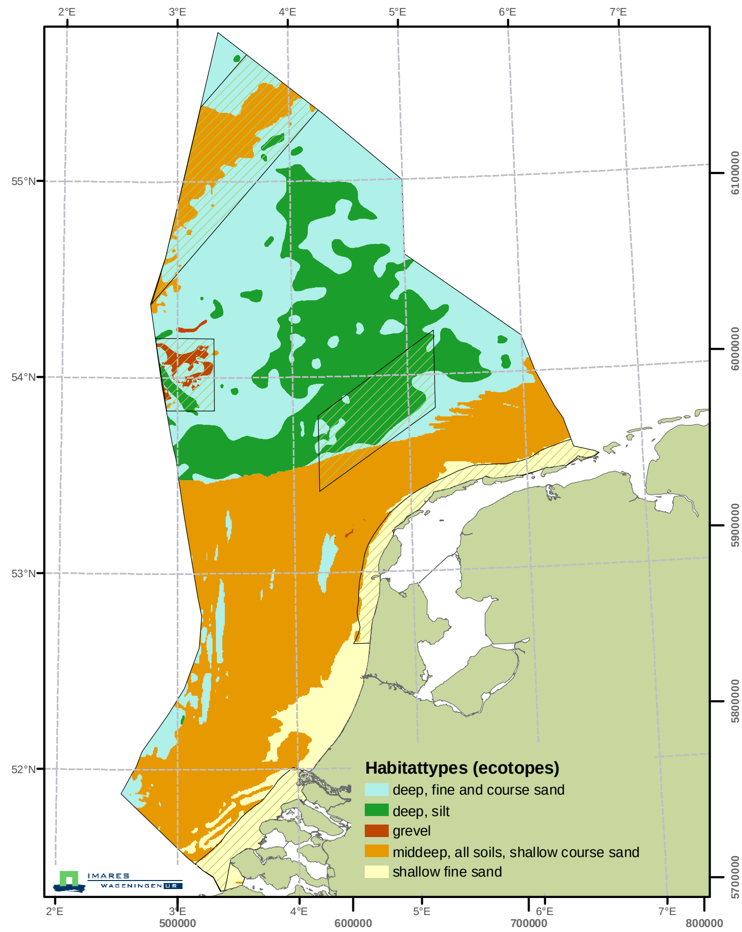


Figure 4.15 EUNIS habitat types (by De Jong 1999) in the Dutch part of the North Sea (De Jong, 1999; Lindeboom et al., 2008)

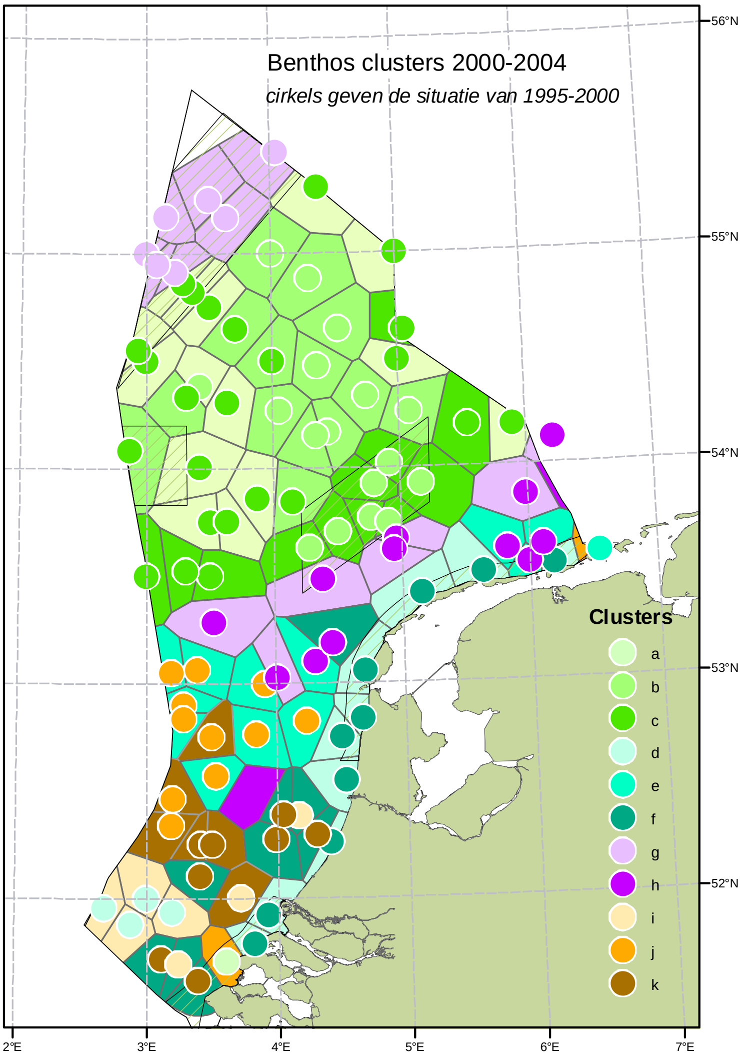


Figure 4.16 Distribution map of macrobenthic communities (Lindeboom et al., 2008)

<u>Characterization of different areas</u> (taken from Bos et al. 2011).

Biodiversity highlights for a number of different areas on the Dutch Continental Shelf (DCS) are described below (Bos et al. 2011). The names of the areas are based on the naming of the areas of special ecological importance in the Integrated Management Plan for the North Sea 2015 (IDON 2005). A number of these areas are now Natura 2000 areas. To fill in the gaps between the areas of special ecological importance, some names have been added (

Figure 4.17). The scale of the areas is in tens of kilometres Table 4.3 provides an overview of biodiversity characteristics per area and their Natura 2000 status.

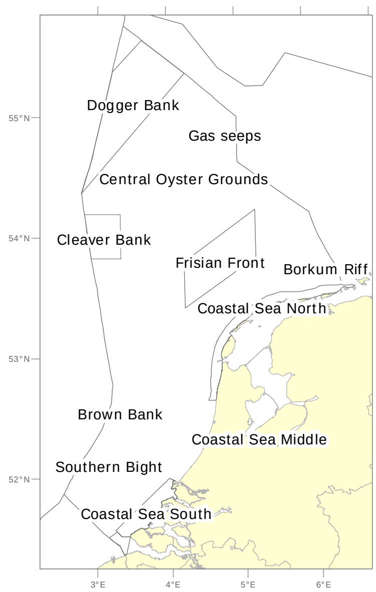


Figure 4.17. Different areas on the DCS and their names. Not all names are official names. The Natura 2000 areas are indicated with lines.

Dogger Bank

The Dogger Bank is a Natura 2000 Special Area of Conservation (SAC) under the Habitat Directive, based on the presence of Natura 2000 habitat type H1110, subtype C (sandbanks in deeper water). The area contains high densities of macrobenthic species, many rare, long-lived and relatively large species, a high species richness and a high evenness. The fish species evenness is high. As far as the other parts of the ecosystem are concerned, the area seems to be less biodiverse. In the deeper part of the area, in the northern tip of the DCS the largest marine mammals of the DCS – minke whales – are occasionally seen.

Gas Seeps

Although some seeping gas has been reported for this area, no structures formed by gas have been found as yet (Natura 2000 habitat type H1180) (Van Bemmelen & Bos 2010). This area does not therefore qualify under the Habitat Directive. The European Commission has removed habitat type H1180 from the reference list of habitats for the Netherlands. The occurrence of H1180 in the Netherlands is unlikely because of bottom disturbance and very slow growth rates (in the order of centuries). Macrobenthos has relatively high values for density and relatively high numbers of long-lived species, and high values for species richness. No really exceptional values have been found for the other species groups and metrics.

Cleaver Bank

The Cleaver Bank, including a deeper trench named the Botney Cut, is a SAC (Natura 2000 habitat type H1170, reefs) under the Habitat Directive, characterised by a macrobenthic community with high scores for biomass, species that potentially grow large (>1000 mg), frequency of occurrence (or rarity) and evenness, and a relatively high density of megabenthos. No other metrics for megabenthos (e.g. species richness) could be determined, since data were not comparable to the megabenthos data. Part of the habitat itself consists of pebbles and larger hard substrate and is rare on the scale of the DCS. The habitat is diverse. The Cleaver Bank also scores high bird values throughout the year.

Table 4.3 Schematic overview of the main biodiversity characteristics for different parts of the North Sea derived from this report. The shaded cells represent the components of the ecosystem that are located within Natura 200 areas (SACs or SPAs). Habitat in the last column refers to a combination of abiotic characteristics and not to Natura 2000 habitat types.

Area	Natura 2000 (+Natura 2000 habitat types)	Macrobenthos	Megabenthos	Fish	Birds	Mammals	Habitat
Dogger Bank	SAC (H1110_C)	High density Many rare species Many long-lived species Many large species High species richness High evenness		High evenness		Minke whale present (occasional sightings)	
Gas Seeps		High density Many long-lived species High species richness					
Cleaver Bank	SAC (H1170)	High biomass Many rare species High evenness	Medium density	High species richness			Rare habitat
Central Oyster Grounds	No protection (qualifies as OSPAR area)	Many long-lived species Many large species High species richness	High density Many rare species High species richness		High bird values (Aug-Sept)		Rare habitat
Frisian Front	SPA	Many large species High species richness	High density High biomass Many rare species High species richness		High bird values (Aug-Sept)		Rare habitat
Borkum Reef	No protection	Long-lived species High density					
Brown Ridge		High evenness		High evenness	Under investigation	White beaked dolphin (occasional sightings)	
Southern Bight		High evenness Lowest species richness					
Coastal sea north	SAC (H1110_B); SPA (many species)	High density High biomass Low species richness	High density High biomass		High bird values (year round)	Important for seals	Rare habitat
Coastal sea middle	No protection	High biomass Many heavy growing individuals Low species richness	High density High biomass		High bird values (year round)		Rare habitat
Coastal sea south (Delta)	SAC (H1110_B); SPA (many species)	High biomass Low species richness	High density	High species richness High evenness	High bird values (year round)	Important for seals	Rare habitat

Central Oyster Grounds
The Central Oyster Grounds contain a relatively large number of long-lived, large macrobenthic species and a high macrobenthic species richness. This area is highly biodiverse with high megabenthos densities, many rare species (with a low frequency of occurrence) and a high species richness. Bird values are mainly high in August-September. The silty deep water habitat is rare. This area is not part of the Natura 2000 network. It is not therefore part of the OSPAR network of MPAs, although it qualifies as such.

Frisian Front
The Frisian Front is a Natura 2000 SPA to protect birds, but the most biodiverse element of this area is the benthos. There are many large macrobenthic species, there is a high macro and megabenthic species richness, the area contains high densities and biomasses of megabenthos, and many rare megabenthic species. Bird values are mainly high in August-September. The area contains relative rare habitat types.

Borkum Stones
In the Borkum Stones area Natura 2000 habitat type H1170 (abiotic reef) is present (Bos 2011 (in prep)). Macrobenthos (of the soft substrate) includes a relatively high number of long-lived species (>10 y) and has a relatively high density.

Between Cleaver Bank, Brown Ridge and Frisian Front
The area in the western part of the North Sea, above Brown Ridge, has a high macrobenthos evenness. The northern part, close to the Cleaver Bank, shows a high megabenthos density, biomass and high species richness. In winter, bird values may be high. The habitat type in part of the area is rare according to this study.

Brown Ridge
Brown Ridge shows a moderately high evenness of macrobenthos, but low values for other benthos biodiversity metrics. Fish also have a relatively high evenness. In the Brown Ridge area and south of it, bird surveys are currently being carried out by IMARES (2009-2012) to determine whether this area qualifies as a SPA. These data have not been analysed in this study.

Southern Bight
The Southern Bight is not very biodiverse in terms of benthos or birds. Part of the area has high values for fish.

Coastal sea north
The northern part of the coastal sea is a Natura 2000 SPA and SAC, starting from Bergen and extending to the German border. This area is rich in biomass and density of macrobenthos and megabenthos, but the species richness is low. Bird values are among the highest on the Dutch Continental Shelf, the area is important for two species of seal and the habitat type is rare.

Coastal sea middle
The middle part of the coastal sea is not protected as a SPA /SAC. It is rich in biomass and has high macrobenthos and megabenthos density, with a low benthic species richness, but high bird values. The area is less important for seals than the northern and southern part of the coastal sea, but the habitat type is rare according to this study.

Coastal sea south
The southern part of the coastal Sea is a Natura 2000 SPA and SAC (Voordelta) and SAC (Vlakte van de Raan). The area contains a high macrobenthic biomass and has low macrobenthic species richness. The number of samples of megabenthos is low but indicates

a high density, high biomass but low species richness. The fish species richness and evenness is high in the third quarter of the year.

Special protection zones (SAC) under the Habitat Directive
The following tables give an assessment of the status of conservation of habitat type 1110 (Sandbanks covered all the time), subdivided into type 1110_B (North Sea Coastal Zone), and type 1110_C (Dogger Bank) and Habitat type 1170 (Open-sea reef, e.g. Cleaver Bank), and of the status of conservation of the Habitat Directive species (Jak et al., 2009).

The quality of each habitat type is specified on the basis of a number of criteria, in accordance with the methodology established by the European Habitats Committee, i.e.:

- Vegetation types (not relevant to marine habitat types)
- Abiotic pre-conditions
- “Typical species”
- Other characteristics of good structure and functioning

The latter two criteria are of importance to biodiversity.

A set of “typical species” have been selected on the basis of their indicative value for the community of the habitat type and its completeness. For the marine habitats, most of these species are invertebrate benthic species and fish. Their absence may indicate a deterioration in the quality of the habitat type.

Other characteristics may also contribute to the quality assessment. For H1110_B, these include the presence of aggregations of bivalve shellfish, which is an important food source for diving ducks. The composition of the benthic species assemblage is considered, and the presence of long-lived, larger species also indicates good quality. Finally, the importance of a nursery area for fish is another quality aspect of this habitat type (Table 4.4).

For Habitat type H1110_C, typical species proposed are benthic and fish species (Jak et al., 2009). The species selected indicate good quality, are characteristic of clean sand, are relatively long-lived and are important to the trophic structure of the habitat type (Table 4.5).

For the habitat type Reefs (H1170), typical species have been selected that are considered to comply with a number of the following criteria: long-lived, indicative of gravel accumulations, sessile and/or contributing to a complex biogenic structure, dependent on stably positioned cobbles, indicative of high water clarity, important to the trophic structure (Table 4.6).

For the marine benthic habitat types, disturbance of the sediments, mainly related to bottom trawling, has led to an of “unfavourable-inadequate” status assessment of the ecological quality (Table 4.7).

The quality assessment criteria described above are also relevant to other descriptors, e.g. food web structure (nursery area, aggregations of bivalves as food for diving ducks), and seafloor integrity (species assemblage, typical species).

Table 4.4 Conservation status of habitat type 1110_B (Sandbanks covered all the time): North Sea Coastal Zone. (Jak et al., 2009)

Aspect	1994	2004	2007
Distribution	Favourable	Favourable	Favourable
Surface area	Favourable	Favourable	Favourable
Quality	Unfavourable-inadequate	Unfavourable-inadequate	Unfavourable-inadequate
Future prospects	Unfavourable-inadequate	Unfavourable-inadequate	Unfavourable-inadequate
Assessment of conservation status	Unfavourable-inadequate	Unfavourable-inadequate	Unfavourable-inadequate

Table 4.5 Conservation status of habitat type 1110_C (Sandbanks covered all the time): Dogger Bank. (Jak et al., 2009)

Aspect	2009
Distribution	Favourable
Surface area	Favourable
Quality	Unfavourable-inadequate
Future prospects	Unfavourable-inadequate
Assessment of conservation status	Unfavourable-inadequate

Table 4.6 Conservation status of habitat type 1170 (Open-sea reefs): Cleaver Bank. (Jak et al., 2009)

Aspect	2009
Distribution	Favourable
Surface area	Favourable
Quality	Unfavourable-inadequate
Future prospects	Unfavourable-inadequate
Assessment of conservation status	Unfavourable-inadequate

Table 4.7 Species in the Habitat Directive. Data for 2007 (Jak et al., 2009)

Aspect	Sea lamprey	River lamprey	Twaite shad	Harbour porpoise	Grey seal	Harbour seal
Distribution	Favourable	Favourable	Favourable	Favourable	Favourable	Favourable
Population	Unfavourable-inadequate	Unfavourable-inadequate	Unfavourable-bad	Unfavourable-bad	Favourable	Favourable
Habitat	Unfavourable-inadequate	Unfavourable-inadequate	Unfavourable-bad	Unfavourable-inadequate	Unfavourable-inadequate	Favourable
Future prospects	Favourable	Favourable	Unfavourable-inadequate	Unfavourable-inadequate	Favourable	Favourable
Assessment of conservation status	Unfavourable-inadequate	Unfavourable-inadequate	Unfavourable-bad	Unfavourable-bad	Unfavourable-inadequate	Favourable

More background information, and information on the Conservation Status of species under the Birds Directive, can be found in Jak et al. (2009). Red-throated diver, common scoter, little gull (unfavourable-inadequate) and eider (unfavourable-bad) have an unfavourable status, whereas lesser and great black-backed gull, great skua and common guillemot have a favourable conservation status. The status of the black-throated diver is unknown due to a lack of data.

4.1.3.7 Ecosystem level

Total biodiversity

A general overview of total biodiversity (fish, birds and benthos) in the Dutch part of the North Sea is presented in Figure 4.18 is obtained by combining the diversity values for benthos, fish and birds. Biodiversity of birds is expressed as total bird values. Biodiversity of benthos is a function of four commonly used biodiversity indices (species richness (Hill index), evenness (Shannon-Wiener and Simpson's index) and frequency of occurrence) and fish biodiversity follows benthos biodiversity. Both benthic and fish biodiversity are calculated by scaling the indices from 1 to 10 (10 classes) and then summing them, following Lavaleye (2000). The values for the birds and fish were attributed to the benthos sampling points using the Voronoi technique. The biodiversity values for each group are scaled to quantiles from 1 to 10 and summed (Lindeboom et al., 2008).

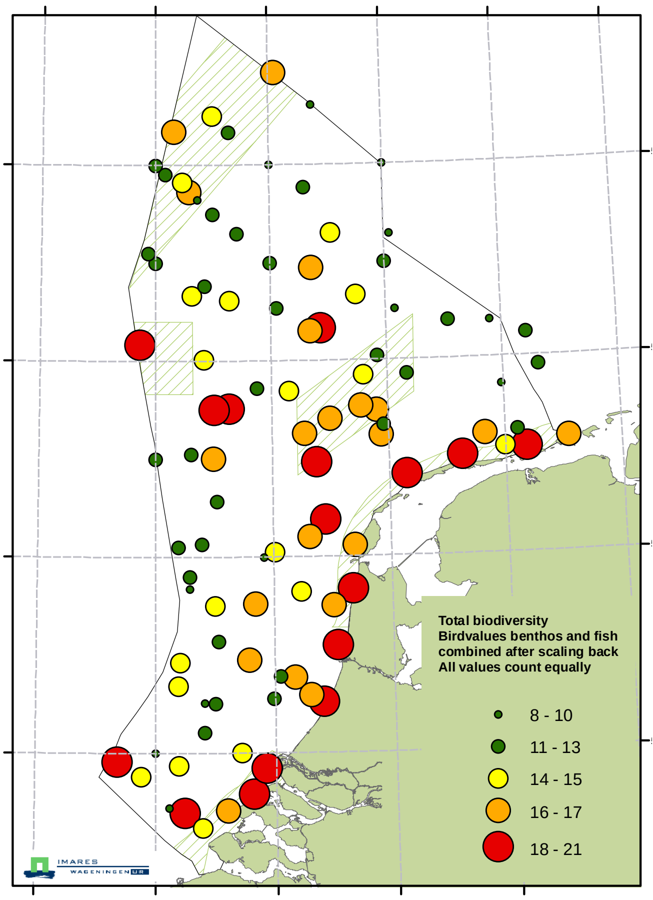


Figure 4.18 Total biodiversity (fish, birds and benthos). Biodiversity of birds is expressed as total bird values. Biodiversity of benthos is a function of 4 commonly used biodiversity indices (species richness (Hill index), evenness (Shannon-Wiener and Simpson's index) and frequency of occurrence) and fish biodiversity follows benthos biodiversity. Both benthic and fish biodiversity are calculated by scaling the indices from 1 to 10 (10 classes) and then summing them, following Lavaleye (2000). The values for the birds and fish were attributed to the benthos sampling points using the Voronoi technique (Lindeboom et al., 2009).

Status of biodiversity
The evolution of the diversity of several species groups in the ecosystem is assessed by comparing the current status with the 'natural' biodiversity expected when human impact is small or absent (Wortelboer, 2010). The natural situation is not known for many species, however. In these cases, the first data acquired by monitoring were used as a reference dataset. These are mainly data from the 1990s.

The "nature value indicator" (Natuurwaarde graadmeter) of the ecosystem is represented as a percentage of a reference value. A comprehensive description of the method is given by Wortelboer (2010). The results of the analysis were included in the Natuurbalans 2008 (PBL, 2008; Van Leeuwen et al., 2008). The calculations for the various species groups are based on averages for a selection of species or indicator scores. As discussed by Wortelboer (2010), the deviation from a hypothetical reference value is less informative than the temporal evolution of the indicator. According to an assessment by Wortelboer (2010) the current biodiversity of the Dutch North Sea is only 40% of its natural state. Fish and mammals have relatively low nature value scores, whereas macrobenthos and birds have relatively high scores. Although the trend in the average biodiversity since 1990 is negligible, phytoplankton and mammals show an overall positive trend, whereas macrobenthos and fish show an overall negative trend. The nature value indicator for mammals is improving slightly.

4.1.3.8 Summary

Summary
Pressures Many activities and the associated pressures in the Dutch part of the North Sea have an impact on biological diversity, by affecting species distribution or abundance or by impacting on habitat condition. The most important activities in this respect are commercial fishing, aggregate extraction, oil and gas exploration, maritime transportation, and pollution from land-based emissions. Pressures such as the removal of species (e.g. by fishing), extraction of target and non-target species, loss of and damage to habitats, the introduction of non-indigenous species, obstacles to species migration and poor water quality are still present. **Species level** The coastal and offshore areas of the Dutch part of the North Sea are periodically of great importance to marine birds. Coastal waters are characterized by high densities. Harbour porpoise, grey seal and harbour seal are common species in the Dutch part of the North Sea. The populations of marine mammals (grey seal, harbour seal, harbour porpoise) have shown an increase in abundance. No specific areas of particular ecological importance (in terms of reproduction, foraging or migration) can be identified for harbour porpoises (Camphuysen & Siemensma, 2011). Three different fish communities can be distinguished in the North Sea, related to environmental conditions like water depth and temperature. Coastal waters in the Dutch part of the North Sea show a higher species diversity than the central North Sea, but species diversity is highest in the northern North Sea. Species richness has increased, probably due to environmental effects (increasing temperatures) as well as anthropogenic influences (commercial fisheries). Fisheries improve the conditions for opportunistic species and scavengers. Selective removal of larger individuals also reduces the predation pressure on smaller fish species.

Biodiversity of benthic invertebrates is higher in the northern offshore waters (north of the Frisian Front). Density and biomass are higher in the coastal waters and in the Frisian Front area.

Phytoplankton composition shows long-term changes, related to environmental factors (meteorology, transport patterns). To some extent, nutrient enrichment may also play a role.

Many components of the ecosystem are not covered by routine monitoring programmes (e.g. epibenthos, hard substrate biota, zooplankton), so information on species distribution, population size and population condition is available only for a selection of groups (marine mammals, birds, commercial fish species, macrozoobenthos, phytoplankton).

Habitat level
Several subareas can be distinguished in the Dutch part of the North Sea, differing in biological diversity. Some of these areas have been designated Natura 2000 sites.
The habitat types ‘shallow banks’ (1110) and ‘open-sea reefs’ (1170), which occur in marine Natura 2000 sites, have an unfavourable-inadequate conservation status.

All marine Habitat species except the harbour seal have an unfavourable Conservation status.

Four bird species under the Birds Directive have an unfavourable conservation status.
Information is available about the spatial distribution of benthic habitats, but information on trends in habitat quality is lacking.

Ecosystem level
According to an assessment by PBL (2008) the nature value indicator shows no clear trend since the 1990s.

4.2 GES descriptor 2: Non-indigenous species

4.2.1 MSFD description

Annex I MSFD
Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystem

Criteria and indicators in the Commission Decision
2.1 Abundance and status characterisation of non-indigenous species, in particular invasive 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)
2.2 Environmental impact of invasive non-indigenous species
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) *Impacts of non-indigenous invasive species at the level of species, habitats and ecosystem, where feasible (2.2.2)*

4.2.2 OSPAR QSR 2010

General description for the North East Atlantic	*OSPAR Quality Status Report 2010*
Non-indigenous species may cause unpredictable and irreversible changes to marine ecosystems, such as predation or competition for indigenous species, modification of habitats and trophic impacts. A variety of economic or human health impacts are possible through, for example, fouling, harmful non-indigenous algal blooms or damage to structures. Over 160 non-indigenous species have been identified in the North East Atlantic but the actual number of species introduced is likely to be greater than this. This is because long-term monitoring and recording data are limited and identifying the species taxonomically can be difficult. Some species are currently misidentified. ICES has identified 30 non-indigenous species that have adverse impacts on ecosystems or human health within the North East Atlantic. Many non-indigenous species have been found in the North Sea. The main vector for the initial introduction of these species has been mariculture followed by ballast water from ships, hull fouling and fishing. The most important and widespread impacts are changes to habitats and competition for food and space with indigenous organisms. Many of these species also have economic impacts. Almost all the species concerned were introduced before the current measures, some as long as several hundred years ago.	

4.2.3 The Dutch part of the North Sea

The North Sea is intensively used for maritime transport, and various international shipping lanes and transport routes to large ports (Antwerp, Vlissingen, Rotterdam and Amsterdam) are found in the Dutch part of the North Sea. The large ports at Vlissingen and Rotterdam are close to intensive aquaculture (shellfish cultivation) in the Eastern Scheldt. Commercial and non-commercial shipping is currently the most important vector for the introduction of non-indigenous species, through ballast water and fouling organisms on ships' hulls. The International Maritime Organization (IMO) ballast water management guidelines coming into force by 2016 require ships to clean ballast water.

4.2.3.1 Occurrence of non-indigenous species

Non-indigenous species, as defined by the JRC Task Group 2 (Olenin et al., 2010), are "species, sub-species or lower taxa introduced outside of their natural range (past or present) and outside of their natural dispersal potential, and that might survive and subsequently reproduce. Their presence in the given region is due to intentional or unintentional introduction resulting from human activities, or they have arrived there without the help of people from an area in which they are alien".

Wolff (2005) provides an overview of marine and estuarine non-indigenous species in the Netherlands. In total, 37 non-indigenous species are reported that (may) have established themselves in the Dutch part of the North Sea (Table 4.8). Several non-indigenous species were observed only a few times in the past, and are therefore considered extinct in Dutch waters. These are not included in the list. Most of the marine non-indigenous species are algae, followed by crustaceans, molluscs and worms.

OSPAR has listed 30 non-indigenous species that are considered problematic. Observed impacts have been classified as habitat modification, fouling, algal blooms, trophic impacts (including competition and predation), nutrient regeneration, biodiversity loss, and damage to structures. The American jackknife clam *Ensis directus* is the most conspicuous non-indigenous species in the Dutch part of the North Sea. It has become very successful over the last two decades (see trends under §4.4).

4.2.3.2 Impacts of non-indigenous species

There are no specific monitoring programmes to monitor the introduction and establishment of non-indigenous species. According to the Quality Status Report (OSPAR, 2010) *E. directus* has an impact on the ecosystem through competition and habitat modification. Although no ecological effects of this introduction were apparent at first, it is now striking that a number of native bivalve species, including four indigenous species closely related to the American jackknife clam *Ensis directus*, in particular, have decreased in numbers during the same period in which the American jackknife clam increased and stabilized in numbers (www.compendiumvoordeleefomgeving.nl).

During the 19th century, fishing led to over-exploitation, failing recruitment, and destruction of the European flat oyster *Ostrea edulis*, which was also affected by extremely cold winters. Then the disease *Bonamia ostrea* spread in the early 1960s and 1970s, drastically reducing the production of *O. edulis* in almost all traditional European rearing areas. In that period Pacific oysters Crassostrea gigas were imported for aquaculture in the Eastern Scheldt estuary. Within a few years the Pacific oyster grew explosively and in the 1980s other Dutch estuaries started to be colonised. The Pacific oyster has now spread into the SW Netherlands and the Wadden Sea. It does not occur in the Dutch North Sea in significant numbers.

Though species like *Mnemiopsis leidyi* and *Didemnum vexillum* are not on Wolff's list (2005), they do have the potential to become highly problematic, as is seen in other areas where they have been introduced. These two species may have an impact along the coastlines of Europe (not in the KRM area), but they are transported through the North Sea by both natural distribution and by ships.

*Table 4.8 Non-indigenous species in the Dutch part of the North Sea, based on Wolff (2005)[2], supplemented with observations from the DAISurIE database (http://www.europe-aliens.org/)(indicated by *). A number of recent publications, partly in Dutch, were also consulted (selection given in reference list below), as well as the Global Invasive Species Database (GISD): 100 worst invasive species. Unpublished results have not been included. The possible impact of the NIS is based on the QSR (OSPAR, 2010 and the GISD).*

Species	Status	Vector	Possible impact
RHODOPHYTA (Red algae)			
Asparagopsis armata	not established	Shellfish (oyster) transport, secondary spread (floating, rafting)	
Bonnemaisonia hamifera	not established	Probably shellfish transport, fouling, secondary spread by currents	Competition, habitat modification
Polysiphonia harveyi	established	Unknown	
BACILLARIOPHYCEAE (Diatoms)			
Coscinodiscus wailesii	established	Ballast water or shellfish (oyster) transport, secondary transport by currents	Algal blooms
Odontella sinensis	established	Ballast water, secondary transport by currents	
Thalassiosira punctigera	established	Probably shellfish (oyster) transport, secondary transport by currents	
PHAEOPHYCEAE (Brown algae)			
Botrytella sp	established	Unknown	
Sargassum muticum	established	Shellfish (oyster) transport, secondary spread by currents	Habitat modification
RAPHIDOPHYCEAE			
Chattonella marina	established	Unknown	
Chattonella antiqua	established	Unknown	
Fibrocapsa japonica	established	Unknown	
Heterosigma akashiwo		Unknown	
DYNOPHYTA (Dinoflagellates)			
Alexandrium leei		Unknown	
Alexandrium tamarense		Unknown	
Gymnodinium mikimotoi	established	Ballast water (?)	
Prorocentrum triestinum		Unknown	
CHLOROPHYTA (Green algae)			
Codium fragile		Fouling, shellfish transport (?), ballast water (?)	Competition, habitat modification, fouling
PLATYHELMINTHES (Flatworms)			
TURBELLARIA			
Euplana gracilis	Unknown	Fouling	
ANNELIDA (Ringed worms)			
POLYCHAETA		Shellfish (oyster) transport	
MOLLUSCA			
GASTROPODA (Snails and slugs)			
Crepidula fornicata	Established	Oyster transport	Predation, competition
Ocinebrellus inornatus	Established	Oyster transport	
*Rapana venosa**		Importation	Competition
Urosalpinx cinerea	Established		Predation
BIVALVIA (Bivalves)			
Crassostrea gigas	Established	Shellfish culture	Competition, habitat modification

[2] Wolff (2005) describes non-indigenous marine and estuarine species. Only species which have been found in the North Sea have been included in the list presented here.

	Ensis directus	Established	Ballast water	Competition, habitat modification
	Mya arenaria	Established	Ballast water	Competition
	Petricola pholadiformis	Established	Shellfish (oyster) transport, secondary transport by currents	Damage to shores; habitat modification
	Psiloteredo megotara		Wooden vessels	
	Teredo navalis		Wooden vessels	Damage to wooden structures, habitat modification
CTENOPHORA				
	Mnemiopsis leidyi	established	ballast water	Competition and predation
CRUSTACEA				
	CIRRIPEDIA (Barnacles)			
	Elminius modestus	Established	Fouling, secondary transport by fouling and marine currents	Competition, habitat modification
	Balanus balanus		Unknown	
	Balanus amphitrite	Established	Fouling, ballast water (?)	
	Balanus improvisus		Fouling	
	Caprella mutica			
Eriocheir sinensis		Established	Ballast water, secondary on its own	
	Megabalanus coccopoma	Unknown	Fouling	
	Megabalanus tintinnabulum	Unknown	Fouling	
	ISOPODA (Isopods)			
	Limnoria lignorum		Wooden vessels	
	Limnoria quadripunctata		Wooden vessels (?), driftwood (?)	
	AMPHIPODS (Amphipods)			
	Corophium sextonae	established	Fouling	
	Platorchestia platensis	established	Dry ballast (?)	
NEMATODA (Roundworms)				
	Anguillicola crassus	established	Eel transport	
INSECTA (Insects)				
	*Telmatogeton japonica**	established	Fouling	Competition, habitat modification
	TUNICATA			
	Styela clava	established	Hull fouling	
	Didemnum vexillum	established	Ballast water (?)	Competition; habitat modification
	Bottrylloides violaceus	established	(Ballast water(?)	
PISCES (Fish)				
	Atherina boyeri	established	Eggs transported by ships (?)	

4.2.3.3 Summary

Summary

Pressures

Commercial and non-commercial shipping is currently the most important vector for the introduction of non-indigenous species through ballast water and fouling organisms on ship hulls. In addition, aquaculture is a factor of secondary importance in the introduction of non-invasive species.

Abundance and status

There are no specific programmes to monitor the introduction and establishment of non-indigenous species in the Dutch part of the North Sea. There are, however, a few databases where observations are reported: the Naturalis species register; the database of the Forum on Alien Species in the Netherlands (www.werkgroepexoten.nl); database of the ANEMOON foundation.

Observations of estuarine and marine non-indigenous species are concentrated in the estuarine waters in the SW Netherlands and the Wadden Sea, and the coastal waters of the North Sea. The monitoring effort in the offshore waters of the North Sea is much smaller.

Environmental impact

The American jackknife clam has successfully established itself in the Dutch coastal zone. It may have caused the decline in several indigenous bivalve species, including four other jackknife species, but no causal relationship has yet been established.

The Pacific oyster *Crassostrea gigas* has established in the Dutch coastal zone, particularly the SW Delta area and the Wadden Sea.

Non-indigenous species can cause considerable adverse and/or harmful change in the North Sea ecosystem potentially leading to the disappearance of habitats, extinction of species and changes in the food web. At present, however, such changes are not known to have occurred in the Dutch part of the North Sea. The risk of impact by non-indigenous species increases as the intensity of related activities increases, but the actual risk might not be equivalent due to the implementation of measures. Furthermore, the magnitude of the actual ecological impact of invasion cannot be predicted.

4.3 GES descriptor 3: Commercially exploited fish and shellfish

4.3.1 MSFD description

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

Criteria and indicators in the Commission Decision
3.1 Level of pressure of the fishing activity
Fishing mortality (F) (3.1.1)
Secondary indicator: Ratio between catch and biomass index (hereinafter catch/biomass ratio) (3.1.2)
3.2 Reproductive capacity of the stock
Spawning Stock Biomass (SSB) (3.2.1)
Secondary indicator: Biomass indices (3.2.2)
3.3 Population age and size distribution
Proportion of fish larger than the mean size at first sexual maturation (3.3.1)
Mean maximum length across all species found in research vessel surveys (3.3.2)
95th percentile of the fish length distribution observed in research vessel surveys (3.3.3)
Secondary indicator: Size at first sexual maturation, which may reflect the extent of undesirable genetic effects of exploitation (3.3.4)

4.3.2 OSPAR QSR 2010

General description for the North East Atlantic	*From: OSPAR Quality Status Report 2010*
Fishing pressure continues to have a considerable impact on marine ecosystems and many problems remain despite efforts to improve management. Exploitation of many stocks continues to be beyond the levels they can sustain, while the status of a large number of stocks cannot be fully assessed due to poor data. Habitat destruction and the depletion of key predator and prey species and consequent food web effects are of concern. **<u>Region II (Greater North Sea), regional summary:</u>** **Some fish stocks improved.** Fisheries management is changing for the better, with long-term management plans for key stocks and substantial decreases in destructive practices such as beam and otter trawl fishing in some areas. The discards of fish are beginning to be addressed. There are signs that fish communities near the seabed may be starting to recover. **Progress towards sustainable fishing is slow** Some important North Sea fish stocks are still outside sustainable limits and while damaging practices have been reduced, the picture is not uniformly good. The poor status of cod is of particular concern.	

4.3.3 The Dutch part of the North Sea

The North Sea has high yields of commercially exploited fish stocks, but also very high fishing pressure. The main pressure on commercial fish stocks comes from the extraction of species by fisheries, including as a consequence of incidental by-catch of non-target species (Figure 4.18). Fishing for shellfish is at a relatively low level at the moment.

4.3.3.1 Fishing mortality and reproductive capacity of fish stocks

The status of commercial fish stocks in the North Sea is assessed annually by ICES as a basis for fisheries management advice . The phrase *"within safe biological limits"* has been adopted from earlier ICES approaches and similar attributes are currently still used to assess the stocks in the ICES area. A stock should be (1) exploited sustainably consistent with high long-term yields and (2) have full reproductive capacity. However, the ICES advice is undergoing a transition to the Maximum Sustainable Yield (MSY) approach to fisheries management (F_{MSY} and biomass target and reference points are not available for all stocks). Thus, until the MSY approach becomes operational other analyses need to be taken into account.

A recent review of stock status in the North Sea by STECF (2010) took the MSY approach further. This STECF assessment is given below, although there are still many challenges to their approach which need to be considered when looking to future reviews of stock status:

4 ICES has already made substantial progress on setting fishing mortality MSY targets which are based on thorough analysis of stock dynamics and not on proxies. These values for fishing mortality will be available by the end of 2011. For many stocks the proxies F_{max} or $F_{0.1}$ are not appropriate.

5 B_{MSY} is not appropriate as a reference level for most commercially exploited fish stocks in the trophically complicated North Sea. ICES currently suggests that the reference level for reproductive capacity of the stock should be B_{pa}, until further analysis can provide more robust reference levels for biomass and reproductive capacity. ICES will not provide B_{MSY} reference levels until it is convinced that values for B_{MSY} are scientifically robust.

6 Many fish stocks were not included in the STECF review, and the greater North Sea was not considered.

7 The analysis does not include information from 2009 or 2010.

ICES is working to operationalise the MSY approach to fisheries management, so the following review of stock status from STECF is the best available information at present:

In the case of the North Sea, consisting of five ICES divisions, i.e. IVa, IVb, IVc, IIIa and VIId, only divisions IVa, IVb, IVc were used for this exercise. The current status of the assessed stocks was summarized using two reference points for biomass and fishing mortality: the precautionary reference points (B_{pa} and F_{pa}), and the proxies based on Maximum Sustainable Yield (MSY) ($B_{0.1}$ and $F_{0.1}$). Both reference points are either given in stock assessment reports or could be computed from the yield per recruit table found therein. The status of each stock is that of the latest assessment available to STECF (2004, 2007 or 2009), depending on the species.

Generally, it appears that none of the assessed stocks can be considered in good condition in relation to the MSY approach (i.e. in the green area in Figure 4.19), and 40% of them are in the unsustainable zones (yellow/orange/red), as defined by their precautionary levels.

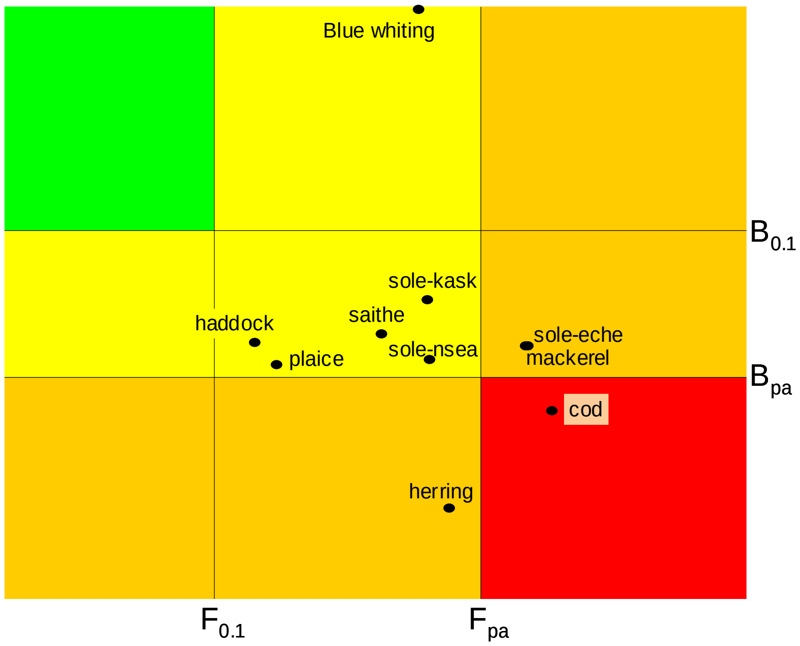


Figure 4.19 Current situation of several stocks in the North Sea (during 2008 or 2007 depending on available information) compared to the precautionary approach (pa) and MSY reference points. MSY is approximated by F= 0.1 (STECF 2010).

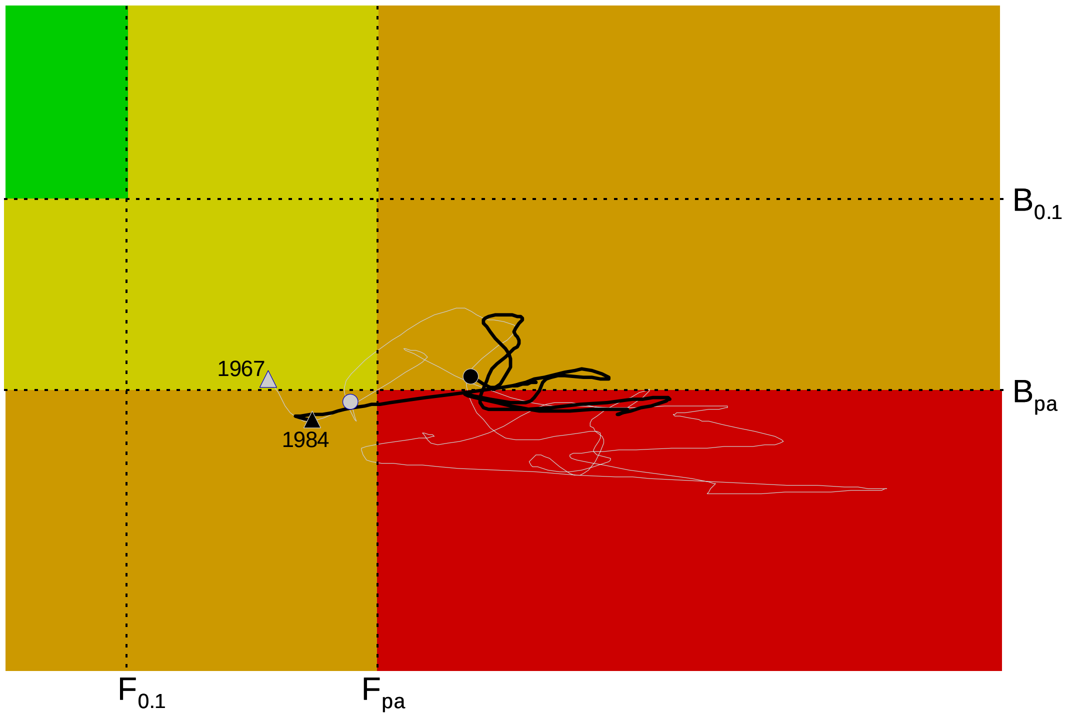


Figure 4.20 Mean situation in the North Sea, computed for the stocks displayed in Figure 4.22. Light curve goes from 1967 (white triangle) to 2008 (white circle) and concerns the following stocks: cod, haddock, herring, North Sea plaice, saithe and North Sea sole. Black curve goes from 1984 (black triangle) to 2007 (black circle) and concerns the previous stocks plus mackerel, as well as two sole stocks in Channel and Kattegat/Skagerrak.

The mean trajectory of the state of the set of assessed stocks is represented in Figure 4.20. The longer time series, starting in 1967 in the overfished (yellow) zone, shows a degradation of the exploited ecosystem state over the years with F and B values in the “high risk” area (red) over a long period. From the 1980s onwards fishing mortality has been decreasing but is still higher than F_{pa}. The biomass has improved a little but still fluctuates around B_{pa}. From an exploited situation in 1967, the ecosystem has been further exploited since, and in spite of attempts to manage the stocks sustainably, the ecosystem has not recovered to a healthy state nor has it recovered to its previous mid-1960s state.

The previous indicators show a fluctuating state in the North Sea ecosystem from 1967 onwards, a period during which the ecosystem was already experiencing high exploitation rates with the highest landings observed since 1950. From 1985 onwards, the mean fishing mortality F has been constantly decreasing. It is worth noting that, in recent years, recruitment has been poor, probably preventing a recovery of the spawning stock biomass in response to the reduced fishing mortality. However, as a certain delay between recruitment and its potential effects on the SSB has to be taken into account, the decrease in mean fishing mortality has probably not been strong enough and/or of sufficient duration to allow the recovery of the North Sea ecosystem from a strongly exploited state. Moreover, looking at the current status of the exploited ecosystem, it is clear that the fishing mortality is higher than the level advised by the MSY approach and should be reduced to allow an improvement in the SSB of the main stocks. In its current situation, the North Sea ecosystem cannot be qualified as sustainably exploited.

4.3.3.2 Population age and size distribution

There is sufficient information available to describe changes in size or age distribution of commercial demersal fish. However, the indicators suggested by the EC (2010) have not been calculated for the commercial fish species. Piet and Jennings (2005) calculated mean maximum fish length for the demersal fish community. This indicator is calculated for the entire fish community, including non-target species, and is probably not the most appropriate indicator as it essentially describes species composition and not the size structure of the fish community. Figure 4.21 shows the decrease in mean maximum length of demersal fish in the North Sea, indicating a shift towards smaller fish species.

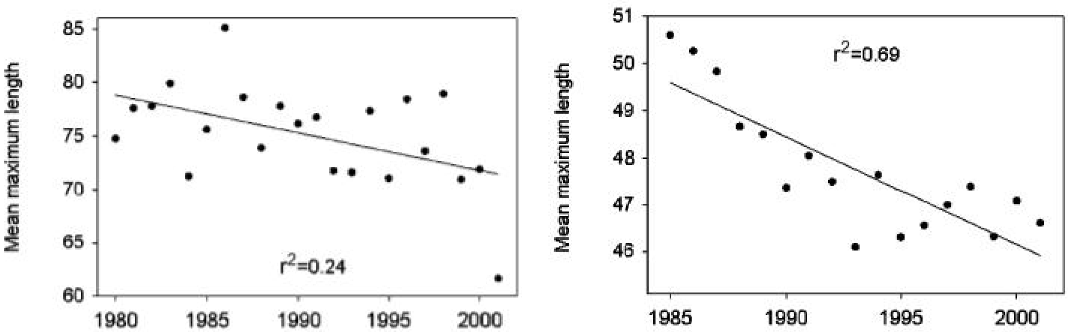


Figure 4.21 Mean maximum length of demersal fish caught in the International Bottom Trawl Survey (left) in the North Sea, Skagerrak and Kattegat, and in the Beam Trawl Survey in the southern North Sea (Piet and Jennings, 2005).

Figure 4.22 shows the proportion of large fish in the demersal fish community (OSPAR, 2010). The proportion of large fish (>40 cm) has declined from approximately 30% before 1980 to less than 10% in 2000, but is currently increasing again, making up more than 30% of the weight of catches. This is an improvement, but there is still some way to go to reach the EcoQO (OSPAR, 2010). The EcoQO indicates a shift in the size structure of the demersal fish community towards smaller individuals. Although the data encompass the entire demersal fish community, including non-commercial species, the changes may have ecological consequences, as the resilience of populations may decline, interactions between species may change, and exploitation by fisheries may be affected.

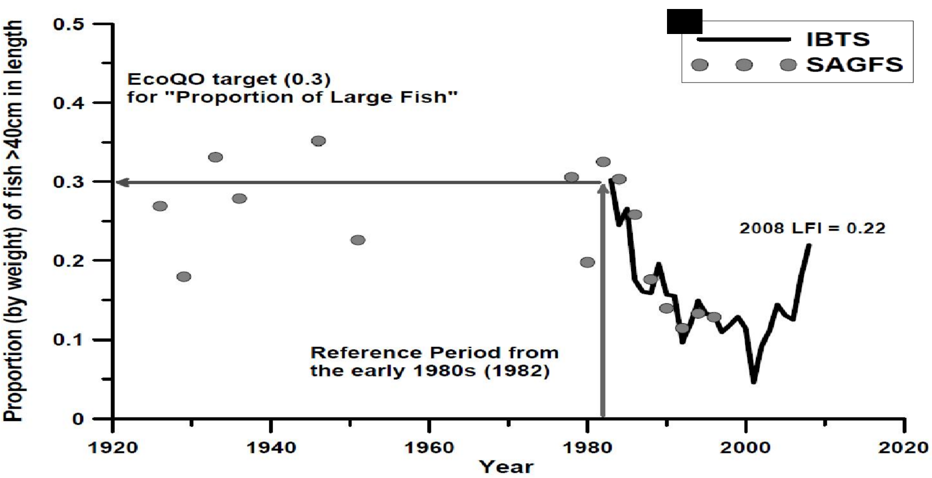


Figure 4.22 Proportion of fish >40 cm among the demersal fish caught in the International Bottom Trawl Survey. Figure from Greenstreet et al 2011.

The probabilistic maturation reaction norm indicator (PMRNI) is an indicator of the potential “genetic effects” of fishing on exploited populations. This indicator is not calculated on a regular basis but two studies exist that show the PMRNI over time for plaice (Grift et al. 2003) and sole (Mollet et al. 2007) in the North Sea. The PMRNI for plaice (Figure 4.23) and sole (Figure 4.24) both show that the reaction norm for age and length at maturation has indeed shifted significantly towards a younger age and shorter length. This is attributed to intensive exploitation which may have caused evolutionary changes in the age and length at maturation of these species. No trends have been found in the length at maturation in pelagic fish, even when PMRN is analysed.

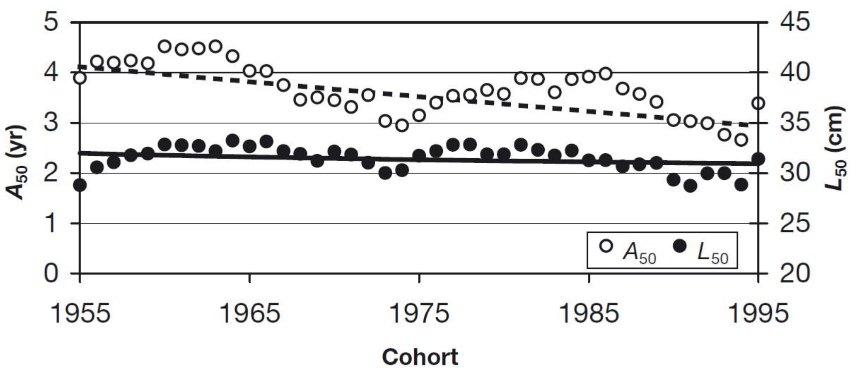


Figure 4.23 PMRNI for plaice (Pleuronectes platessa): trends in the age (A50) and length (L50) at which 50% of fish are mature in each cohort. Data from logistic models with cohort either as a factor (open and filled circles) or as a variate (dashed and continuous lines). In both cases, the decline of A50 and L50 over time is significant (p < 0.0001)

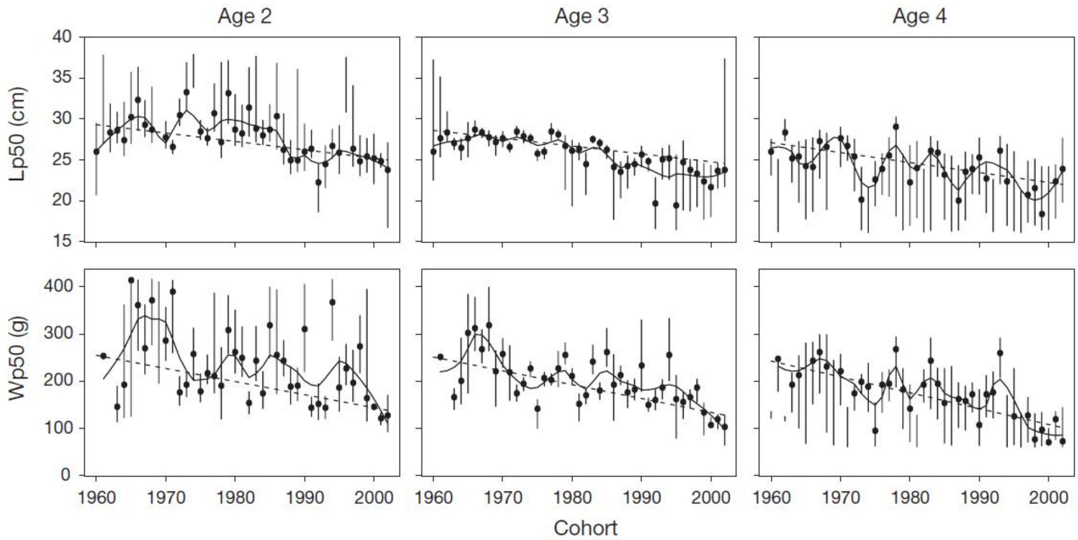


Figure 4.24 PMRNI for North Sea sole (Solea solea): reaction norm midpoints Lp50 and Wp50 over time (dots), bootstrapped 95% percentiles (vertical bars), trend regression weighted by the inverse bootstrap variances (---) and fit with a non-parametric smoother. All trends are significant on a level of α = 10^{-4}

4.3.3.3 Status of commercial shellfish stocks

Until the late 1990s, the most important commercially exploited shellfish species in the Dutch coastal zone was *Spisula subtruncata*. Their abundance and biomass showed high annual fluctuations (Figure 4.25). Over the last decade, however, *S. subtruncata* has disappeared almost completely from the coastal zone. Considerable densities are still present only to the north of the island of Ameland. The reason for the decline is not clear. The disappearance of *Spisula* coincided with the appearance of the American jackknife clam *Ensis directus*, an introduced species that was able to colonize the space previously occupied by *S. subtruncata* (Figure 4.26).

The abundance and biomass of the jackknife clam have increased since the beginning of this century. They often occur in very high densities, and dominate the benthic community biomass. In recent years, limited fishing for this clam has been permitted.

Other types of shellfish fisheries (such as fisheries for mussels or cockles) are currently of only minor importance.

No Information is available on the population age and size distribution of shellfish stocks.

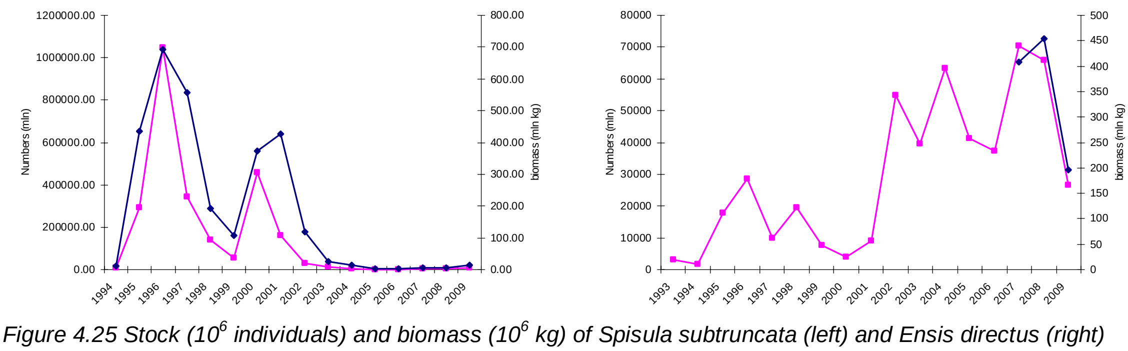


Figure 4.25 Stock (10^6 individuals) and biomass (10^6 kg) of Spisula subtruncata (left) and Ensis directus (right) (pink: densities, blue: biomass) (Data: WOT survey – IMARES).

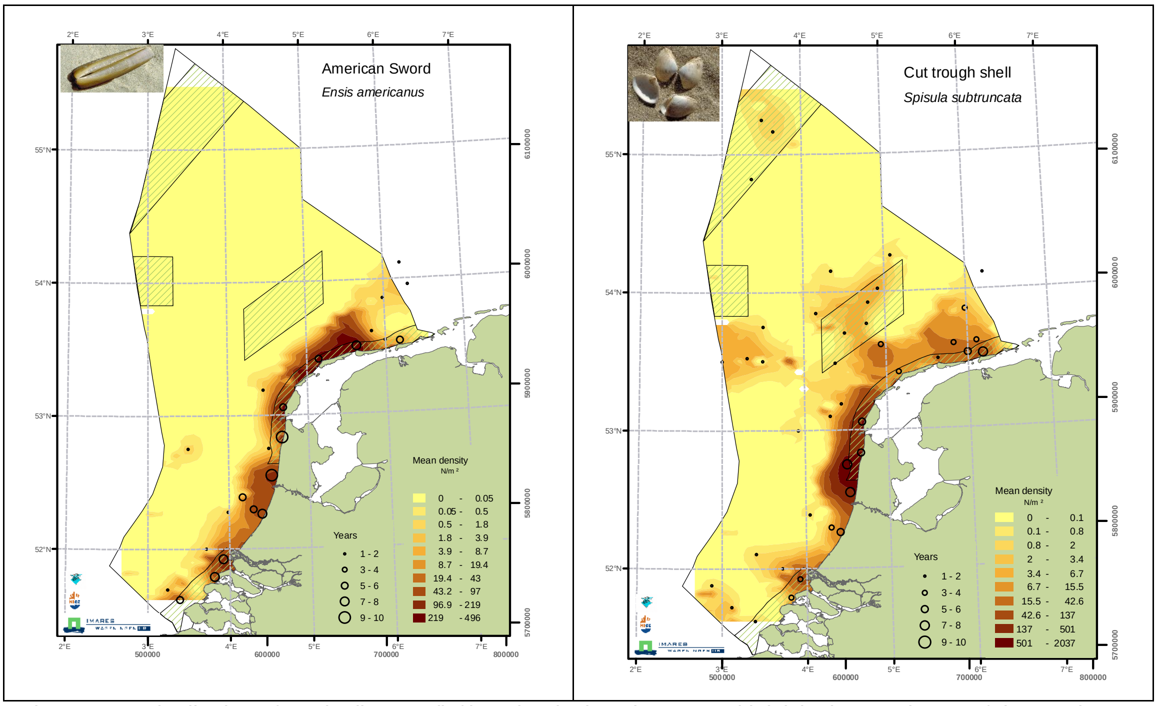


Figure 4.26 Distribution of Ensis directus (left) and Spisula subtruncata (right) in the Dutch part of the North Sea (Lindeboom et al., 2008). The densities of E. directus are averaged over 11 years (1995-2005) and densities of S. subtruncata are averaged over 13 years (1993-2005).

4.3.3.4 Summary

Summary

Pressures

The main pressure on commercial fish stocks comes from the extraction of species by fisheries, including extraction as a consequence of incidental by-catch of non-target species. At present, there is only limited exploitation of shellfish stocks (mainly American jackknife clam).

Fishing mortality and reproductive capacity of fish stocks

Stock status based on the level of fishing pressure and the reproductive capacity of the stocks show that fishing mortality has decreased in recent years. However, spawning stock biomass SSB has hardly increased. Most commercial stocks in the North Sea cannot be considered to be sustainably exploited, in relation to the MSY approach.

Population age and size distribution of fish stocks

There has been a decline in the size distribution of demersal fish in the North Sea over the period 1975-2005. This probably also applies to commercial species.
The OSPAR EcoQO on the proportion of large fish has shown improvement, but has not been met yet.
For at least two commercial species (plaice, sole) the probabilistic maturation reaction norm indicator age shows that length at maturation has indeed significantly shifted towards a younger age and shorter length. This is attributed to intensive exploitation which may have caused evolutionary changes in the age and length at maturation of these species

Status of commercial shellfish stocks

In the 1990s, the cut trough shell *Spisula subtruncata* was commercially exploited. The abundance of this species has shown an unexplained decline. Nowadays, some fishing for the American jackknife clam *Ensis directus* occurs in the coastal zone.

4.4 GES descriptor 4: Food webs

4.4.1 MSFD description

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

Criteria and indicators in the Commission Decision
4.1 Productivity (production per unit biomass) of key species or trophic groups
Performance of key predator species using their production per unit biomass (productivity) (4.1.1)
4.2 Proportion of selected species at the top of food webs
Large fish (by weight) (4.2.1)
4.3 Abundance/distribution of key trophic groups/species
Abundance trends of functionally important selected groups/species (4.3.1)

4.4.2 OSPAR QSR 2010

General description for the North East Atlantic	*OSPAR Quality Status Report 2010*
Changes in fishing activity, discards and fish community structure affect the food web and, in turn, populations of predators and scavengers. These relationships are complex and often linked to other factors. Fishing causes changes in community structure and marine food webs, which may be irreversible. The depletion of larger predatory species has strong effects on fish community structure. **Region II (Greater North Sea), regional summary:** No specific information relating to the southern North Sea	

4.4.3 The Dutch part of the North Sea

Like the GES descriptor biological diversity, food webs in the Dutch part of the North Sea are influenced by the high intensity of human activity. Many activities and the associated pressures probably have an impact on food webs. Some of the most important activities in this respect are commercial fishing, aggregate extraction, oil and gas exploration, maritime transportation, and pollution from land-based emissions. The descriptor of food webs is strongly connected and intertwined with descriptor 1 ‘Biodiversity’ and descriptor 6 ‘Seafloor integrity’. Information in these chapters may therefore also apply to this descriptor. As this descriptor is not yet well developed, either nationally or internationally, the information presented here focuses on currently available knowledge that fits the descriptor ‘Food webs’. Information on other relevant food web items such as jellyfish, cephalopods, sharks, rays and birds, and more integrated methods for describing food web quality are currently not readily available or have been identified as a knowledge gap.

4.4.3.1 Productivity of key species or trophic groups

The actual design and implementation of this indicator is still under discussion, both nationally and internationally. This indicator is part of a wider interpretation of how carbon flows through a food web and where key species play an assumed pivotal role. Top predators are often seen as key species, but species that form a key link within a food web are of equal importance. Performance of key predator species is interpreted here as reproduction or population growth relative to other production levels (carbon flow) through the food web.

No information is readily available at present for the Dutch Continental Shelf. Therefore, information on marine mammal reproduction or population trends is presented wherever possible in combination with a qualitative description of their main prey items. In future, this needs to be complemented with information on other key species or trophic groups.

Grey seal (*Halichoerus grypus*)
OSPAR has developed an EcoQO for grey seals in the North Sea. The EcoQO is defined as: "Taking into account natural population dynamics and trends, there should be no decline in pup production of grey seals of ≥10 % as represented in a five-year running mean or point estimates (separated by up to five years) within any of a set of defined sub-units of the North Sea." Based on the five years up to 2006, the EcoQO was met for grey seals in all significant units of the North Sea population (Figure 4.27).

The maximum number of newborn pups in the Wadden Sea is seen in late December. Most pups are born on Richel, a relatively high sandbank between Terschelling and Vlieland. Maximum numbers are encountered during the moult (March/April). At that time, more than 90% of all the animals in the western Wadden Sea are found in the Engelschhoek, to the east of Texel and Vlieland (Brasseur et al. 2008). It is still unclear whether the changes in numbers are a direct result of local births or of emigration or migration from other areas. The population has continued to expand since 2004. Contrary to expectations, grey seal numbers have not increased since 2006 (Jak et al, 2009). This may be due to an increase in abundance outside the monitoring area, to the east of the Wadden Sea.

Grey seals have been included in the Standard Data forms for notifying the following N2000 areas to the European Commission. Conservation objectives for this species have been set for Vlakte van de Raan and the North Sea Coastal Zone (Jak et al., 2009):

- Cleaver Bank
- Dogger Bank
- Vlakte van de Raan
- (Expansion of) North Sea Coastal Zone

The current conservation goal is defined as: "Maintain the extent and quality of habitat in order to maintain the population" (Jak et al, 2009). The current assessment of the grey seal remains 'unfavourable–inadequate' (Jak et al, 2009). This is because many resting places that are theoretically suitable for grey seals on the islands and the mainland are not currently in use due to their being subject to disturbance. In addition, the possibly harmful effects of underwater noise on the grey seal and its habitat is currently the topic of much debate.

Grey seals seem to have a preference for areas of coarse sand (Jak et al., 2009). The prey choice of grey seals is largely dependent on abundantly present prey items and may vary between and within years (Brasseur et al., 2004). Sand eel (*Ammodytes* sp.), several flat fish species (sole (*Solea solea*), dab (*Limanda limanda*), flounder (*Platichthys flesus*) and plaice (*Pleuronectus platessa*)), cod (*Gadus morhua*) and whiting (*Merlangius merlangus*) are amongst the favourite prey items of grey seals. It may be that the moult and reproduction periods are followed by a period of increased foraging (Brasseur et al. 2008). For the grey seal this period falls in late spring and early summer.

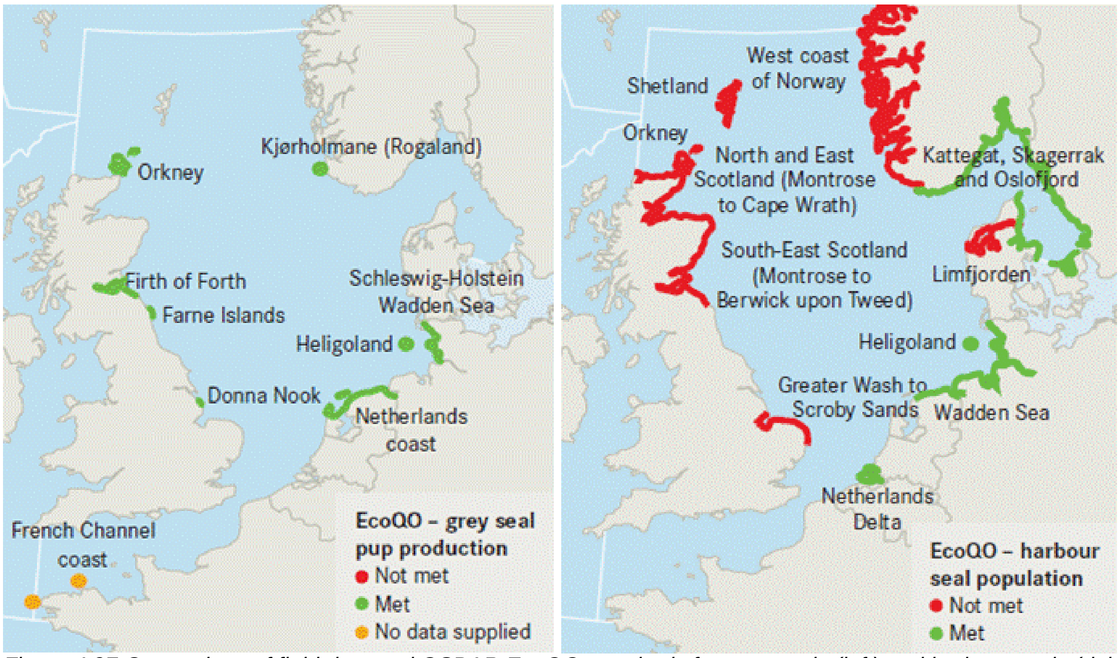


Figure 4.27 Comparison of field data and OSPAR EcoQO standards for grey seals (left) and harbour seals (right) for all significant units of the North Sea population, based upon five years up to 2006 (OSPAR 2010).

Harbour seal (*Phoca vitulina*)
OSPAR has developed an EcoQO for harbour seals in the North Sea. The EcoQo is defined as: “Taking into account natural population dynamics and trends, there should be no decline in harbour seal population size (as measured by numbers hauled out) of ≥10% as represented in a five-year running mean or point estimates (separated by up to five years) within any of eleven sub-units of the North Sea.” Based on the five years up to 2006, the harbour seal EcoQO was met in the Dutch coastal area (Figure 4.27). However, the EcoQO was not met in all areas. In several areas declines of seals of more than 10 % occurred (Shetland, Orkney, east of Scotland, Greater Wash to Scroby Sands, Limfjorden in Denmark and the west coast of Norway). Of these areas only the Limfjorden area has been affected by an outbreak of the morbillovirus in recent years. In other areas, the cause of the decline is unknown.

Harbour seals have been included as a target species for the following areas of the Dutch Continental Shelf under Natura 2000 legislation (Jak et al., 2009):

- Cleaver Bank
- Dogger Bank
- Vlakte van de Raan
- North Sea Coastal Zone 2

The current conservation goal is defined as: ”Maintain the extent and quality of habitat in order to maintain the population”. The national conservation status is ‘favourable’ (Jak et al, 2009). In spite of this, the national objective has been formulated as an improvement target: ‘Maintain distribution, increase extent and improve quality of habitat for the purposes of expanding the population’. The extent to which disturbances within Natura 2000 sites have a negative impact on occurrence is unclear, but it is in all probability limited. In any case, they are not hindering the observed increase in the population in the Wadden area.

The offshore areas are significant for harbour seals as foraging sites (Jak et al, 2009). In their search for food, the water depth throughout the Dutch Continental Shelf is not a limiting factor since harbour seals can dive to depths greater than 150 m (Frost et al. 2001). It is unknown whether the notified offshore areas are of special significance for foraging. The prey choice of harbour seals is largely dependent on individual behaviour and abundantly present prey items, and it may vary between and within years (Brasseur et al., 2004). Several flat fish species (sole, flounder and plaice), cod, whiting, sand eel and herring (*Clupea harengus*) are amongst the favourite prey items of harbour seals. Little is known about the distribution of seals in open sea. The entire North Sea lies within the habitat range of the seals that forage there (Jak et al., 2009).

<u>Harbour porpoise (</u>*Phocoena phocoena*)
Harbour porpoises are believed to have been common in waters off the coast of the Netherlands and Belgium in the 19th century and the first half of the 20th century, with data suggesting a decline in the southern North Sea between the 1970s and 1990s. Since the mid-1970s there has been an increase in the number of sightings and strandings in Belgian waters and the Netherlands. With the more recent findings from the SCANS surveys, it is generally agreed that this increase could well be explained by a population shift to the southern North Sea (OSPAR 2009).

Based on years of aerial surveys, areas have been identified in the German sector of the North Sea that are important for harbour porpoise reproduction (Gilles et al. 2009).
Recently, too, surveys have been carried out in a 100 km strip along the Dutch coast, on which basis it is estimated that approx. 37,000 harbour porpoises were located in the survey area in the spring of 2009. Owing to the limited number of counts performed, no final conclusion can drawn be made about the function of the site in terms of reproduction (Scheidat & Verdaat).

Harbour porpoises have been included as a target species for the following areas of the Dutch Continental Shelf under Natura 2000 legislation (Jak et al., 2009):

- Cleaver Bank
- Dogger Bank
- Vlakte van de Raan
- North Sea Coastal Zone 2

The current conservation goal is defined as: ”Maintain the distribution, extent and quality of habitat for the purposes of maintaining the population”. The assessment of the conservation status changed from “unfavourable-bad” to “unfavourable-inadequate” in 2009 based on the changed assessment of the aspect “population” from “unfavourable-bad” to “unfavourable-inadequate” (Jak et al, 2009).

Since harbour porpoises have a fast metabolism, they need to eat several times a day. Harbour porpoises swallow their prey whole. This may explain why almost all their prey fish are smaller than 25 cm (M. Leopold pers. comm.). Harbour porpoises have a wide choice of prey (Santos & Pierce, 2003). Cod, whiting, goby (goby sp.), herring and sand eel are amongst the favourite prey items of harbour porpoises. In the Dutch North Sea no special foraging sites can be identified based on our currently limited knowledge about distribution and diet (Brasseur et al,. 2008). No specific areas of particular ecological importance (in terms of reproduction, foraging or migration) have so far been identified for harbour porpoises (Camphuysen & Siemensma, 2011).

4.4.3.2 Proportion of selected species at the top of food webs

This indicator focuses on the proportion of selected species at the top of the food web. This is currently monitored regularly for demersal fish species (EcoQO proportion of large fish). The indicator may be extended to include the proportion of large fish for pelagic species and the proportion of large individuals of long-lived invertebrates (shellfish). However, this information is currently not readily available for the Dutch Continental Shelf.

Information on the proportion of large fish among demersal fish species is therefore presented here. In future, this needs to be complemented with information on pelagic and invertebrate species.

Proportion of large fish

OSPAR has developed an EcoQO for the proportion of large fish in the North Sea. The EcoQo is defined as: “At least 30 % of fish (by weight) should be greater than 40 cm in length”. The trend in the proportion of large fish in the Greater North Sea in 1969 – 2008 is presented in §4.3 (Figure 4.22). The proportion of large fish (>25 cm) has declined from more than 30% before 1980 to 10% in 2007.

4.4.3.3 Abundance/distribution of key trophic groups/species

This indicator is focused on the abundance and distribution of important species or trophic groups. A wide variety of indicators can be included here. However, at the moment these indicators are still under discussion and information is not directly available.

The OSPAR EcoQO on harbour porpoise by-catch fits well here, as it focuses on groups/species that are targeted by human activities or that are indirectly affected by them (in particular, by-catch and discards). This EcoQO is therefore presented here.

Harbour porpoise by-catch

OSPAR has developed an EcoQO for by-catch of harbour porpoises in the North Sea. The EcoQo is defined as: “Annual by-catch levels of harbour porpoises should be reduced to below 1.7 % of the best population estimate”. Currently, the monitoring of by-catch and population estimates of harbour porpoises in the North Sea is inadequate for assessment of whether the OSPAR EcoQO on harbour porpoise by-catch is being met.

In the southern North Sea, up to half of stranded porpoises have been killed incidentally in fishing gear, a rate that justifies concern (OSPAR 2010). As higher species in the food chain harbour porpoises play an important role in the food web structure and in ecosystem functioning. Incidental removal of such species can lead to cascading ecological changes.

4.4.3.4 Summary

Summary
The actual design and implementation of indicators for this descriptor are still under discussion, both nationally and internationally. A complete overview of information under this descriptor cannot therefore be presented for the Dutch Continental Shelf. The information currently available that falls within the scope of the indicators is presented below. **Pressures** As with biological diversity (GES descriptor 1), many activities and the associated pressures in the Dutch part of the North Sea have an impact on food webs by affecting species distribution or abundance. The most important activities in this respect are commercial fishing, aggregate extraction, oil and gas exploration, maritime transportation, and pollution from land-based emissions. **Productivity of key species or trophic groups** The OSPAR EcoQO for grey seal pup production on the Dutch Continental Shelf has been met. The current conservation status of grey seals under Natura 2000 is “unfavourable–inadequate”. The OSPAR EcoQO for harbour seal population on the Dutch Continental Shelf has been met. The current conservation status for harbour seals under Natura 2000 is “favourable”. The number of sightings and strandings of harbour porpoises in Dutch waters has increased. The current conservation status for harbour porpoises under Natura 2000 is “unfavourable-inadequate”. **Proportion of selected species at the top of food webs** The OSPAR EcoQO for proportion of large fish (>40 cm) has declined from more than 30% before 1980 to 10% in 2007. **Abundance/distribution of key trophic groups/species** Currently, there is no reliable information on by-catch numbers in the North Sea to indicate whether the OSPAR EcoQO for harbour porpoise by-catch has been met. In the southern North Sea, up to half of stranded porpoises have been killed incidentally in fishing gear, a rate that justifies concern.

4.5 GES descriptor 5: Human-induced eutrophication

4.5.1 MSFD description

Annex I MSFD
Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters

Criteria and indicators in the Commission Decision
5.1 Nutrients levels
Nutrient concentrations in the water column (5.1.1)
Nutrient ratios (silica, nitrogen and phosphorus), where appropriate (5.1.2)
5.2 Direct effects of nutrient enrichment
Chlorophyll concentration in the water column (5.2.1)
Water transparency related to increase in suspended algae, where relevant (5.2.2)
Abundance of opportunistic macroalgae (5.2.3)
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)
5.3 Indirect effects of nutrient enrichment
Abundance of perennial seaweeds and seagrasses (e.g. fucoids, eelgrass and Neptune grass) adversely impacted by decrease in water transparency (5.3.1)
Dissolved oxygen, i.e. changes due to increased organic matter decomposition and size of the area concerned (5.3.2)

4.5.2 OSPAR QSR 2010

General description for the North East Atlantic	*OSPAR Quality Status Report 2010*
Nutrients, especially nitrogen and phosphorus, are essential for the growth of aquatic plants, which are at the base of marine food webs. The natural balance between nutrients, growth of plants and growth of animals is disturbed by an excess of nutrients which are introduced by human activities. This may result in accelerated algal growth and an adverse effect on water quality and the ecology of the marine system. Eutrophication is "the enrichment of water by nutrients, especially compounds of nitrogen and/or phosphorus, causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned" (EC, 2009). Eutrophication generally favours the growth of opportunistic algae and animals. Dense growth of algae in the water column can reduce the depth at which light is available for long-lived seagrass species. The decay of the algae leads to the release of toxic hydrogen sulphide and oxygen depletion. This may kill fish and benthos. Some algae produce toxins which are harmful to animals. Humans can also be affected if they eat contaminated shellfish, for instance. In coastal and marine waters, an elevated level of nitrogen is generally considered to be the main cause of eutrophication. Climate change may alter the impact of eutrophication in marine waters. More rain and	

increased flooding as a result of climate change are expected to enhance nutrient enrichment through increased freshwater input and run-off from land. Rising sea temperature, and changes in salinity, stratification and ocean acidification may influence phytoplankton composition.

Nutrients are imported through river run-off, which transports land-based nitrogen and phosphorus to the sea. The amount of nutrients released on land varies according to land use and population density. Urban areas (point release) and farming areas (diffuse release) are the main sources of nutrient input. Nutrients which are stored in the soils of farming areas can be released over decades after the nutrient input has been reduced. Deposition from atmospheric nitrogen, originating from agriculture and combustion processes associated with industry and traffic, is another pathway by which eutrophication of the sea occurs. Emissions are not necessarily deposited in areas close to their source. They can be carried over long distances by winds.

Eutrophication is not a local problem, as transboundary transport is significant in the North Sea. Water masses from different regions interact and transport nutrients from one area to another. Nutrient-rich water from the Atlantic is transported by residual currents northwards along the continental West European coast. Models have shown that the German Bight receives nutrients that originate in the Atlantic and become progressively enriched by nutrients from river inputs and atmospheric deposition as they move through the Channel and the North Sea.

Countries bordering the North Sea have made great efforts over the past few decades to reduce the input of N and P. Efforts to reduce the input of P have proved more successful than measures to reduce the input of N. Differential reductions in nitrogen and phosphorus inputs can, however, alter nitrogen/phosphorus ratios in seawater and this may cause shifts in algal species composition, for example from diatoms to flagellates, some of which are toxic.

Region II (Greater North Sea), regional summary:
Reduced inputs of hazardous substances and nutrients. Most OSPAR countries have met, and many have exceeded, the OSPAR target for reducing phosphorus inputs to eutrophication problem areas, and three countries are approaching the 50% reduction target for nitrogen. Inputs of mercury and lead to the sea from several major rivers have dropped.
Eutrophication on the coasts. Eutrophication caused by nutrient inputs is a problem along the east coast of the North Sea from Belgium to Norway, and in some small estuaries and bays of eastern England and north-west France. Associated problems include fish dying in the fjords of Denmark and Sweden, and sugar kelp declining along parts of the Norwegian coast. Nitrogen inputs, largely from agriculture, are the biggest cause of eutrophication and few countries are nearing OSPAR’s 50% reduction target for nitrogen inputs to problem areas. It can take decades before reduced nutrient inputs benefit the marine environment because nutrients can continue to be released from soil and sediments.

4.5.3 *The Dutch part of the North Sea*

The southern part of the North Sea is strongly influenced by freshwater discharges from the UK and the European continent. Along the south-eastern coast of the North Sea, from northern France to Germany, several large rivers (e.g. Scheldt, Meuse, Rhine, Ems, Weser, Elbe) discharge into the sea. Consequently, even under unimpacted conditions the water along the south-eastern coast of the North Sea is rich in nutrients. Due to eutrophication in the freshwater systems, elevated concentrations of nutrients and phytoplankton biomass occur in Dutch coastal waters. The river influence is limited to the coastal waters, and hence the offshore areas of the Dutch part of the North Sea do not show elevated concentrations of nutrients or phytoplankton biomass. The residual current along the Dutch coast transports nutrients and organic matter from Dutch coastal waters to the German Bight.

4.5.3.1 *Nutrient levels*

Nutrient concentrations and nutrient ratios

Nutrient concentrations in Dutch coastal waters show a strong correlation with riverine nutrient loads, which are dominated by the loads from the Rhine. As a consequence of the strong impact of river discharges on nutrient concentrations, the concentrations are highly correlated with salinity and are high near the coast, and close to natural background concentrations in the offshore areas (Baretta-Bekker et al., 2008) (Figure 4.28). Riverine phosphorus loads have shown a decrease of over 50% during the period 1990-2009, and concentrations in the coastal waters have decreased by approximately 40% (Figure 4.28). Nitrogen loads have decreased by approximately 20-40% over the same period, and this has resulted in decreased concentrations in coastal waters, too (Figure 4.28).

Winter averaged dissolved inorganic nitrogen concentrations, standardized for salinity, are still higher than the OSPAR elevated level of 50% above natural background concentrations in the coastal waters (30 μM at salinity 30), while they are below the OSPAR assessment level in the offshore areas (Baretta-Bekker et al., 2008). An assessment for the years 2006-2008, using the WFD classification, also showed that winter averaged dissolved inorganic nitrogen concentrations are above the WFD assessment level (33 μM at salinity 30) in all coastal WFD water bodies. Those WFD coastal water bodies were classified as having “moderate” or ”poor” status in terms of nitrogen concentration (Bommelé & Baretta-Bekker, 2009).

As a logical consequence of the elevated nitrogen concentrations, the nutrient ratios also show elevated N:P ratios and N:Si ratios.

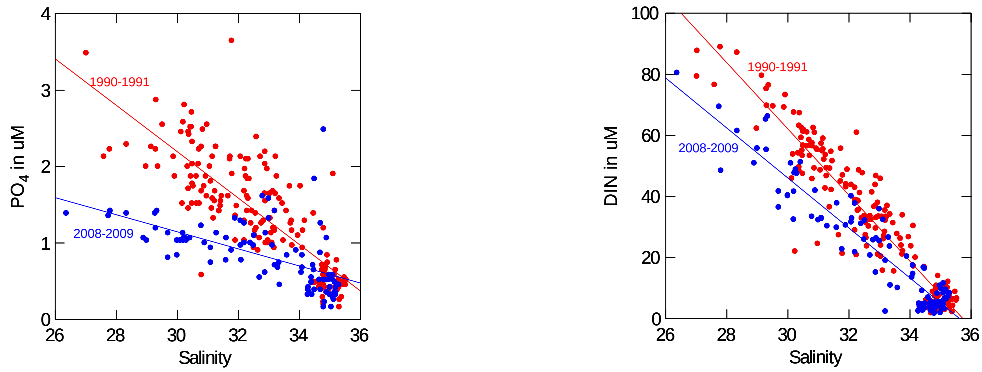


Figure 4.28 Winter means of dissolved phosphate (left) and dissolved inorganic nitrogen (right) concentrations against salinity in the Dutch part of the North Sea, in 1990-1991 (blue) and 2008-2009 (red) (Baretta-Bekker et al., 2008).

4.5.3.2 Direct effects of nutrient enrichment

Chlorophyll concentrations

Chlorophyll-a concentrations are relatively high near the coast and lower in the offshore areas, reflecting the gradient in nutrient concentrations from high near the coast to low in offshore waters (Figure 4.29). The monitoring data over the period 1990-2009 do not show a clear trend in chlorophyll concentrations in coastal waters, in spite of decreased nutrient concentrations over this period.

In the OSPAR Comprehensive Procedure (OSPAR COMPP) assessment, elevated levels of chlorophyll-a are defined as 50% above regionally specific natural background concentrations. The assessment (Baretta-Bekker et al., 2008) shows that chlorophyll-a levels in the coastal waters in the years 2001-2005 are still above the OSPAR assessment level, although there was a decreasing trend over the period 1995-2005.

In the WFD assessment, chlorophyll-a is a submetric of the biological quality element phytoplankton. To account for differences in salinity (and consequently differences in nutrient concentrations), the Netherlands applies higher class boundaries for polyhaline waters than for euhaline waters. As a result, the WFD classification differs from the OSPAR assessment in the water bodies that are near the main river discharge points of Haringvliet, Nieuwe Waterweg and Ems-Dollard. In 2006-2008, the chlorophyll-a concentrations in the coastal water bodies fluctuated close to the good/moderate boundary. The water bodies “Zeeland coast” and “Northern delta coast” were classified as moderate in all three years, whereas the coast of Noord- and Zuid-Holland, Wadden coast and Ems coast varied between good and moderate status (Bommelé & Baretta-Bekker, 2009 and background data).

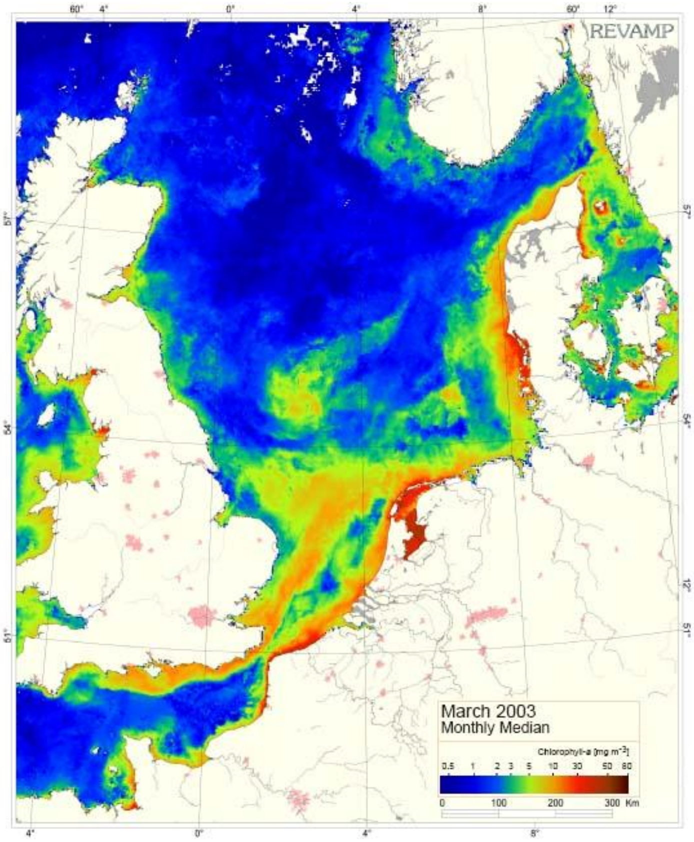


Figure 4.29 The March 2003 median chlorophyll-a image, showing that spring algal blooming has started along the coasts of Belgium, Holland and Denmark and the SE coast of the UK, with concentrations above 10 µg/l.(From: Peters et al., 2005).

Water transparency related to increase in suspended algae

In Dutch coastal waters turbidity levels are high as a result of high natural levels of suspended matter. Consequently, the enhanced levels of algal biomass have an insignificant impact on water transparency (Suijlen & Duin, 2001).

Species shifts in floristic composition – nuisance algal bloom

Blooms of the nuisance alga *Phaeocystis globosa* are considered to be one of the most conspicuous symptoms of eutrophication in the Southern Bight of the North Sea (Lancelot et al., 2009). *Phaeocystis* generally forms blooms in the period April/May, at the end of the spring phytoplankton bloom. Blooms are characterized by the occurrence of large colonies of cells embedded in a mucus. These large colonies cannot be grazed by zooplankton. Foam formation on beaches, and occasional oxygen depletion at sites with high sedimentation of colonies (Peperzak & Poelman, 2008), can occur at the end of the blooms. Blooms mainly affect the coastal waters of Belgium, the Netherlands and Germany, and the offshore Southern Bight area, but do not occur further north at the Oyster Grounds or the Dogger Bank.

Phytoplankton species composition and abundance is monitored as part of the Dutch MWTL monitoring programme since 1990. Results indicate that *Phaeocystis* blooms show large variation between years. Years with dense blooms are very frequent, while blooms are virtually absent in some years. There is no clear trend in annual levels of *Phaeocystis* blooms, expressed as maximum cell densities or average biomass (Figure 4.30) (Baretta-Bekker et al., 2009).

In the OSPAR assessment (Baretta-Bekker et al., 2008) *Phaeocystis globosa* is used as a region-specific indicator species. Its blooms show a clear spatial pattern, but so far no clear long-term temporal trends have been observed. In the OSPAR assessment concentrations of *Phaeocystis* in the coastal waters and the offshore Southern Bight exceeded the assessment level (maximum concentration exceeding 10^7 cells/l).

In the WFD assessment, *Phaeocystis* blooms are the other submetric of the biological quality element phytoplankton (in addition to chlorophyll-a), and the assessment is based on the frequency of blooms exceeding a level of 10^6 cells/l. Based on this submetric, some Dutch coastal water bodies were classified as having moderate status in 2008, whereas the classification for other years and other water bodies was good. It should be noted, however, that there is a large annual variation in *Phaoecystis* blooms, and observations over the years 1990-2008 show no trends. The overall WFD classification for Phytoplankton in the coastal water bodies was moderate.

In the OSPAR Comprehensive Procedure (COMPP) several other species can be used as indicator species for eutrophication. This includes a number of dinoflagellate species that potentially form toxic blooms. The results of the application of the OSPAR COMPP (Figure 4.31) show that the offshore areas Oyster Grounds and Dogger Bank could be considered eutrophication problem areas if these phytoplankton indicator species were taken into account, due to the fact that the assessment levels for the phytoplankton indicator species *Alexandrium* spp., *Chrysochromulina* sp and *Dinophysis* spp. are exceeded. Since the cause-effect relationship between nutrient availability and elevated levels of these species is uncertain, and all other criteria do not indicate a eutrophication problem in these areas, the Oyster Grounds and Dogger Bank are classified as non-problem areas in the final classification (Baretta-Bekker et al., 2008).

The use of (potentially toxic) phytoplankton species (like *Alexandrium* spp., *Chrysochromulina* sp., *Dinophysis* spp. and other species) as eutrophication indicators is subject to criticism (ICES, 2004) and it is felt that more research is needed on the causal relationship between blooms of these species and elevated nitrogen levels. Another indicator species that has been used in the OSPAR COMPP is the heterotrophic species *Noctiluca scintillans*. It is also considered a nuisance species as it can form dense floating layers that may severely deplete oxygen. This species remained below assessment levels in the years 2001-2005. The use of this species as an indicator of eutrophication also lacks causal evidence (Van Duren, 2006).
None of these indicator species is included in the WFD assessments.

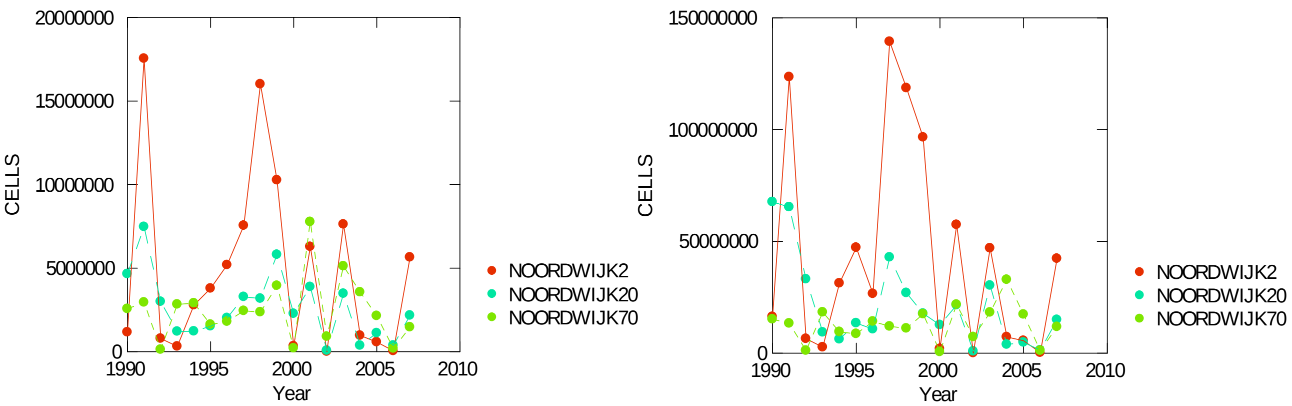
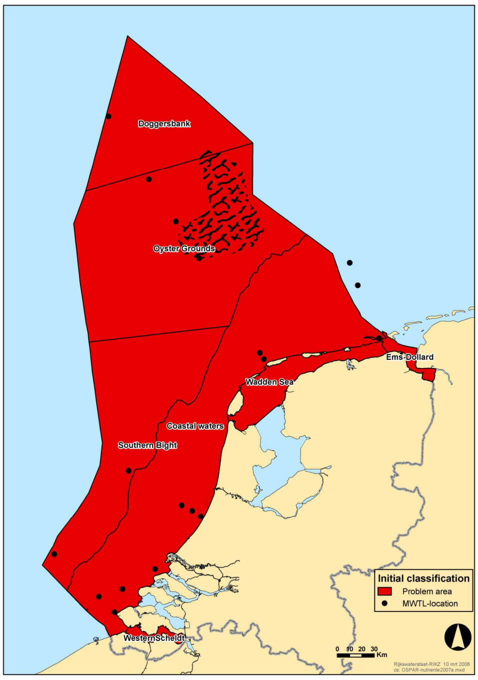


Figure 4.30 Average (left panel) and maximum (right panel) concentration of Phaeocystis (cells/litre) at sampling stations on a transect off Noordwijk, at 2, 20 and 70 km offshore. Note difference in vertical scales. (Baretta-Bekker et al., 2008)



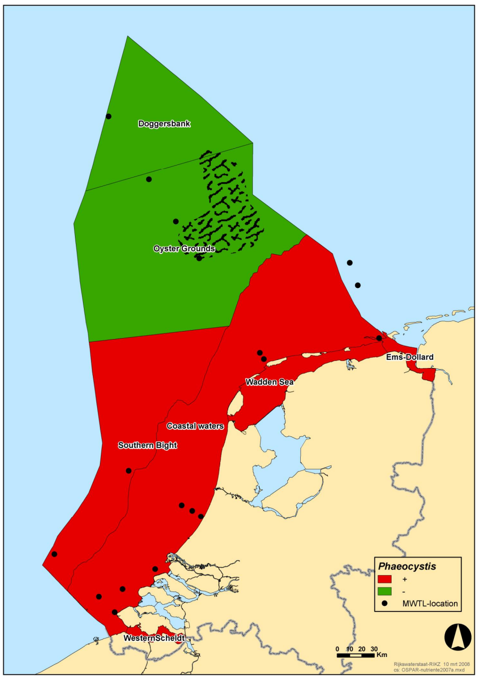


Figure 4.31 Overall assessment results from the application of the OSPAR Comprehensive Procedure (Baretta-Bekker et al., 2008). Left: Initial classification taking into account all criteria; Right: Final classification where phytoplankton indicator species (other than Phaeocystis) were excluded. Red: Problem Area; Green: Non-Problem Area. Black shading: Oyster Grounds proper.

4.5.3.3 Indirect effects of nutrient enrichment

Abundance of perennial seaweeds and seagrasses

Perennial seaweeds and seagrasses hardly occur in Dutch coastal waters, due to the fact that natural conditions (hydrodynamics and light conditions) are unfavourable for their growth.

Dissolved oxygen

In the well-mixed areas of the Dutch part of the North Sea (coastal waters and offshore Southern Bight) no stratification occurs and oxygen concentrations never fall below 6 mg/l (Baretta-Bekker et al., 2008). In stratified parts of the North Sea (Oyster Grounds), oxygen concentrations in the summer have fallen well below 6 mg/l in some years (e.g. 3.3 mg/l in the summer of 2003) (Figure 4.32; Figure 4.33). Low oxygen levels at the Oyster Grounds indicate that this area has the potential to develop hypoxia. More recently (2007, 2008), low oxygen levels have been observed at the Oyster Grounds. Low oxygen conditions are to a large extent due to physical conditions, viz. thermal stratification (Weston et al., 2008; Greenwood et al., 2009). Transport of organic matter from nutrient-enriched coastal waters to the Oyster Grounds contributes to oxygen depletion in this area (Peeters et al., 1995).

The effects of oxygen depletion on benthic fauna and fish are not monitored.

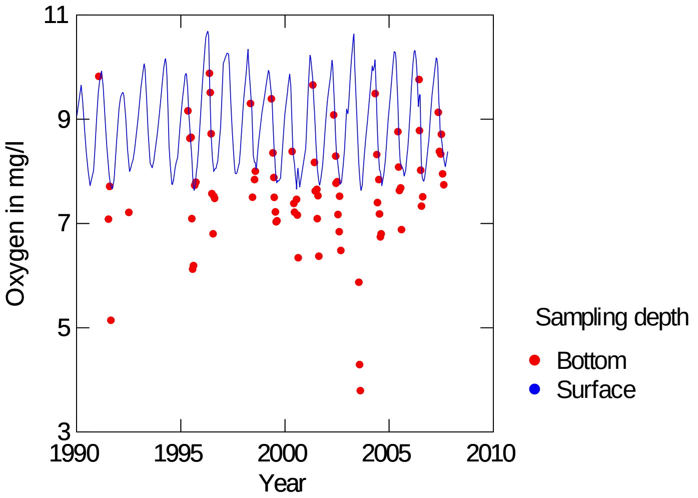


Figure 4.32 Oxygen concentrations observed in the MWTL programme in surface and bottom waters at the Oyster Grounds

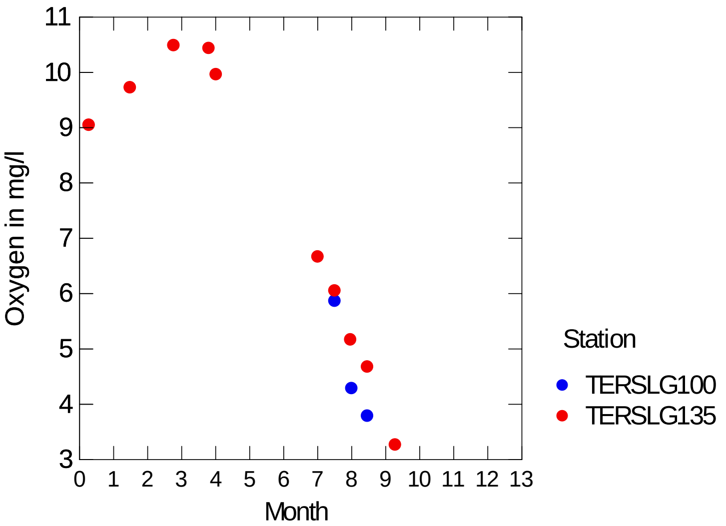


Figure 4.33 Oxygen concentrations in bottom waters at two monitoring stations at the Oyster Grounds in 2003.

4.5.3.4 Summary

Summary
Pressures The predominant pressure is the discharge of nutrient-enriched freshwater into coastal waters. **Nutrient levels** River discharges are the main anthropogenic source of nitrogen and phosphorus in Dutch marine waters. Nitrogen and phosphorus concentrations in coastal waters have decreased proportional to the decrease in river loads of nitrogen (20-40%) and phosphorus (>50%). According to both the WFD assessment and the OSPAR Comprehensive Procedure, the target for nitrogen concentrations in coastal waters has not yet been met. **Direct effects** Over the period 1990-2009 chlorophyll concentrations in coastal waters showed no clear trend, despite decreasing nutrient concentrations Blooms of the nuisance alga *Phaeocystis globosa* are the most conspicuous symptom of eutrophication in the southern North Sea. Blooms show large interannual variation, but no clear trend. According to both the WFD assessment and the OSPAR Comprehensive Procedure, concentrations of chlorophyll-a and of blooms of the indicator species *Phaeocystis* in coastal waters are still higher than target levels **Indirect effects** Low oxygen levels occasionally occur at the Oyster Grounds. This is to a large extent due to natural physical factors.

4.6 GES descriptor 6: Seafloor integrity

4.6.1 MSFD description

Full description	Annex I MSFD
Seafloor integrity is at a level that ensures that the structure and function of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.	

Criteria and indicators in the Commission Decision
6.1 Physical damage, having regard to substrate characteristics
Type, abundance, biomass and areal extent of relevant biogenic substrate (6.1.1)
Extent of the seabed significantly affected by human activities for the different substrate types (6.1.2)
6.2 Condition of benthic community
Presence of particularly sensitive and/or tolerant species (6.2.1)
Multi-metric indexes assessing benthic community condition and functionality, such as species diversity and richness, proportion of opportunistic to sensitive species (6.2.2)
Proportion of biomass or number of individuals in the macrobenthos above some specified length/size (6.2.3)
Parameters describing the characteristics (shape, slope and intercept) of the size spectrum of the benthic community (6.2.4)

4.6.2 OSPAR QSR 2010

General description for the North East Atlantic	*OSPAR Quality Status Report 2010*
Heavy towed demersal fishing gear (e.g. beam trawls, otter trawls, scallop dredges) causes considerable physical damage to seabed habitats and communities. They are a major source of disturbance on the continental shelf to habitats such as horse mussel beds, sea-pen and burrowing megafauna communities and *Sabellaria spinulosa* reefs. The seabed is physically disturbed when pipelines, cables, subsea structures and platforms are installed. Placement and removal of power cables causes temporary local disturbance of the seabed. The main impacts from the extraction of mineral deposits are the removal of substrate and associated organisms, which can affect the stability of the seabed and lead to changes in food webs. Areas from which sand and gravel have been extracted may start to recolonise quite quickly. Biomass is restored two to four years after short-term extraction activities. Recovery after intensive or protracted periods of extraction takes longer or may not occur at all depending on local conditions. There are also transitory plumes of suspended material, but the impacts, including lowered dissolved oxygen levels and interference with foraging fish and seabirds, are considered negligible **Region II (Greater North Sea), regional summary:** **Damage to seabed habitats.** Significant damage has occurred to shallow sediment habitats and reefs as a result of bottom fishing practices, especially beam trawling. In the western Channel, thick beds of red calcareous seaweed called maerl have declined in extent and quality, partly as a result of damage resulting from its extraction for use as an agricultural soil conditioner.	

4.6.3 The Dutch part of the North Sea

The main activities affecting seafloor integrity are fishing with bottom tending gear, in particular beam trawls, but also other practices like otter trawling and shrimp fishing. These activities result in physical damage to the seafloor and biological disturbance of the benthic community.

Other local disturbance of seafloor integrity is related to infrastructural works, such as cables and pipelines, aggregate extraction and coastal nourishments.

4.6.3.1 Physical damage

Biogenic substrate

Biogenic substrate can consist of reefs, shellfish beds or other structures formed by living organisms. Examples are beds of shellfish like the horse mussel *Modiolus modiolus* (OSPAR, 2009). The horse mussel is a large, long-lived bivalve species, that may form “beds” (biogenic reefs) on the seabed where dense populations occur. Individuals can grow to lengths >150 mm and can live for >45 years. The mussels attach to the substratum and to each other with byssal threads so that they aggregate into clumps. They can cover much of the underlying seabed to create a distinctive biogenic habitat (OSPAR, 2009). No beds currently exist in the Dutch part of the North Sea. Reefs of the polychaete *Sabellaria spinulosa* are another example of a biogenic substrate that occurs in the North Sea (OSPAR, 2010). *Sabellaria* reefs are sensitive to physical disturbance, and no reefs are currently present (OSPAR, 2010). In general, biogenic substrates are sensitive to physical disturbance, like bottom trawling, and many are threatened (OSPAR, 2010).

The tube-dwelling polychaete *Lanice conchilega* is found in subtidal areas of the southern North Sea (Figure 4.34). This species can also be considered reef-building ecosystem engineers (Rabaut, 2009). The tubes are made of mucus and particles and protrude 1-4 cm above the sediment surface. They trap sediment particles, thereby altering the sedimentary and hydrodynamic environment. Their presence alters infaunal abundance, diversity and species composition. Juveniles of the flatfish species *Pleurnecta platessa* and dab use the *Lanice* reef for shelter and as a feeding ground. *Lanice conchilega* is relatively resistant to physical disturbance, for instance from bottom trawling. The impact on the associated fauna is more pronounced, but the recovery rate is fast (Rabaut, 2009 and references therein).

Extent of the seabed significantly affected by human activities

By far the most important factors impacting the seafloor in the Dutch part of the North Sea are beam trawling, otter trawling and shrimp fishery *(*Figure 3.8). The beam trawling effort is concentrated in the southern part of the Dutch Continental Shelf. Earlier estimates of the distribution of the beam trawling effort showed that, within the most heavily trawled ICES rectangles, an average 15% of the surface area is trawled less than once a year, and 4% is estimated to be trawled less than once every five years (Rijnsdorp et al., 1998). Piet & Quirijns (2009) estimated that, in an average ICES rectangle fished for 50-100 days at sea per year, 34% of the rectangle was not fished in a year. In ICES rectangles with low effort this is more than 70%, in rectangles with high effort, less than 5%.

Based on the differential effects of the various types of bottom trawling, Lindeboom et al. (2008) constructed maps ranking the extent to which the seafloor habitats were impacted by bottom trawling, distinguishing between "ploughed" and "raked" seafloor habitats. Beam trawling with tickler chains has the most severe impact on the seabed and its associated fauna. The heavy chains which are attached to the net disturb sediments up to a depth of 2 to 6 cm (‘geploegde bodem’ [ploughed] in Figure 4.35). Apart from modifications to the physico-chemical characteristics of sediments (disturbance of sediment gradients, overturning of boulders, resuspension of silt) there is a direct and indirect effect on the mortality of benthic fauna.

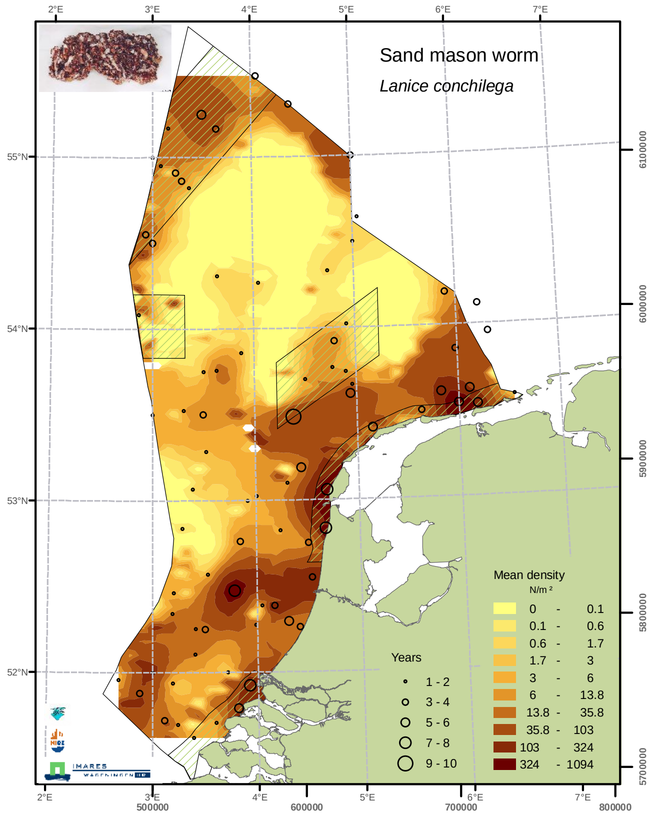


Figure 4.34 Distribution of Lanice conchilega in the Dutch part of the North Sea (Lindeboom et al., 2008). Densities are averaged over 11 years (1995-2005) (based on NIOZ data).

Effects on large long-lived species are most conspicuous. After a rapid initial deterioration of the habitat caused by single trawl events, repeated trawling further affects the benthic communities, keeping them in an early successional state. Indirect effects caused by trawling are probably related to different food web structures caused by species-specific (fishing) mortality (of both fish and by-catch) as well as associated changes in the competitive relationships between surviving species brought about by trawling. Furthermore, differences in the spatial intensity of bottom trawling cause habitat fragmentation which might be a critical factor in the survival and spread of sparsely distributed and rare species. The impact of otter trawling and shrimp fishing is less severe ('geharkte bodem' in Figure 4.35). In these types of fisheries it is mainly the boards that disrupt seafloor integrity, although the nets themselves are likely to damage fragile epifauna as well. In conclusion, all types of fishing have an impact on the biodiversity of the seabed, whether direct or indirect (Lindeboom et al., 2008). Recent developments which have led to new ways of beam trawling are likely to open up areas which were formerly inaccessible with the heavy traditional beam trawl gears. Previously less impacted areas might therefore become subject to more severe damage in the near future.

Sand extraction and beach and shore nourishments also have an impact on the integrity of the seafloor. The effects are however very local and recolonisation of the sites is expected to be rapid, occurring within 4-6 years. Areas impacted by beach nourishments and sand extraction are mostly located in a zone characterised by naturally high dynamics caused by the high levels of energy input from tides and waves. In this respect, the extent of seabed affected by sand extraction and nourishments is considered to be of minor importance at present (Prins et al., 2009) compared to the widespread effects of bottom trawling.

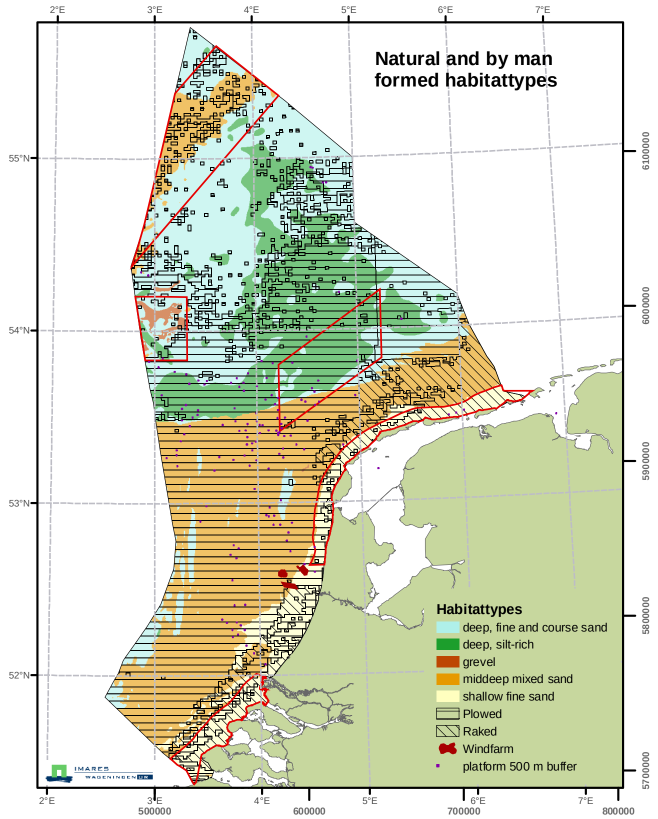


Figure 4.35 The Dutch part of the North Sea with the EUNIS habitat types and an indication of the disturbance of the seabed by human activity (Lindeboom et al., 2008).

4.6.3.2 Condition of benthic community

Presence of particularly sensitive species

There is a suite of species that are particularly sensitive to the effects of bottom trawling, especially beam trawling. Based on research and model estimates it has become evident that large species, living superficially in or at the sediment surface suffer most from degradation and disturbance of their habitat. These include brittle sessile epifauna, mobile large epifauna and large infaunal species such as large crustaceans and molluscs, sponges and other life forms. Various scientific studies have demonstrated effects on large molluscs, such as the red whelk *Neptunea antiqua*, the common whelk *Buccinum undatum,* the horse mussel *Modiolus modiolus* and the ocean quahog *Arctica islandica*. *Lanice* is vulnerable to physical damage caused by the dredging and deposition of sediments, for example. However, its recoverability is high due to its short life span. The population effects of repeated pressures are consequently higher than those of single pressures. *Sabellaria* is a reef forming species vulnerable to physical damage. It is assumed that, as a consequence of an ecological feedback mechanism, once existing “older” reefs are gone, settlement of juveniles is hampered and recovery is probably limited. Scientific knowledge of the recoverability of *Spisula* is too limited to contribute in this section (pers comm Witbaard).

For example, *Arctica islandica* is a bivalve mollusc with an exceptionally high longevity. Maximum ages of over 400 years have been recorded. In the Dutch part of the North Sea, individuals of about 170 years have been found. *Arctica islandica* starts reproducing at about six years of age (Witbaard, 2007). On the Dutch Continental Shelf, the species is only found in the northern parts (Figure 4.36) with maximum densities of around 1 individual per m^2, but in most areas densities are lower. Combined with the fact that irregular successful reproduction takes place, this low density means that impaired reproduction might be a factor. It is uncertain whether the current population on the Dutch Continental Shelf is self-sustaining.

Arctica islandica lives in the seabed, just below the surface, and beam trawling has been shown to have a negative effect on the population (Witbaard & Klein, 1995). Although a single trawl passage catches only a few percent of the standing stock, about 80% of this catch is lethally damaged. This implies that population densities have been drastically reduced in just a few decades. Recent assessments (2006-2007) do indeed show that the population along the southern edge of the Frisian Front has strongly declined in comparison to the period between the late 1980s and mid-1990s.

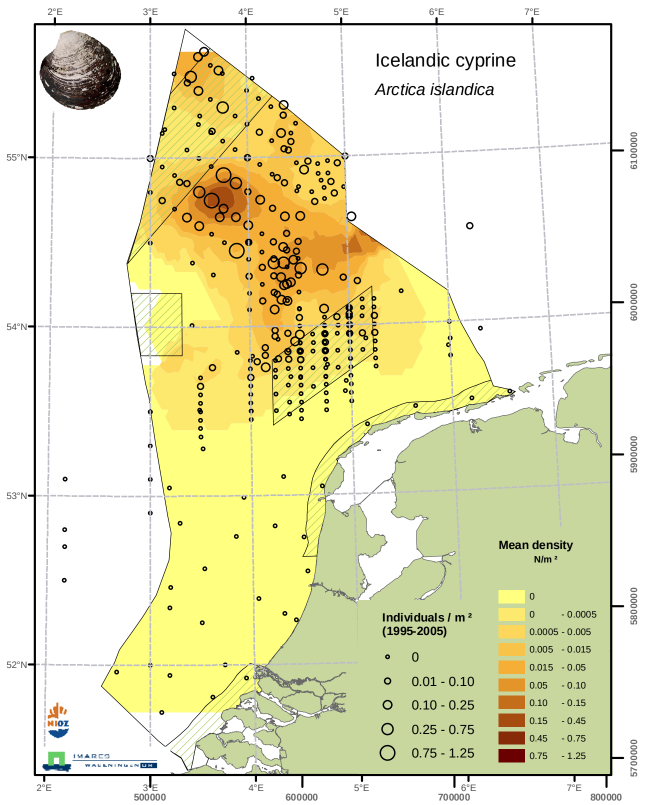


Figure 4.36 Distribution of Arctica islandica in the Dutch part of the North Sea (Lindeboom et al., 2008). Densities are averaged over 11 years (1995-2005) (based on NIOZ data).

Similar detrimental effects probably underlie the disappearance of the common whelk from the southern North Sea and Wadden Sea. Like the red whelk and the horse mussel, the common whelk is often found with repaired injuries, suggesting that the shells have suffered non-lethal physical damage. The disappearance of large gastropods was also partly due to the effects of pollution disrupting normal reproduction.

Multi-metric indexes

Benthic community composition and diversity is briefly discussed in §4.1. The value of the application and use of multimetric indices to monitor shifts in species composition and diversity to identify changes in habitat integrity is often overrated. Changes in communities are often small, and identification of changes is only possible if either long time series (decades) are analysed, or large community changes occur. Using multimetric indices to quantify habitat integrity will always require insight into which species underlie the observed index change to understand the direction and magnitude of the observed change.

4.6.3.3 Summary

Summary
Pressures The seafloor in a large part of the Dutch North Sea is strongly influenced by fishing Other activities, like sand extraction, have strong, but very local, impacts **Physical damage** Biogenic substrates of species sensitive to physical disturbance, like beds of long-lived shellfish or reefs of *Sabellaria spinulosa*, are rare. The tube-dwelling polychaete *Lanice conchilega* can be considered a reef-building ecosystem engineer. This species is relatively resistant to physical disturbance. A large proportion of the seafloor on the Dutch Continental Shelf is physically disturbed by bottom trawling. **Condition of the benthic community** The population of long-lived species, as exemplified by the ocean quahog *Arctica islandica* is declining in comparison to the 1980s.

4.7 GES descriptor 7: Hydrographical conditions

4.7.1 MSFD description

Full description	Annex I MSFD
Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems	

4.7.2 OSPAR QSR 2010

Criteria and indicators in the Commission Decision
7.1 Spatial characterisation of permanent alterations
Extent of area affected by permanent alterations (7.1.1)
7.2 Impact of permanent hydrographical changes
Spatial extent of habitats affected by the permanent alteration (7.2.1)
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)

General description for the North East Atlantic — *OSPAR Quality Status Report 2010*

Construction activities can have a range of impacts on the marine environment. They may cause loss or damage of coastal habitats, changes to the physical nature of the seabed, which in turn cause erosion, sedimentation and physical and chemical disturbance of ecosystems.

OSPAR countries regulate land reclamation, coastal defence works and the construction of other structures through national legislation. The aim is to minimise and put right any adverse environmental effects. National regulations for coastal defence often prioritize natural and soft techniques. This is supported by EU legislation, such as the EIA Directive, the Habitat and Birds Directives and the Recommendation on Integrated Coastal Zone Management.

EIAs for land reclamation, coastal defence works and other structures have identified various effects on marine ecosystems. Although the regulatory system appears adequate for controlling impacts on a site by site basis, in most cases monitoring data are not available to evaluate the actual changes in environmental quality. An extensive monitoring programme will be carried out to investigate the recovery of benthic fauna, concentrations and spread of suspended matter, physical effects and underwater noise associated with the expansion of the Port of Rotterdam in the Netherlands (Maasvlakte), work on which began recently. In such developments, when negative effects are expected and observed, compensation for the loss of habitat is often more feasible than remediation.

Region II (Greater North Sea), regional summary:
No specific information

4.7.3 The Dutch part of the North Sea

In the past, large infrastructural projects have been carried out in the Netherlands for the purposes of coastal defence. After the disastrous floods of 1953 dams, sluices and a storm-surge barrier were constructed in the estuaries in the south-western Netherlands in the period 1958-1986. These infrastructural works have transformed several estuaries into lakes that are disconnected from the sea (Haringvliet, Veere Lake, Grevelingen Lake). The main environmental impacts have occurred within these former estuaries, while the environmental impacts on the seaward side are assumed to have been relatively small (Holzhauer et al., 2010). At present, the extension of the Port of Rotterdam (Maasvlakte 2) is a project that is relevant to GES descriptor 7 Hydrographical conditions. Another project, work on which only recently started, is the “Sand Engine”. This pilot project is exploring innovative approaches to coastal protection, involving a large-scale coastal nourishment near Ter Heijde.

4.7.3.1 Spatial characterisation of permanent alterations

Extent of area affected by the alteration
Maasvlakte 2 project
The Maasvlakte extension to the Port of Rotterdam built in 1970 is one of the largest land reclamation projects in the OSPAR area to date, covering 2000 ha. An extension of this site, Maasvlakte 2, was proposed in 1997, comprising a further 2455 ha to provide port facilities and deep-sea docks for container ships, chemical carriers and other large vessels. Land reclamation began in September 2008 with the aim of having the new facility operational from 2013.

A series of environmental assessments for the Maasvlakte project was published in 2007 to comply with Dutch and EU regulations (Berkenbosch et al., 2007). The studies concluded that, although the project design minimises environmental impact as far as possible, there will be unavoidable environmental impacts in the nearby marine and coastal environment. The impacts for the marine environment as a consequence of the land reclamation concerned loss of Habitat 1110, and loss of foraging area for Sandwich tern, common tern and common scoter in the Natura 2000 site Voordelta. The assessments used worst-case scenarios, and acknowledge uncertainties in the prediction of longer-term impacts.

Sand Engine project
In the Sand Engine project, a temporary peninsula of approximately 100 ha, connected to the beach, will be created by a nourishment of 21.5 million m^3 of sand extracted further offshore. Within approximately 20 years this nourishment is expected to be gradually dispersed along the coast by waves and currents. The objective of the project is to study the potential of large-scale nourishments for coastal protection, with lower ecological impacts than current practice. An Environmental Impact Assessment has been carried out (DHV, 2010a), and the effects of the Sand Engine will be studied in a monitoring programme (DHV, 2010b). Effects on hydrographical conditions are expected to occur in a limited area.

4.7.3.2 Impact of permanent hydrographical changes

Spatial extent of benthic habitat affected by the permanent alteration: Maasvlakte 2
There will be a loss of 2455 ha of shallow sandbanks (2.8% of the Habitat type 1110 in the Natura 2000 site Voordelta). Compensation measures have been taken into account for the loss of benthic biomass, by the creation of an area of 24550 ha, in the Natura 2000 site Voordelta, where beam trawling (>260 hp) is prohibited. This measure should lead to an increase in benthic biomass, compensating for the loss of biomass at the land reclamation site.

Changes in habitat functions: Maasvlakte 2

The environmental impact assessment for the Maasvlakte 2 project indicates that a loss of foraging area for Sandwich tern, common tern and black scoter in the Natura 2000 site Voordelta will occur as a result of the land reclamation. Measures taken in the framework of the Birds Directive aim to compensate for this loss by decreasing disturbance to the birds caused by human activities, and by improving feeding conditions.

According to the environmental impact assessment, the Maasvlakte 2 project will have no other permanent effects on habitat functions.

4.7.3.3 Summary

Summary
Pressures At present, the extension of the Port of Rotterdam in the Maasvlakte 2 project and the Sand Engine pilot project are relevant to this descriptor. **Spatial characterisation of permanent alterations** The Maasvlakte 2 project is currently the largest reclamation project in the North Sea, covering approximately 2000 ha. The Sand Engine project will create a temporary peninsula of approx. 100 ha. **Impact of permanent hydrographical alterations** 2455 ha of benthic habitat (Habitat type 1110_B) will be lost due to the Maasvlakte 2 project. Foraging habitat for common scoter, Sandwich tern and common tern will be lost due to the Maasvlakte 2 project. Measures have been taken to compensate for the impacts of this project. The Maasvlakte 2 project will not lead to permanent alteration of habitat functions at any sites other than the reclamation site.

4.8 GES descriptor 8: Contaminants

4.8.1 MSFD description

Full description	*Annex I MSFD*
Concentrations of contaminants are at levels not giving rise to pollution effects.	

Criteria and indicators in the Commission Decision
8.1 Concentration of 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)
8.2 Effects of contaminants
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) *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)*

4.8.2 OSPAR QSR 2010

General description for the North East Atlantic	*OSPAR Quality Status Report 2010*

Chemicals can be naturally occurring, like metals in the Earth's crust, formed as unintended by-products of natural and human-induced chemical processes, or synthesized specifically for use in industrial processes and consumer products. Some of these substances are hazardous because they are persistent, liable to accumulate in living organisms and toxic. They can contaminate the marine environment, with harmful effects on marine life and, ultimately, human health via the food web.

Hazardous substances are found in seawater, sediments and marine organisms throughout the North East Atlantic. Historic pollution in riverine, estuarine and marine sediments acts as a continued source of releases, especially where sediments are dredged from rivers and estuaries to improve navigation and are disposed of at sea. It is not yet possible in most cases to link the chemical monitoring with observations of effects in species in such a way that conclusions can be drawn about the impact of contaminants on the functioning of ecosystems at a regional level. Various biological effects have been observed and relevant biological effects techniques which could act as targets and indicators for Good Environmental Status on ecosystem components for integrated assessment have been developed. For the group of substances including metals, PCBs, polychlorinated dibenzodioxins, furans and PAHs, an integrated assessment approach has been identified on the basis of the scientific evidence available and the ability to assess the data in an integrated manner. The suite of methods should cover a range of mechanisms of toxic action, such as the production of specific enzymes. The use of tributyltin (TBT) antifouling paint on ships is known to cause imposex in gastropods. Recent studies of individual fish diseases have been able to link a general decline in liver tumours in fish in the Dutch waters of the North Sea since the late 1980s with a decrease in exposure to organic pollutants, such as genotoxic/carcinogenic PAHs.

Since the 1980s measures have been taken to reduce the emission and discharge of hazardous substances (OSPAR, EU legislation). The phasing out of many chemicals is well underway in the North East Atlantic, but several are being replaced by other chemicals. This often benefits the environment, but can lead to new and unexpected problems if properties of the replacement chemicals are not well understood.

Region II (Greater North Sea), regional summary:
Pollution by hazardous substances. Concentrations of metals (cadmium, mercury and lead) and persistent organic pollutants are above background in some offshore waters of the North Sea, and unacceptable in some coastal areas. Lead levels, for example, were unacceptable at 40% of locations monitored, while PAHs and PCBs were at unacceptable levels at more than half the monitoring sites.

4.8.3 The Dutch part of the North Sea

The southern part of the North Sea is strongly influenced by freshwater discharges from the UK and the European continent. Along the south-eastern coast of the North Sea, from northern France to Germany, several large rivers (e.g. Scheldt, Meuse, Rhine, Ems, Weser, Elbe) discharge into the sea. Consequently, the water along the south-eastern coast of the North Seawater has high anthropogenic inputs of natural compounds as well as synthetic substances. Emissions from sources at sea (shipping, oil and gas exploration) and atmospheric deposition are also sources of contaminants.

4.8.3.1 Concentrations of contaminants

Concentrations in water

EU legislation such as the EU Water Framework Directive (Directive 2000/60/EC) and the Priority Substances Directive (Directive 2008/105/EC) describes target levels of a selection of priority substances in the North Sea. OSPAR also sets target levels for a list of substances. These substances are monitored on regular basis. According to WFD measuring and assessment methods, chemical substances (excluding nutrients) seldom exceed the WFD standards in the North Sea up to the maximum of 12 nautical miles (see Box 1).

Only TBT in suspended matter exceeds the WFD target levels. Target levels of some priority substances under the WFD (e.g. PAH, PBDE, pesticides) cannot be evaluated due the fact that detection limits are too high. This does not necessarily mean that the standards are being met (or not). These substances are considered “substances of special attention” (Bommelé & Baretta-Bekker, 2009) and, until proven otherwise, they are considered potential problem substances (Table 4.9).

Table 4.9 Priority substances of special attention that are considered likely to cause problems in the marine environment (Bommelé and Baretta-Bekker, 2009).

Priority substances	*Other substances*
4-tert-octylphenol	Dibutyltin
Sum of benzo(g,h,i)perylene and indeno(1,2,3)pyrene	Dichlorvos (2,2-dichlorovinyl dimethyl phosphate)
Sum PDBE’s	Tetrabutyltin
	Cis-heptachloroepoxide (coast of Noord- and Zuid-Holland)
	Heptachlor (coast of Noord- and Zuid-Holland)
	Trichlorofon (coast of Noord- and Zuid-Holland)
	Triphenyltin (Wadden Sea coast)

Box 1.
The WFD and OSPAR strategies differ, with OSPAR aiming for near background concentrations for naturally occurring substances and close to zero for man-made synthetic substances, whereas WFD has the objective of achieving good ecological and chemical status. The WFD framework stipulates quality standards that are not necessarily similar to the OSPAR quality standards. Moreover, OSPAR measures chemical substances in sediment and biota of marine organisms as well as in water. WFD analyses are concerned only with substances in water.

The phasing out of a third of the 26 priority chemicals and groups of chemicals that pose a risk to the marine environment is well underway in the OSPAR area (OSPAR, 2010). As a result, it is likely that discharges, emissions and losses of these substances will be brought to an end by 2020 if current efforts continue. These priority chemicals are: six pesticides (dicofol, endosulfan, lindane, methoxychlor, pentachlorophenol and trifluralin); short-chained chlorinated paraffins (SCCPs); nonylphenol/ethoxylates; TBT; and the two brominated flame retardants, penta- and octa-brominated diphenyl ethers (BDEs). The scientific literature shows an increase in emerging substances over the past decade, including discharges of pharmaceuticals and personal care products to the marine environment (Walraven and Laane, 2009). The ecotoxicological risks of these highly biologically active compounds are largely unknown. River discharges from the Rhine and Scheldt have been shown to act as important sources of polyfluoroalkyl substances (PFAS) in the North Sea (Möller et al., 2010). The implementation of REACH should ensure that these substances are included in future priority lists.

<u>Contamination levels in biota and sediments</u>
Contamination of marine life by persistent hazardous substances is widespread in the North Sea (OSPAR, 2010) (Figure 4.37). In the OSPAR assessment of contaminant concentrations in biota and sediment (OSPAR, 2009; OSPAR 2010) several metals (cadmium, lead, mercury), some PCB congeners and some PAHs (benzo[ghi]perylene, benz[a]anthracene, chrysene) exceed assessment levels in the North Sea Coastal Zone, reaching concentrations where there is a potential for significant adverse effects to the environment or to human health via seafood products.

Concentrations of most metals and organic compounds in sediments have shown a steep decrease since 1980, but the rate of decrease has slowed since 2000. In the Dutch part of the North Sea, the highest concentrations of contaminants are found in coastal waters, and the lowest 50-70 km offshore.

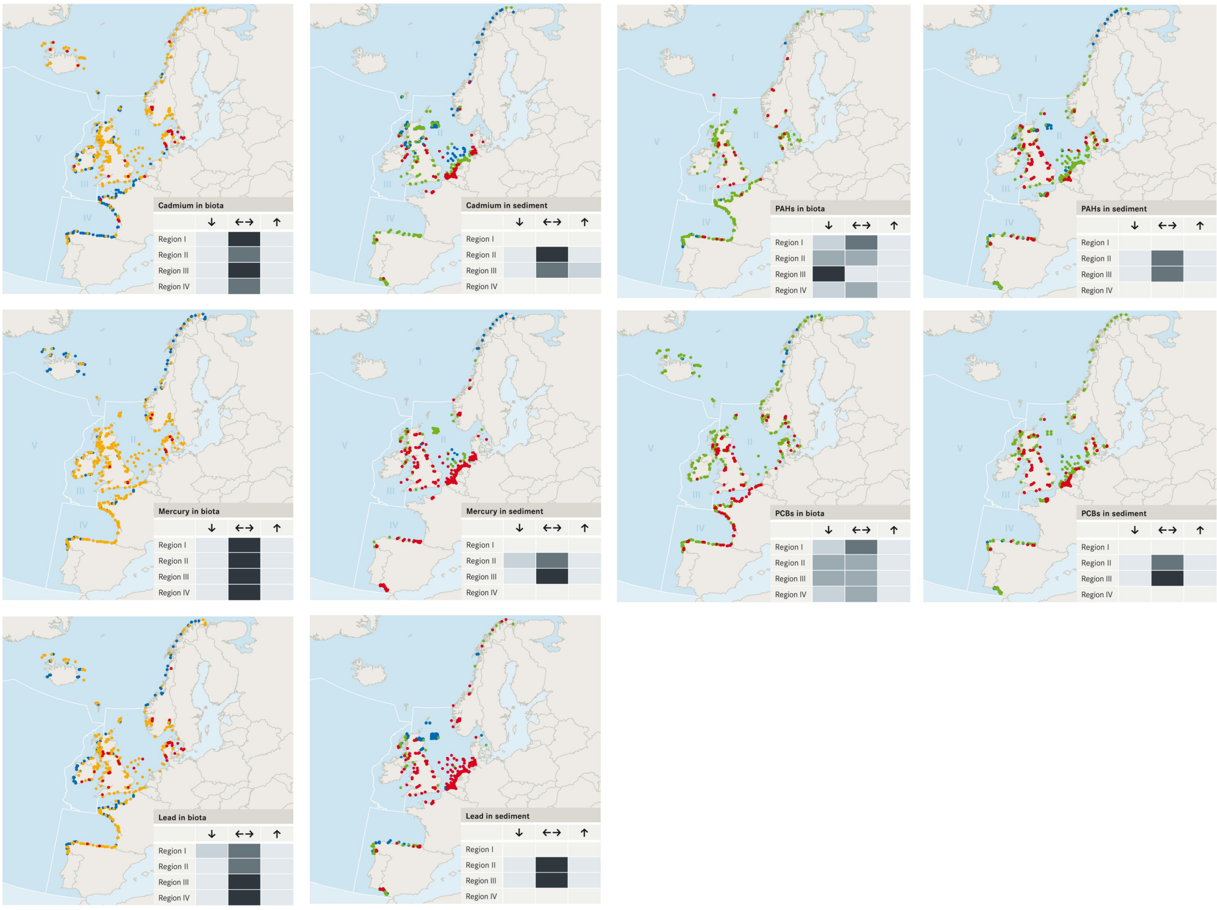


Figure 4.37 Geographical distribution and temporal trends in contamination from cadmium, lead, PAHs and PCBs in biota and sediment based on OSPAR CEMP. Status is indicated for the most recent years of monitoring (2003-2007).

<u>Radioactivity in the marine environment</u>

Radioactivity in the marine environment occurs in conjunction with the introduction of radioactive substances, which have also spread widely in European seas. The EU Council Directive sets a limit value of 1 mSv/year for additional radiation exposure to members of the general public resulting from human activities. Law et al. (2010) report that the actual doses resulting from consumption of marine food from European sea areas are significantly below this limit.

4.8.3.2 Effects of contaminants

A wide range of substances in sediments and water are responsible for toxicological and undesirable effects in a large variety of marine organisms in many areas of the European marine environment. Such effects on marine organisms range from mortality, cellular and biochemical alterations and histopathological lesions, to subtle impacts on reproduction and normal endocrine function. Although contaminants will affect processes from molecular to ecosystem level, the contaminant specificity of detection methods is complex. There are limited direct relationships between tissue levels of contaminants and their biological effects and there is limited understanding of the effects of mixtures of contaminants and of interactions between contaminants and other environmental stressors (Law et al., 2010).

Biological effects where a relationship with substances is evident in the Dutch coastal zone are:

- *Imposex and intersex: TBT-specific effects*

Well-known effects of tributyltin (TBT) compounds are shell malformation in oysters, imposex and intersex in marine snails (Gibbs et al., 1988), reduced resistance to infection in fish, and immunomodulating effects on humans. The TBT-specific biomarker detecting intersex and imposex in gastropods is part of OSPAR CEMP and JAMP (Schipper et al., 2008). Several countries bordering the North Sea use intersex in *Littorina littorea* or imposex in *Nucella lapillus* to demonstrate the effects of TBT (ICES, 2009a).

In Dutch coastal waters TBT effects are assessed in dog whelks or periwinkles, and by studying population trends in gastropods in this area (Figure 4.38; Schipper et al. 2010). TBT-specific effects like imposex are still found over large parts of the OSPAR area and EcoQO TBT-specific biological effects (Heslenfeld and Enserink, 2008) are not yet being met in the Netherlands. Since the IMO Convention banned TBT in anti-fouling paints for ships as of 1 January 2008, TBT concentrations are expected to fall. Due to the often slow degradation of TBT and its derivatives and their affinity to particulate matter, they readily accumulate in sediments and may be present there for a long time. The TBT problem in sediments will remain for many years due to the persistence of this substance, so the assessment criteria set for imposex will not be met by 2020 (Van Gils J, 2008).

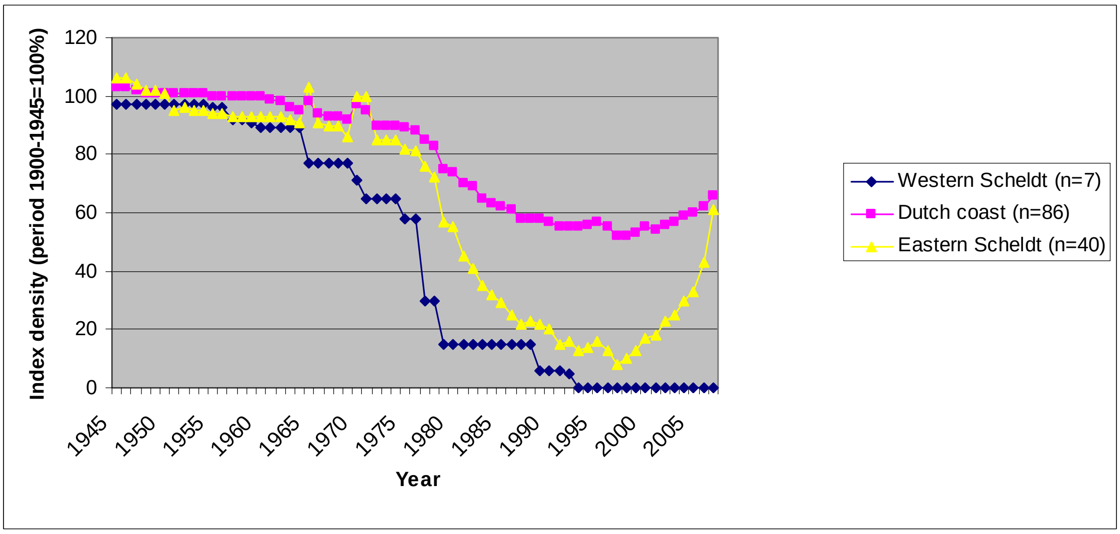


Figure 4.38 Population development of dog whelk Nucella lapillus in the period 1945-2007 along the Dutch coast, expressed relative to the average number of organisms present in the period 1900-1945 (set as 100%) (Schipper et al., 2010).

- *Fish diseases*

There is evidence of a link between exposure to carcinogenic/genotoxic compounds such as PAHs and the development of liver tumours and other liver lesions in flatfish (Hylland et al., 2006; Grinwis et al. 2009; Vethaak et al., 2009). Fish diseases are part of the OSPAR CEMP and JAMP (OSPAR 2008) monitoring system. Fish disease studies in the OSPAR region (including the Netherlands) showed a worsening of the status of fish disease in dab *Limanda limanda* in the majority of geographical areas in the North Sea in the period 2000-2005 (Figure 4.39). Although the fish disease index is not considered a direct measure of effects of exposure to chemical contaminants, liver neoplasms in wild fish have been associated with exposure to chemical contaminants such as PAHs and chlorinated hydrocarbons (e.g. PCBs) in numerous field studies in Europe and North America (ICES, 2009b). However, a significant fall towards natural background levels has been reported for PAH-related liver tumours and major skin diseases in Dutch flatfish populations in the past 15 to 20 years(Vethaak et al., 2011). Although this has no direct impact on the population of flatfish, the improved health status of fish has been attributed to improved water quality in this region, including a decrease in carcinogenic and other toxic contaminants (Vethaak et al., 2011).

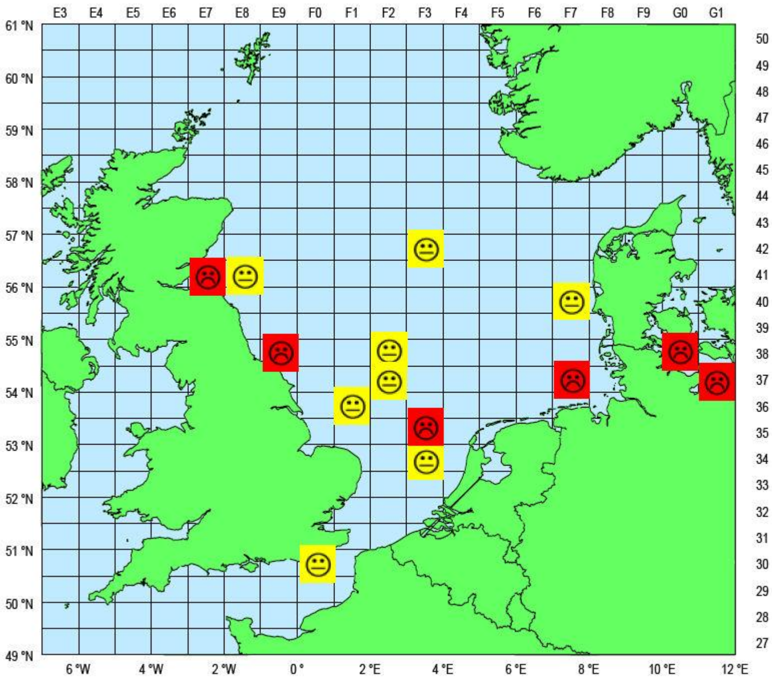


Figure 4.39 Results of the assessment of the Fish Disease Index values for externally visible diseases: changes in disease status of dab (Limanda limanda) in the North Sea in the period 2002–2007 compared to the period 1992–2001. The assessment is based on trends. Yellow indifferent faces denote no significant change; red frowning faces a significant worsening of the disease status (ICES, 2009b).

- *Contamination and effects from persistent organic pollutants* (POPs)

There has been growing environmental concern regarding persistent organic pollutants (POPs), which include substances like dioxins, and other compounds that have dioxin-like properties. The major concerns with dioxin-like compounds are their effects upon wildlife and human health due to their persistence, resistance to degradation and risk of bioaccumulation. The dioxin-like POP compounds include some polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofuran (PCDFs), coplanar polychlorinated biphenyls (PCBs) and polybrominated biphenyls (PBBs) have been shown to produce a wide variety of toxic and biochemical effects (Mandal, 2005). The effects on laboratory animals and wildlife include developmental and reproductive effects, immunotoxicity, neurotoxicity and carcinogenesis (OSPAR, 2007). Animals at particular risk are fish-eating top predators such as otters (Murk et al., 1998), seals (Vos et al., 2000) and birds (Bosveld, 1995; Henshel, 1998). The effects of dioxin-like POP compounds in humans include high acute toxicity, skin lesions, developmental and reproductive abnormalities, and probably cancer (WHO, 2000; Aylward et al., 2002). The DR-Luc assay is a suitable screening method for dioxins and dioxin-like-PCBs (Schipper et al., 2010). The analysis of dioxins and dioxin-like chemicals (based on DR Luc assays) in Dutch dredged sediments in the coastal zone showed TEQ ranges of 12–70 ng TEQ per kg dry weight and an average 24 ng TEQ per kg dry weight (Schipper et al., 2010). In other studies from the Dutch and Belgian coastal zone, a range of TEQ values was observed between 9 and 27 ng TEQ per kg dry weight (Klamer et al., 2005) and 10-42 ng TEQ per kg dry weight in sediment (Sanctorum et al., 2007). The level of serious concern is: >40(pg TEQ per gram dry weight (OSPAR, 2011). This means that dioxin-like effects cannot be ruled out in the Dutch coastal zone, and these potential effects have a heterogeneous character.

- *Other biological effects in Dutch estuarine / marine waters*

There has been growing emphasis on the use of toxicity bioassays to identify and qualify the toxicity of estuarine and coastal environments. Several studies in Dutch estuarine and coastal waters have demonstrated biological effects, including:

1 results of toxicity tests showing dioxin-like, estrogenic and genotoxic activity in coastal and offshore sediment and suspended matter extracts by known and as yet unknown contaminants (Klamer et al. 2005).

2 using a newly developed early life stage (ELS) test Foekema et al. (2008) demonstrated adverse effects of the dioxin-like PCB 126 on the early development of sole. Prolonged ELS with this native marine flatfish suggests that persistent compounds accumulated by the female fish and passed on to the eggs (Foekema et al. 2008) can affect the reproductive success of fish populations at contaminated sites. Levels that induce the effect were not field relevant in this study, but these innovative techniques can address potential effects (as an early warning tool).

- *Impact of oil spills: EcoQO oiled guillemots*

Discharges of process water from the routine operation of production platforms and careless practices by oil tankers causing oil to leak into the ocean are a constant source of oil and chemical emissions. The amount of oil spilt has drastically decreased since 1992 (Grontmij, 2010). Moreover, the surface area and volume of the observed spills have also decreased, indicating not only that the number of spills has declined, but also that the average amount discharged at sea is now less than it was almost twenty years ago (Figure 4.40).

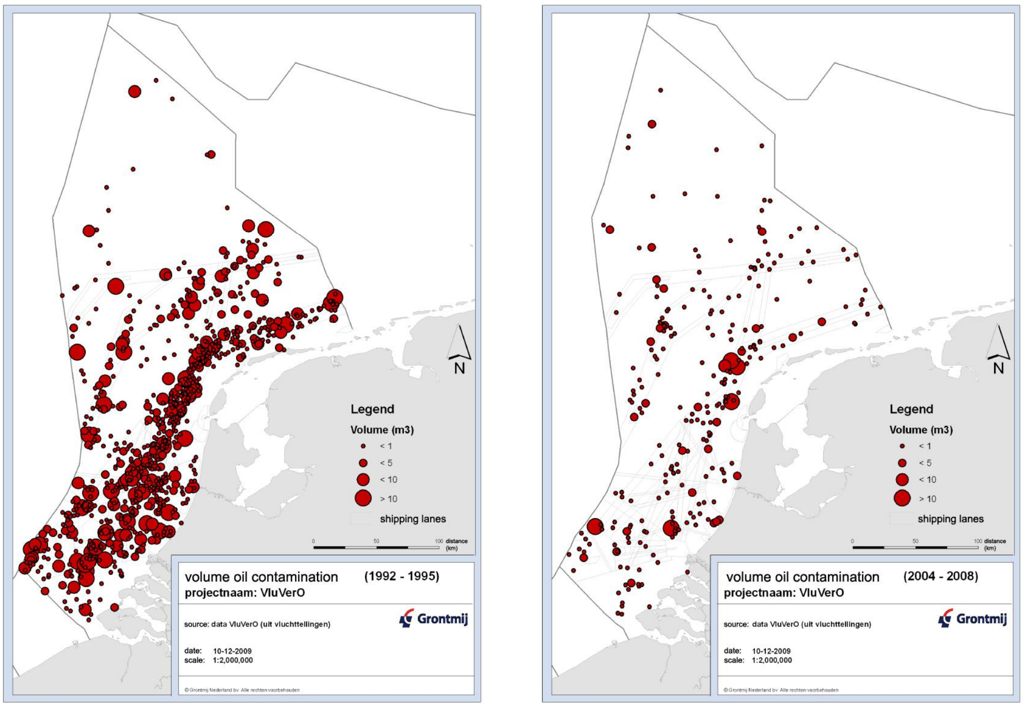


Figure 4.40 Oil spill volumes and incidents monitored by aircraft observations on the Dutch Continental Shelf during the periods 1992-1995 and 2004-2006 (Grontmij, 2010).

As part of the North Sea system of Ecological Quality Objectives (EcoQOs), targets and indicators have been set to measure progress towards a clean and healthy sea (OSPAR, 2007). OSPAR has formulated an EcoQO for oiled seabirds. Guillemot *Uria aalge* oil rates (% oiled) stranded on the Dutch coast in the period 1997/98-2001/02 was 61.4%. The proportion of oiled guillemots washing ashore on Dutch beaches is declining (Figure 4.41). The OSPAR assessment criteria set for the EcoQO oiled guillemots have not yet been met, but if the current trend continues, the goal may be achieved by 2020.

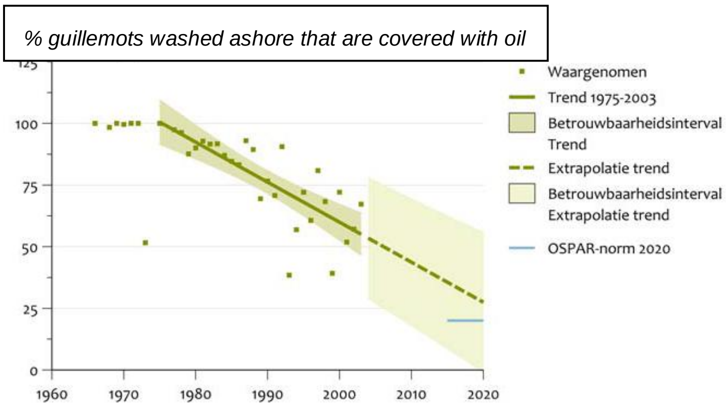


Figure 4.41 Percentage of guillemots washed ashore that are covered with oil (Wortelboer et al., 2010) based on OSPAR 2009.

- *Impacts of chemical pollution on marine mammals*

It has been shown that marine mammals can ingest dioxin-like compounds that have been flushed into surface water from land, creating a potential pathway into the food chain. Studies by Murk et al. (1998) and Traas et al. (2001) concluded that the exposure of marine mammals to contaminants was associated with biological effects at population level, mediated through the disruption of endocrine processes (caused by dioxins). In harbour porpoises (*Phocoena phocoena*) high levels of POPs were associated with possible inhibition of ovulation and disruption of pregnancy (Murphy et al., 2010). In 2008 harbour seals (*Phoca vitulina*) were found to have levels of the dioxin-like compounds in the range of 100-633 pg TEQ/g lipid weight in the Dutch Wadden Sea, 144-565 pg TEQ/g lw in the Dutch Delta, and 106-355 pg TEQ/g lipid weight in the Norwegian Sea (Schipper et al., 2010). Harbour seals with 209 ng TEQ/g lipid weight were reported to display significantly more immunotoxic effects than the reference seals containing 62 pg TEQ/g lipid weight (Ross et al, 2002).

Concentrations of the man-made surfactant perfluorooctane sulfonate (PFOS) in stranded harbour porpoise have shown an increase in recent years (Kwadijk et al., 2010). No clear relationship between PFOS and the strandings could be established.

The assessment criteria for biological effects developed by ICES and OSPAR (OSPAR, 2011) cover all the effect measurements in the ecosystem components and assessment of effects monitoring for contaminants. Background assessment levels (BAC) and environmental assessment criteria (EAC) have been developed for biological effects. EACs are assessment tools intended to represent the contaminant concentration in sediment and biota below which no chronic effects are expected to occur in marine species, including the most sensitive species. EACs continue to be developed for use in data assessments. Concentrations below the EAC are unlikely to give rise to unacceptable biological effects.

4.8.3.3 Summary

Summary
Pressures Elevated concentrations of chemical substances are caused by land-based emissions and emissions at sea. Major inputs come from riverine discharges, with additional contributions from atmospheric deposition. Sea-based sources include shipping and oil and gas exploration. **Concentrations of contaminants** In the WFD assessments of total concentrations in water, TBT exceeds assessment levels in all coastal water bodies. TBT concentrations are predicted to decline to non-problem levels in 2021. There is a list of ”substances of special attention” that are to be considered potentially problematic until proven otherwise (= properly assessed). These priority chemicals are pesticides, short-chained chlorinated paraffins (SCCPs), nonylphenol/ethoxylates, TBT, and brominated flame retardants (BDEs). The MSFD states that measurement should take place in the relevant matrix (such as biota, sediment and water) in a way that ensures comparability with the assessments under the WFD. In the OSPAR assessments of concentrations in sediments and biota, several metals, PCBs and PAHs have concentrations that have a potential for significant adverse effects. Concentrations of most contaminants are decreasing. **Effects of contaminants** The provisional assessment criteria for the OSPAR EcoQO for TBT-specific effects are not being met, indicating that TBT levels are still too high. In the eastern North Atlantic zone high dioxin-like POP burdens in sea mammals (e.g. harbour seals) tend to be associated with (immunotoxic and reproductive) effects. “Serious concern” levels of TEQ values were observed in sediment in the Dutch and Belgian coastal zone. The average proportion of oiled guillemots beached along the Dutch coast is higher than the assessment criteria for the OSPAR EcoQO oiled guillemots. The proportion of oiled guillemots is declining, however.

4.9 Descriptor 9: Contaminants in fish and seafood

4.9.1 MSFD description

Full description	**Annex I MSFD**
Contaminants in fish and other seafood for human consumption do not exceed levels established by Community legislation or other relevant standards	

Criteria and indicators in the Commission Decision
9.1 Levels, number and frequency of contaminants
Actual levels of contaminants that have been detected and number of contaminants which have exceeded maximum regulatory levels (9.1.1) *Frequency of regulatory levels being exceeded (9.1.2)*

4.9.2 OSPAR QSR 2010

General description for the North East Atlantic	*OSPAR Quality Status Report 2010*
No information available	

4.9.3 The Dutch part of the North Sea

As already described in section 4.8, the Dutch part of the North Sea is strongly influenced by emissions of contaminants from land-based and maritime sources.

4.9.3.1 Actual levels of contaminants that have been detected and number of contaminants which have exceeded maximum regulatory levels

A current Dutch monitoring programme designed to address the requirements set by the JAMP programme (Joint Assessment Programme) and run by Rijkswaterstaat focuses on analysis of contaminants in flounder (*Platichthys flesus*) and blue mussels (*Mytilus edulis*) in the Dutch coastal areas (Western Scheldt, Eastern Scheldt, coast of Noord- and Zuid-Holland, Wadden Sea and Ems-Dollard). The chemical groups analysed are: metals, organotin, PBDEs, PCBs and OCPs, PAHs (see Appendix D for specific contaminants per tissue).

RIKILT and IMARES run a monitoring programme called “Monitoring NL” on behalf of the Dutch agriculture and fisheries ministry (LNV). In this programme, fish and seafood are tested for a wide variety of contaminants. The chemical groups analysed are: dioxins, furans and dioxin-like PCBs, OCPs, PCBs, TCPM(e), PAHs, PBDEs (only in 2008). Samples are collected from both coastal areas and open seas (see Appendix D for specific contaminants per chemical group).

- JAMP monitoring programme levels (RWS)

The maximum permissible levels for food safety, both in mussels and in flounder have not been exceeded (NB: most contaminants were analysed in liver). Lead and cadmium levels in mussels are relatively high in contaminated coastal areas but do not exceed the legal limits. Decreasing trends in contaminants are less pronounced at sea than in freshwater. As in freshwater, the main decrease in contaminant loads was achieved in the 1980s and early 1990s.

- Monitoring NL levels (LNV)

This programme, too, found that the permissible levels for food safety have not been exceeded (Table 4.10). Only fish from relatively polluted coastal areas have elevated levels of contaminants, but they are all clearly below the maximum levels. These results indicate that for the contaminants that are currently analysed and for which a food safety standard has been established, there is only a minor risk of the limits being exceeded. For contaminants which have no legal limit (as yet), analysis indicates there is no reason for concern. Exposure limits for some contaminants like PBDEs and PFCs are under discussion. Concentrations of these compounds can be substantial in fish in some areas.

No trends can be established, since products have been tested from several locations and from fish auctions (no exact location known).

4.9.3.2 Frequency of regulatory levels being exceeded

No regulatory levels have been exceeded.

Table 4.10 Levels of contaminants in fishery products from Dutch coastal waters in the period 2004-2008

Species	**Number of samples**	**Cadmium**		**Mercury**	
		range (mg/kg)	*Permissible level (mg/kg)*	range (mg/kg)	*Permissible level (mg/kg)*
Shrimp	9	0.006 - 0.051	*0.5*	0.018 - 0.047	*0.5*
Herring	17	<0.004 - 0.021	*0.05*	0.016 - 0.053	*0.5*
Cod	9	<0.004 - <0.005	*0.05*	0.071 - 0.10	*0.5*
Pollack	2	<0.004 - <0.005	*0.05*	0.039 - 0.049	*0.5*
Norway Lobster	2	0.051 - 0.080	*0.5*	0.096 - 0.16	*0.5*
Mackerel	14	<0.004 - 0.032	*0.05*	0.023 - 0.13	*0.5*
Mussels	15	0.028 - 0.23	*1.0*	0.014 - 0.031	*0.5*
Oyster	1	0.096 -	*1.0*	0.023 -	*0.5*
Red Perch	1	<0.004 -	*0.05*	nb	*0.5*
Dab	3	<0.004 - <0.005	*0.05*	0.11 - 0.24	*0.5*
Haddock	6	<0.004 - 0.005	*0.05*	0.046 - 0.063	*0.5*
Plaice	8	<0.004 -	*0.05*	0.035 - 0.049	*0.5*
Smelt	1	<0.004 -	*0.05*	0.026 -	*0.5*
Turbot	1	<0.005 -	*0.05*	0.091 -	*0.5*
Sole	8	<0.004 - <0.005	*0.05*	0.034 - 0.058	*0.5*
Sea bass	2	<0.005 -	*0.05*	0.22 - 0.44	*0.5*
total	***99***				

Table 4.10 Continued

Species	**Lead**		**Selenium**		**Zinc**	
	range (mg/kg)	*Permissible level (mg/kg)*	range (mg/kg)	*Permissible level (mg/kg)*	range (mg/kg)	*Perm. level (mg/kg)*
Shrimp	<0.04 - 0.11	*0.5*	0.38 - 0.97	*none*	22 - 32	*none*
Herring	<0.04 - 0.19	*0.3*	<0.2 - 0.49	-	3.9 - 15	-
Cod	<0.04 - <0.068	*0.3*	<0.2 - 0.30	-	3.3 - 5.1	-
Pollack	<0.068 -	*0.3*	0.22 -	-	5.2 - 5.6	-
Norway Lobster	<0.05 - 0.056	*0.5*	0.76 - 0.84	-	14 - 15	-
Mackerel	<0.04 - <0.068	*0.3*	<0.2 - 0.58	-	3.6 - 14	-
Mussels	0.14 - 0.26	*1.5*	<0.2 - 0.58	-	10 - 19	-
Oyster	0.12 -	*1.5*	0.28 -	-	248 -	-
Red Perch	<0.04 -	*0.3*	0.30 -	-	2.8 -	-
Dab	<0.005 - <0.04	*0.3*	<0.2 - 0.20	-	4.2 - 4.8	-
Haddock	<0.005 - 0.09	*0.3*	<0.2 - 0.44	-	2.5 - 4.7	-
Plaice	<0.04 - <0.068	*0.3*	<0.2 - 0.47	-	3.3 - 5.6	-
Smelt	<0.04 -	*0.3*	0.17 -	-	15 -	-
Turbot	<0.05 -	*0.3*	0.46 -	-	3.4 -	-
Sole	<0.005 - 0.069	*0.3*	<0.2 - 0.30	-	4.1 - 4.5	-
Sea Bass	<0.05 -	*0.3*	<0.2 - 0.28	-	3.2 - 3.4	-
total						

4.9.3.3 Summary

Summary
Pressures Contaminant levels in the Dutch part of the North Sea are influenced by land-based emissions and maritime sources. **Levels, number and frequency of substances** The maximum permissible levels for food safety, in both mussels and flounder have not been exceeded (NB: most contaminants were analysed in liver). Fish from relatively polluted coastal areas have elevated levels of contaminants, yet all are below the permissible levels.

4.10 GES descriptor: 10 Litter

4.10.1 MSFD description

Full description	**Annex I MSFD**
Properties and quantities of marine litter do not cause harm to the coastal and marine environment.	

Criteria and indicators in the Commission Decision
10.1 Characteristics of litter in the marine and coastal environment
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)
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)
Trends in the amount, distribution and, where possible, composition of micro-particles (in particular micro-plastics) (10.1.3)
10.2 Impacts of litter on marine life
Trends in the amount and composition of litter ingested by marine animals (e.g. stomach analysis) (10.2.1)

4.10.2 OSPAR QSR 2010

General description for the North East Atlantic	*OSPAR Quality Status Report 2010*
Marine litter is a collective term for any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment. It includes a wide variety of slowly degradable items. The main sources from land include tourism, sewage, fly-tipping, local businesses and unprotected waste disposal sites. The main sea-based sources are shipping and fishing, including abandoned and lost fishing gear. Marine litter is a persistent problem affecting the seabed, the water column and coastlines. It poses risks to a wide range of marine organisms, such as seabirds, marine mammals and turtles, through ingestion and entanglement, and has economic impacts for local authorities and on a range of sectors, for example aquaculture, tourism, power generation, farming, fishing, shipping, harbours, and search and rescue. Sixty-five percent of items monitored on beaches are plastic. These degrade very slowly over hundred-year time scales and are prone to breaking up into small particles. The widespread presence of microscopic plastic particles and their potential uptake by filter-feeding organisms is of increasing concern given the capacity of plastic particles to absorb, transport and release pollutants. International and EU legislation addressing sources of litter includes the MARPOL Convention Annex V, and the EU Port Waste Reception Facilities Directive. In 2007,	

OSPAR published Guidelines for the Implementation of Fishing-for-Litter projects in the OSPAR area.

Region II (Greater North Sea), regional summary:
Amounts of litter are a concern. Over 90% of fulmars have microscopic plastic particles in their stomachs and 45% to 60% have more than the Ecological Quality Objective (EcoQO) set by OSPAR. Beach litter in the southern North Sea is at the OSPAR-wide average (around 700 items per 100 m beach), but levels are higher in the northern North Sea.

4.10.3 The Dutch part of the North Sea

Due to a lack of knowledge, there is uncertainty about the quantitative contribution of various sources to the amount of litter found at sea (Vethaak, pers. communication.). Shipping and fishing are assumed to be the main sea-bound sources, in addition to land-based sources.

4.10.3.1 Characteristics of litter in the marine and coastal environment

Amount of litter washed ashore
In the framework of OSPAR a beach litter monitoring programme has been running since 2002. Four reference beaches have been selected in the Netherlands: Bergen, Noordwijk, Veere and Terschelling. Items are counted over 100 m and 1 km. On the 100m transect items of various sizes are collected, while on the 1 km transects items larger than 50 cm are counted (RWS Noordzee, 2010).

According to Stichting Noordzee (2010) (Figure 4.42), the average number of waste items (of various sizes) found on 100 metres of the reference beaches in 2009 was 321. This represents a slight fall on 2008. The average number of items per reference beach has ranged from 250 to 500 per 100 metres between 2002 and 2009.

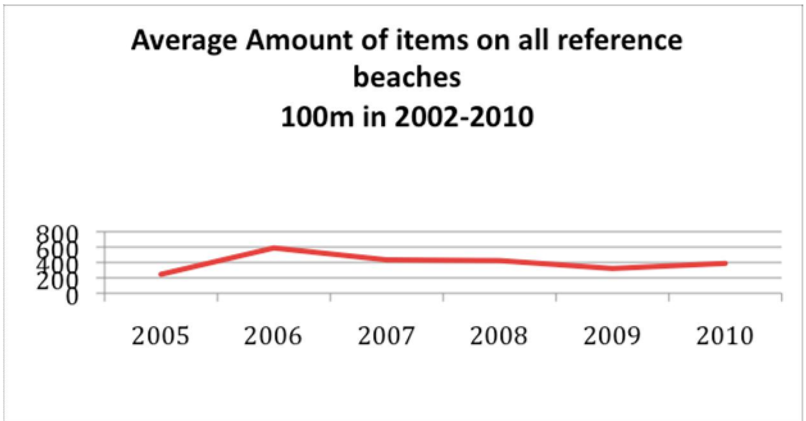


Figure 4.42 The average number of waste items washed ashore on the reference beaches in 2002-2009 on a length of 100 m for items of various size (Stichting de Noordzee, 2010).

The average number of items (>50 cm) on 1 km of the reference beaches in 2009 was 59, a decrease in comparison with 2008. These trends have not been statistically tested, however. OSPAR is developing a method for obtaining statistically significant data. Most of the litter washed ashore in the southern North Sea is plastics (75% by number of items; Figure 4.43)

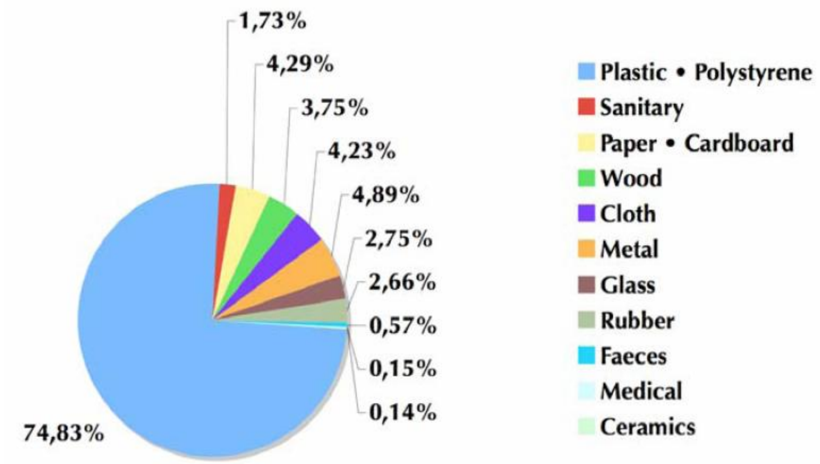


Figure 4.43 Proportion of marine litter categories on southern North Sea beaches (OSPAR, 2009)

Amount of litter on the surface, in the water column and on the seabed

Quantitative data on amounts of litter floating at the surface or in the water column are not known for the Dutch sector. Data on amounts of litter on the seabed are scarce and need some further evaluation. Likely, International Bottom Trawl Surveys (IBTS) coordinated by the UK will contribute to regional patterns of amounts of litter on the seabed. Data for 1988 give values between 100 and 1000 items per km^2 in the Dutch Continental Shelf (Galgani et al., 2000).

Figure 4.44 shows the different types of litter items collected by fisherman in the Netherlands and Belgium. In 2009 approximately 75 ships participating in "Fishing-for-Litter" initiatives collected 5–10 tonnes per ship per year. The percentage of plastic items collected from the seabed is lower than for the coastline. This is to be expected, as many plastic items are buoyant and either remain on the surface of the sea or wash up on the coastline. Different marine litter items were found, mostly rubber (104 gauntlets, 47 strings and belts) and textile (91 items from clothing and shoes), but also mechanically processed wood such as wooden pallets, plastic and polystyrene (69 buoys, 32 ropes and cords, 49 fishing nets and fishing lines, 20 large oil barrels and also metal oil drums) (OSPAR, 2009).

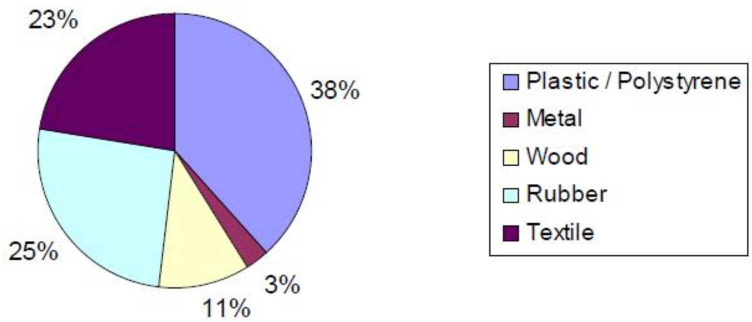


Figure 4.44 Types of items of marine litter collected by fishermen participating in KIMO Netherlands and Belgium Fishing-for-Litter schemes (OSPAR, 2009).

Most surveys of debris on beaches or the seabed are based on the "number" of items. Due to the widely varying sizes and types of objects, characterisation by number of items gives totally different results than characterisation by volume or mass. The latter metrics are more difficult to assess. In a large cleanup of the beach on Texel in April 2005, approx. 30 tons of litter were removed and analysed in terms both of number of items and of mass (Figure 4.45). Over 70% of litter was classified as synthetic (plastic, rope & net; textile, large rubber) by number of items. However, by mass these same categories represented approx. 45% of the debris. Processed wood, mainly freight pallets, represented over 50% of litter mass, but only 16% of numbers of items (Van Franeker, 2005).

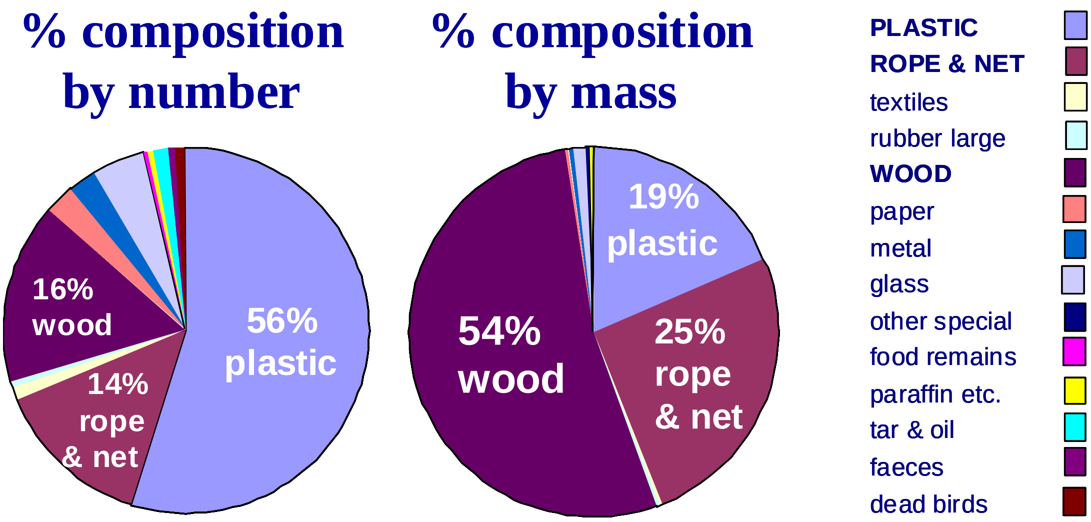


Figure 4.45 Difference in number and mass proportions of debris in a large clean-up operation on the island of Texel in April 2005 (Van Franeker, 2005).

Amount of microparticles
At present, no information is available for the Dutch part of the North Sea (Vethaak personal communication).

4.10.3.2 Impact of litter on marine life

OSPAR has set an EcoQO for plastic particles in seabird stomachs. The EcoQO is currently being used as an indicator of floating debris in relation to the delivery of ships' waste to Port Waste Reception Facilities. To meet the goal set by the OSPAR EcoQO fewer than 10% of northern fulmar (*Fulmarus glacialis)* should have more than 0.1 g plastic particles in their stomach in samples from 50 to 100 beach-washed fulmars found in each of four to five areas of the North Sea over a period of at least five years. This goal has not yet been met in the Netherlands (Figure 4.46). In 2004-2008 more than 60% of individuals had this amount of plastic in their stomach. The downward trend in plastic in stomachs was highly significant around the turn of the century, but no further significant change has been recorded in recent years.

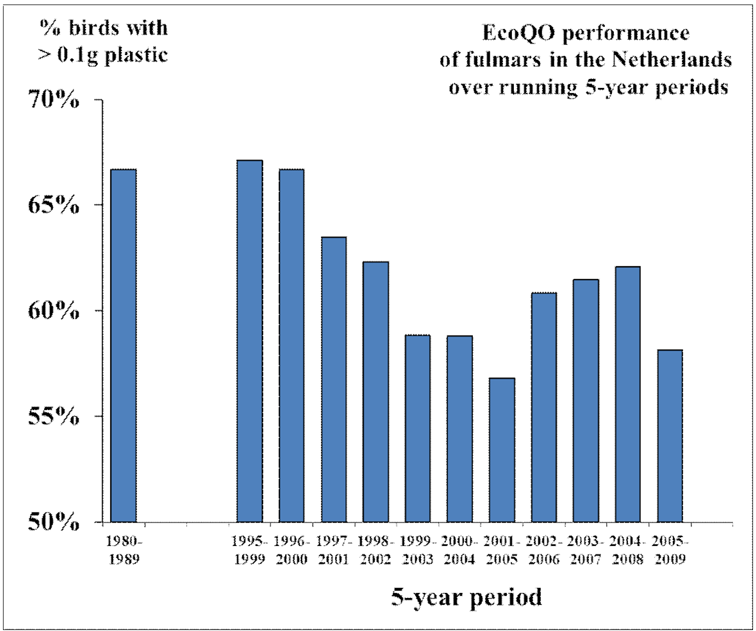


Figure 4.46 Developments in the Northern fulmar (Fulmarus glacialis) litter EcoQO 1980-2009. Trend in the percentage of Northern fulmars with more than 0.1 g of plastics in their stomach, as a moving average over five-year periods. Only a single average has been calculated for the 1980s. Note the Y-axis scale, where the lowest value shown is 50% of birds, well above the critical EcoQO target level of 10% (Van Franeker,, 2010).

4.10.3.3 Summary

Summary
Pressures Limited quantitative information is available about the sources of marine litter. **Characteristics of litter** Monitoring of numbers of waste items on beaches has been standardised by OSPAR, but strong local variability and analytical problems have so far hampered the gathering of appropriate statistics and the identification of target values for acceptable quality. No clear trend can be observed in the number of waste items found on Dutch beaches since 2002. No direct information is available as to the amount or composition of litter on the sea surface or in the water column in the Dutch sector. Data on litter on the seabed are fragmentary and have not been developed as a monitoring tool, although international trawl surveys may yield some information. **Impact of litter on marine life** A monitoring method considering the impact of litter on marine life has been developed by OSPAR in the form of an EcoQO for the mass of plastic in the stomachs of Northern fulmars. Trends in different categories of plastic have been monitored over the past decades. OSPAR has identified a target value for acceptable ecological quality for the North Sea. The target for the EcoQO on plastic in the stomachs of fulmars has not yet been met in the Dutch part of the North Sea.

4.11 GES descriptor 11: Introduction of energy, including underwater noise

4.11.1 MSFD description

Full description	***Annex I MSFD***
Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.	

Criteria and indicators in the Commission Decision
11.1 Distribution in time and place of loud, low and mid frequency impulsive sounds
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 1µPa^{2}·s) or as peak sound pressure level (in dB re 1µPa$_{peak}$) at one metre, measured over the frequency band 10 Hz to 10 kHz (11.1.1)
11.2 Continuous low frequency sound
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)

4.11.2 OSPAR QSR 2010

General description for the North East Atlantic	*OSPAR Quality Status Report 2010*
Many human activities generate noise and contribute to the general background level of noise in the sea. They include offshore construction, sand and gravel extraction, drilling, shipping, use of sonar, underwater explosions, seismic surveys, acoustic harassment devices and scarers (pingers). Marine mammals, many fish species and even some invertebrates use sound in communication – to find mates, to search for prey, to avoid predators and hazards, and for navigation. Underwater noise from anthropogenic sources has the potential to mask biological signals and to cause behavioural reactions, physiological effects, injuries and mortality in marine animals. Impacts depend on both the nature of the sound and the acoustic sensitivity of the organism. There are difficulties in quantifying the extent and scale of the impacts as there is great variability in the characteristics of the sounds, the sensitivities of different species and the scale of noise-generating activities. Data on all these aspects is generally scarce. But with the relatively intense concentrations of human activities in the North Sea, and the probability that these will increase, it is important that the effects of increased levels of underwater sound are fully considered. Studies show that noise does affect marine organisms but so far there is a lack of knowledge on specific effects and possible cumulative effects, which hampers understanding of dose-response relationships. Research is needed on the propagation and effects of underwater sound on marine life, as well as behavioural and auditory studies, programmes to monitor the distribution of sound sources and the relevant marine species, and anthropogenic sound budgets. There is an urgent need to standardise methods for assessing the impacts of sound on marine species and to address the cumulative effects of different sources.	

4.11.3 The Dutch part of the North Sea

The Dutch part of the North Sea is intensively used for shipping, which is an important source of underwater noise. Other relevant activities are seismic exploration, construction at sea (e.g. windfarms) and military activities.

Cooling water

The MSFD not only includes underwater noise under this descriptor, but also other means of introducing energy. The Task Group 11 report mentions other sources, like heat dissipation from underwater power cables and cooling water discharges from power plants. The Commission Decision does not mention any criteria and indicators for these latter sources, however.

Electromagnetic fields

Anthropogenic electromagnetic fields are introduced into the marine environment whenever electrical energy is transmitted from one point to another. They are therefore generally linked to operational submarine cables. A number of marine species including fish, marine mammals, sea turtles, molluscs and crustaceans are sensitive to electromagnetic fields and use them for things like orientation, migration and prey detection. As far as effects on fauna are concerned, there is no doubt that electromagnetic fields are detected by a number of species and that many of these species respond to them. Given the gaps in the knowledge of the impacts of electromagnetic energy on marine biota, combined with the problem of measuring the amount of energy emitted into the environment, no final conclusions can be drawn (Tasker et al., 2010).

Underwater noise

Anthropogenic sound emitted to the marine environment can potentially affect marine organisms in various ways. Documented effects on marine life range from very subtle behavioural changes, avoidance reaction, hearing loss, to injury and death in extreme cases.

Assessing the scale of the potential effects is challenging. OSPAR (2009) suggested that pressures due to underwater noise emissions might be relatively high in OSPAR Regions II and III due to the comparably large amount of human activities in these areas. Within Region II the southern North Sea is probably one of the most intensively used areas. In order to assess the possible impact of various activities, it is important to identify some key ones that are most likely to be problematic for marine life, such as those that emit the highest acoustic energy levels into the environment, and to sort out those where relatively low-level noise is a mere by-product of the activity.

In 2009 such an assessment was made of anthropogenic sound sources in the Dutch part of the North Sea, identifying the existing knowledge and revealing gaps in the knowledge (Ainslie, 2009). The study produced an inventory of all relevant natural and anthropogenic sources of sound in the water column was made.

Source levels, frequency bands, and other characteristic information was collected for these anthropogenic sources. Based on this information, an acoustic energy budget comparison was made. The study concluded that the main contributions to anthropogenic sound energy in the Dutch part of the North Sea come from shipping, seismic surveys (airguns), underwater explosions and pile driving (Table 4.11).

Table 4.11 Estimate of total acoustic energy for the most important anthropogenic sources in the Dutch part of the North Sea.

Type of source	Order of magnitude estimate of annual average of acoustic power output in the North Sea [GJ/year]	Order of magnitude estimate of frequency [kHz]	Order of magnitude estimate of absorption [dB/km]	Order of magnitude estimate of total (free space) energy $E = W/(2\alpha c)$ [kJ]
Airgun arrays	100	0.1	0.0012	**8000**
Shipping	270	0.3	0.01	**3000**
Wind farm construction (pile driving)	9	0.1	0.0012	**700**
Explosions	7	0.1	0.0012	**500**
Navigation echo sounders	60	30	8.2	0.7
Fisheries sonar	10	30	8.2	0.1
Military search sonar[12]	0.2	10	1.2	0.02

In line with the findings in the OSPAR Commission 2009 assessment and the OSPAR QSR 2010, this research effort concluded that clear generic guidelines / procedures should be established for the measurement, processing and quantification of underwater sound, such that future studies and measurement campaigns lead to comparable results. There is a large demand for proper measuring protocols and measurements of natural and anthropogenic underwater sound in the North Sea (i.e. measurements that comply with the guidelines) for further development of the propagation modelling and validation of the resulting sound maps.

As stated above, the need for acoustic measurement guidelines and standards was recently identified. However, since 2009 considerable work has been done as part of an international research effort to fill this knowledge gap. Institutes from the Netherlands, the United Kingdom and Germany have made a first step towards European standardisation for measuring and reporting underwater sounds, and follow-up work is being carried out in 2010 and 2011, leading to a report on acoustic standards. Although wider adoption and a process of formal standardisation will take some years, it is nevertheless felt that considerable progress is made in this field.

4.11.4 Summary

Summary
Pressures Shipping is an important source of underwater noise. Other relevant activities are seismic exploration, construction at sea (e.g. windfarms) and military activities, including explosions due to dismantling of old ammunition. **Distribution in time and place of loud, low and mid frequency impulsive sounds** **Continuous low frequency sound** Currently only very limited information is available on disturbance caused by underwater noise to cetaceans and other mammals, fish, fish larvae or other marine life, and the effects on species abundance or distribution in the Dutch part of the North Sea. Due to this lack of information, the current environmental status of the Dutch North Sea sector cannot be evaluated with respect to impacts of underwater noise. Generic guidelines/procedures for the measurement and quantification of underwater sound are presently lacking.

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B Glossary

List of species names

English names in alphabetical order

English	Dutch	Scientific name
allis shad	elft	*Alosa alosa*
American jackknife clam	Amerikaanse zwaardschede	*Ensis directus*
avocet	kluut	*Recurvirostra avosetta*
bar-tailed godwit	rosse grutto	*Limosa lapponica*
black-throated diver	zwartkeelduiker	*Gavia arctica*
blue whiting	blauwe wijting	*Micromesistius poutassou*
cod	kabeljauw	*Gadus morhua*
common scoter	zwarte zee-eend	*Melanitta nigra*
common tern	visdief	*Sterna hirundo*
common whelk	wulk	*Buccinum undatum*
cormorant	Phalacrocorax carbo	*Phalacrocorax carbo*
curlew	wulp	*Numenius arquata*
cut trough shell	halfgeknotte strandschelp	*Spisula subtruncata*
dab	schar	*Limanda limanda*
dog whelk	wulk	*Nucella lapillus*
dunlin	bonte strandloper	*Calidris alpine*
eider	eider	*Somateria mollissima*
flounder	bot	*Platichthys flesus*
fulmar	Noordse stormvogel	*Fulmarus glacialis*
gadwall	krakeend	*Anas strepera*
gannet	jan-van-gent	*Morus bassanus*
goldeneye	brilduiker	*Bucephala clangula*
great black-backed gull	grote mantelmeeuw	*Larus marinus*
great crested grebe	fuut	*Podiceps cristuatus*
great skua	grote jager	*Catharactus skua*
grey plover	zilverplevier	*Pluvialis squatarola*
grey seal	grijze zeehond	*Halichoerus grypus*
greylag goose	grauwe gans	*Anser anser*
guillemot	zeekoet	*Uria aalge*
haddock	schelvis	*Melanogrammus aeglefinus*
hake	heek	*Merluccius merluccius*
harbour porpoise	bruinvis	*Phocoena phocoena*
harbour seal	gewone zeehond	*Phoca vitulina*
herring	haring	*Clupea harengus*
horned grebe	kuifduiker	*Podiceps auritus*
horse mussel	gewone paardenmossel	*Modiolus modiolus*
Kentish plover	strandplevier	*Charadrius alexandrinus*
kittiwake	drieteenmeeuw	*Rissa tridactyla*
lesser black-backed gull	kleine mantelmeeuw	*Larus fuscus*
lesser sand eel	zandspiering	*Ammodytes marinus*
little auk	kleine alk	*Alle alle*

little gull	dwergmeeuw	*Larus minutus*
little tern	dwergstern	*Sterna albifrons*
mackerel	makreel	*Scomber scombrus*
Norway pout	kever	*Trisopterus esmarki*
ocean quahog	noordkromp	*Arctica islandica*
oystercatcher	scholekster	*Haematopus ostralegus*
Pacific oyster	Japanse oester	*Crassostrea gigas*
periwinkle	alikruik	*Littorina littorea*
pintail	pijlstaart	*Anas acuta*
plaice	schol	*Pleuronectus platessa*
plaice	schol	*Pleuronectus platessa*
puffin	papegaaiduiker	*Fratercula arctica*
razorbill	alk	*Alca torda*
red fox	vos	*Vulpes vulpes*
red knot	kanoet	*Calidris canutus*
red whelk	noordhoren	*Neptunea antiqua*
red-breasted merganser	middelste zaagbek	*Mergus serrator*
redshank	tureluur	*Tringa totanus*
red-throated diver	roodkeelduiker	*Gavia stellata*
ringed plover	bontbekplevier	*Charadrius hiaticula*
river lamprey	rivierprik	*Lampetra fluviatilis*
ross worm	kokerworm	*Sabellaria spinulosa*
saithe	koolvis	*Pollachius virens*
sand mason worm	schelpkokerworm	*Lanice conchilega*
sanderling	drieteenstrandloper	*Calidris alba*
sandwich tern	grote stern	*Sterna sandvicensis*
scaup	topper	*Aythya marila*
sea lamprey	zeeprik	*Petromyzon marinus*
shelduck	bergeend	*Tadorna tadorna*
shoveler	slobeend	*Anas clypeata*
small sand eel	zandspiering	*Ammodytes tobianus*
sole	tong	*Solea solea*
spoonbill	lepelaar	*Platalea leucorodia)*
teal	wintertaling	*Anas crecca*
turnstone	steenloper	*Arenaria interpres*
twaite shad	fint	*Alosa fallax*
whiting	wijting	*Merlangius merlangus*
wigeon	smient	*Anas penelope*

Scientific names in alphabetical order

Scientific name	English	Dutch
Alca torda	razorbill	alk
Alle alle	little auk	kleine alk
Alosa alosa	allis shad	Elft
Alosa fallax	twaite shad	Fint
Ammodytes marinus	lesser sand eel	Zandspiering
Ammodytes tobianus	small sand eel	Zandspiering
Anas acuta	pintail	Pijlstaart
Anas clypeata	shoveler	slobeend
Anas crecca	teal	wintertaling
Anas penelope	wigeon	smient
Anas strepera	gadwall	krakeend
Anser anser	greylag goose	grauwe gans
Arctica islandica	ocean quahog	noordkromp
Arenaria interpres	turnstone	steenloper
Aythya marila	scaup	topper
Buccinum undatum	common whelk	wulk
Bucephala clangula	goldeneye	brilduiker
Calidris alba	sanderling	drieteenstrandloper
Calidris alpina	dunlin	bonte strandloper
Calidris canutus	red knot	kanoet
Catharactus skua	great skua	grote jager
Charadrius alexandrinus	Kentish plover	strandplevier
Charadrius hiaticula	ringed plover	bontbekplevier
Clupea harengus	herring	haring
Crassostrea gigas	Pacific oyster	Japanse oester
Ensis directus	American jackknife clam	Amerikaanse zwaardschede
Fratercula arctica	puffin	papegaaiduiker
Fulmarus glacialis	fulmar	Noordse stormvogel
Gadus morhua	cod	kabeljauw
Gavia arctica	black-throated diver	zwartkeelduiker
Gavia stellata	red-throated diver	roodkeelduiker
Haematopus ostralegus	oystercatcher	scholekster
Halichoerus grypus	grey seal	grijze zeehond
Lampetra fluviatilis	river lamprey	rivierprik
Lanice conchilega	sand mason worm	schelpkokerworm
Larus fuscus	lesser black-backed gull	kleine mantelmeeuw
Larus marinus	great black-backed gull	grote mantelmeeuw
Larus minutus	little gull	dwergmeeuw
Limanda limanda	dab	schar
Limosa lapponica	bar-tailed godwit	rosse grutto
Littorina littorea	periwinkle	alikruik
Melanitta nigra	common scoter	zwarte zee-eend
Melanogrammus aeglefinus	haddock	schelvis
Mergus serrator	red-breasted merganser	middelste zaagbek
Merlangius merlangus	whiting	wijting
Merluccius merluccius	hake	heek
Micromesistius poutassou	blue whiting	blauwe wijting

Modiolus modiolus	horse mussel	gewone paardenmossel
Morus bassanus	gannet	jan-van-gent
Neptunea antiqua	red whelk	noordhoren
Nucella lapillus	dog whelk	wulk
Numenius arquata	curlew	wulp
Petromyzon marinus	sea lamprey	zeeprik
Phalacrocorax carbo	cormorant	Phalacrocorax carbo
Phoca vitulina	harbour seal	gewone zeehond
Phocoena phocoena	harbour porpoise	bruinvis
Platalea leucorodia)	spoonbill	lepelaar
Platichthys flesus	flounder	bot
Pleuronectus platessa	plaice	schol
Pleuronectus platessa	plaice	schol
Pluvialis squatarola	grey plover	zilverplevier
Podiceps auritus	horned grebe	kuifduiker
Podiceps cristuatus	great crested grebe	fuut
Pollachius virens	saithe	koolvis
Recurvirostra avosetta	avocet	kluut
Rissa tridactyla	kittiwake	drieteenmeeuw
Sabellaria spinulosa	ross worm	kokerworm
Scomber scombrus	mackerel	makreel
Solea solea	sole	tong
Somateria mollissima	eider	eider
Spisula subtruncata	cut trough shell	halfgeknotte strandschelp
Sterna albifrons	little tern	dwergstern
Sterna hirundo	common tern	visdief
Sterna sandvicensis	sandwich tern	grote stern
Tadorna tadorna	shelduck	bergeend
Tringa totanus	redshank	tureluur
Trisopterus esmarki	Norway pout	kever
Uria aalge	guillemot	zeekoet
Vulpes vulpes	red fox	vos

List of geographicsl names

English	Dutch
Borkum Stones	Borkumse Stenen
Brown Ridge	Bruine Bank
Channel	Kanaal
Cleaver Bank	Klaverbank
Dogger Bank	Doggersbank
Frisian Front	Friese Front
Gas Seeps	Gasfonteinen
North Sea Coastal Zone	Noordzeekustzone
Oyster Grounds	Oestergronden

List of abbreviations

Abbreviation	English
BaP	benzo[a]pyrene
BbF	benzo[b]fluoranthene
BghiPe	benzo[g,h,i]perylene
BkF	benzo[k]fluoranthene
Cd	Cadmium
CEMP	Co-ordinated environmental monitoring programme
Cu	Copper
EcoQO	Ecological Quality Objective (OSPAR)
EEZ	Exclusive Economic Zone
ICES	International Council for the Exploration of the Sea
InP	indeno[1,2,3-cd]pyrene
JAMP	Joint assessment and monitoring programme
JRC	Joint Research Centre
OSPAR	Oslo-Paris Commission
PAH	polyaromatic hydrocarbon
PBDE	polybrominated diphenyl ethers
PCB	polychlorinated biphenyl
QSR	Quality Status Report
TBT	Tributyltin
Zn	Zinc

C Description of pressures

MSFD Annex III, Table 2	OSPAR	Definition	Activities in the Dutch part of the North Sea
Physical loss			
smothering (e.g. by man-made structure, disposal of dredging spoil)	siltation rate changes, including smothering (code D4)	**"The physical covering of the species or community and its substratum with additional sediment (silt), spoil, detritus, litter, oil or man-made objects." (**Tyler- Walters et al. 2001**).** With deposits of >20cm depth most species of marine biota unable to adapt, e.g. sessile organisms are unable to make their way to the surface. Regarding the coverage with detritus and litter one can argue the reversibility of the impact. Litter is known to be persistently present in ecosystems, and it accumulates in lee areas. Therefore coverage by litter can be defined as physical loss. Coverage by detritus can be defined as habitat loss if the detritus does not decompose (e.g. due to low/lack of oxygen).	relocation of dredged material, coastal nourishments, man-made structures (exploration for oil and gas and related structures, cables and pipelines, extraction of marine aggregates, renewable energies), land reclamation
sealing (e.g. by permanent structures)	physical loss (to another seabed type) (code L2)	In Slijkerman & Tamis (2010) sealing is defined as: **"The sealing of the seabed or intertidal areas by constructions that separate the benthic environment from the overlying water" (**WRc & IECS 2008**).** OSPAR defines this as a permanent change to another marine habitat through the change in substratum	permanent structures (wind turbines, oil and gas rigs, cables & pipelines), construction for coastal defence
permanent change*	physical loss (to land or freshwater habitat) (code L1) physical loss (to another type) (code L2)	This pressure can be described as the permanent loss of marine habitats. Associated activities are land reclamation, new coastal defences. Permanent change could also mean the introduction of a new habitat type, e.g. the permanent change of one marine habitat type to another marine habitat type, through the change in substratum. Associated activities include the installation of infrastructure (e.g. surface of platforms or windfarm foundations, marinas, coastal defences, pipelines and cables), and the placement of scour protection where soft sediment habitats are replaced by hard/coarse substrate habitats	land reclamation
Physical damage			
changes in	siltation rate	**Changes in the siltation**	land-based emissions,

siltation (e.g. by outfalls, increased run-off, dredging/disposal of dredging spoil)	changes, including smothering (code D4) changes in suspended solids (code D3)	**characteristics of a water body (e.g. changes in sediment deposition areas or changes in turbidity**) are induced by changes in the hydrodynamics of the water body (WRc & IECS 2008). This relates to changes in turbidity from sediment & organic particulate matter concentrations (OSPAR, 2011). This pressure also relates to changes in turbidity from suspended solids of organic origin. It can result in short-lived sediment concentration gradients and the accumulation of sediments on the seafloor, but also in mobilisation in the water column. The rate of siltation or suspension is dependent on the availability of suspended sediment (which could be from natural or anthropogenic sources), its particle size range and the water flow rate (Tyler-Walters et al. 2001) and thus related to the change in suspended sediment. Salinity, turbulence and temperature may result in flocculation of suspended organic matter. Anthropogenic sources are mostly short-lived and extend over relatively small spatial areas. The accumulation of sediments is synonymous with "light" smothering, i.e. deposits of <20cm depth to which most biota may be able to adapt. It is associated with activities such as sea disposal of dredged materials where sediments are deliberately deposited on the seabed.	dredging for navigational purposes, cables & pipelines (placement, maintenance, presence), extraction of marine aggregates, activities that disturb sediment and/or organic particulate matter such as dredging, disposal at sea, cable burial, secondary effects of construction works (e.g. breakwaters)
abrasion (e.g. impact on the seabed of commercial fishing, boating, anchoring)	Penetration and/or disturbance of the substrate below the surface of the seabed, including abrasion (code D2)	In Slijkerman & Tamis (2010) 'Abrasion' is defined as: "**Damage of seabed and habitats by boating, anchorage and commercial fishing**" (WRc & IECS 2008). Tyler-Walters (2001) described abrasion or physical impact as follows: "Abrasion includes mechanical interference, crushing, physical blows against, or rubbing and erosion of the organism of interest. Due to abrasion protrusive species may be crushed, and delicate organisms with a fragile skeleton or soft bodies may be physically damaged or broken (snapped)" (Tyler-Walters et al. 2001). The OSPAR definition of abrasion falls under 'Penetration and/or disturbance of the substrate below the surface of the seabed, including abrasion', which is described as '**the local disturbance of sediments where there is limited or no loss of substrate from the system'** and	marine commercial fisheries, maritime tourism, anchoring

		abrasion **'relates to damage of the seabed surface**.' This report uses the definition in Slijkerman & Tamis, since it has a separate definition for abrasion which is more complete than the one from OSPAR.	
selective extraction (e.g. exploration and exploitation of living and non-living resources on seabed and subsoil)	Habitat structure changes – removal of substratum (code D1)	(Slijkerman & Tamis, 2010) The Marine Life Information Network for Britain and Ireland (MarLIN) uses the term 'substratum loss', defined as: **the physical removal of the substratum inhabited or required by the species or community in question** (Tyler-Walters et al. 2001). If the loss is irreversible, this type of habitat loss is considered "loss" whereas temporary and reversible alterations are considered "damage". OSPAR (2011) calls this pressure "Physical change (to another seabed type)" under the pressure theme "Physical loss (permanent change)". This pressure can be described as the **permanent change of one marine habitat type to another marine habitat type, through the change in substratum.** It uses another definition for reversible changes (damage), namely **"habitat structure change" pressure type relates to temporary and/or reversible change.** This report uses the definition in Slijkerman & Tamies (2010), since it specifies that the activity is the physical removal of substrate, but also has an impact on marine species and communities. This is distinguishable from the pressure "selective extraction of species" by the fact that extraction of sediment focuses on *extraction of the aggregate* where organisms are removed accidentally. Selective extraction of species, however, focuses on the *extraction of the organism*.	exploration and exploitation of living and non-living resources on seabed and subsoil
Other physical disturbance			
underwater noise (e.g. from shipping, underwater acoustic equipment),	Underwater noise changes (code O3)	This pressure type relates **to increases over and above background noise levels (consisting of environmental noise (ambient) and incidental man-made/anthropogenic noise (apparent) at a particular location** (OSPAR, 2011)**.** Noise in relation to marine ecosystem elements and activities can be described as	maritime transportation, underwater acoustic equipment, exploration for oil and gas (incl. seismic exploration) and placement or removal of structures for exploration, construction activities (for example pile-driving and the operation of

		(Slijkerman & Tamis, 2010): **"disturbance of aquatic organisms by for example seismic exploration, sonar and boat activities"** (WRc & IECS 2008). The physical or behavioural effects are dependent on a number of variables, including the sound pressure, loudness, sound exposure level and frequency (OSPAR, 2011). Some species may be responsive to the associated particle motion rather than the usual concept of noise. Noise propagation can be over large distances (tens of kilometres) but transmission losses can be attributable to factors such as water depth and seabed topography. Species known to be affected are primarily marine mammals and fish. Noise associated with construction activities, such as pile-driving, are typically significantly greater than operational phases (i.e. shipping, operation of a windfarm).	windfarms)
marine litter	Litter (code O1)	This pressure type relates to **the introduction of any materials from anthropogenic activities (excluding legitimate disposal).** Any persistent, manufactured or processed solid material disposed of or abandoned in the marine and coastal environment can be defined as marine litter (UNEP 2005). Marine litter consists of items that have been made or used by people and deliberately discarded into the sea or rivers or on beaches; brought indirectly to the sea with rivers, sewage, storm water or winds; accidentally lost, including material lost at sea in bad weather (fishing gear, cargo); or deliberately left by people on beaches and shores and includes: plastics, metals, timber, rope, fishing gear etc and their degraded components, e.g. microplastic particles. Effects can be physical (smothering), biological (ingestion) and/or chemical (leaching). This can eventually lead to degradation of the environment	Sources of marine litter are shipping, sewage treatment, storm overflows, tourism, offshore oil & gas installations, aquaculture installations
electromagnetic changes*	Electromagnetic changes (code O2)	This pressure type relates to the localised electrical and magnetic fields associated with operational telecommunications and power cables.	cables
other physical damage*	Barrier to species movement (code O5) Death or injury by	This pressure type relates to the physical obstruction of species movements This pressure type relates to injury or	This pressure is currently not a concern in the Dutch Continental Shelf. In the future renewable energy might pose a risk

	collision (code O6)	mortality from collisions of biota with both static &/or moving structures	
Interference with hydrological processes			
significant changes in thermal regime (e.g. by outfalls from power stations)	temperature changes – local (code H1)	Slijkerman & Tamis (2010): the Marine Life Information Network for Britain and Ireland (MarLIN) uses the term “changes in temperature”, defined as (Tyler-Walters et al. 2001): **“A change in the ambient temperature of seawater”.** This is most likely from thermal discharges, e.g. the release of cooling waters from power stations. As such this pressure applies only within a thermal plume generated by the pressure source.	Land-based emissions (i.e. cooling water from power stations)
significant changes in salinity regime (e.g. by structures impeding water movement, water abstraction)	salinity changes – local (code H2)	In Slijkerman & Tamis (2010) changes in the salinity regime are described as: “**Changes in the salinity regime of the affected water body by, for example, abstractions, restriction of, or changes, in freshwater flows into the water body by barriers and other constructions. Could also be a result of changes in mixing processes and characteristics by physical modifications of the water body**” (WRc & IECS 2008). According to OSPAR this only relates to anthropogenic sources/causes that have the potential to be controlled, e.g. freshwater discharges from pipelines that reduce salinity, or brine discharges from salt cavern washings that may increase salinity, or hydromorphological modification, e.g. capital navigation dredging if this alters the halocline, or erection of barrages or weirs that alter freshwater/seawater flow/exchange rates. The pressure may be temporally and spatially delineated on the basis of the causal event/activity and local environment. This excludes floods or other 'natural' events. For marine areas that are regularly subjected to freshwater ingress from flood events this is arguably part of the ecosystem so is not classed as a pressure.	coastal defence structures, port infrastructure, dredging for navigational purposes
other hydrological changes*	water flow changes – local (code H3) wave exposure changes – local (code H5)	Changes in hydrodynamics can be described as: **“Changes in the hydrological regime of the affected water body related to water flow (tidal current) or wave exposure”** (OSPAR). The pressure is associated with	coastal nourishments, renewable energy (e.g. tidal energy generation), dredging for navigational purposes, canalisation and/or structures that alter flow speed and direction, construction

		activities that have the potential to modify energy flows, e.g. tidal energy generation devices remove (convert) energy and such pressures could be manifested leeward of the device, capital dredging may deepen and widen a channel and therefore decrease the water flow, canalisation or structures may alter flow speed and direction. The pressure will be spatially delineated. Pressures on wave exposure are related to changes in wave length, height and frequency. Exposure on an open shore is dependent upon the distance of open seawater over which wind may blow to generate waves (the fetch) and the strength and incidence of the winds. Anthropogenic sources of this pressure include artificial reefs, breakwaters, barrages that can directly influence wave action or activities that may locally affect the incidence of winds, e.g. a dense network of wind turbines may have the potential to influence wave exposure, depending upon their location relative to the coastline. The pressure extremes are a shift from a high to a low energy environment (or vice versa). The biota associated with these extremes will therefore be markedly different as will the substrate, sediment supply/transport and associated seabed elevation changes. As such these pressures could be associated with multiple and complex impacts. OSPAR includes the 'Emergence regime changes' (code H4) in this pressure. However, since this is less relevant in marine environments, this pressure is not included.	and placement of artificial reefs, breakwaters and barrages (i.e. dense network of wind turbines)
Contamination by hazardous substances			
introduction of synthetic compounds (e.g. priority substances under Directive 2000/60/EC which are relevant for the marine environment such as pesticides, antifoulants, pharmaceuticals, resulting, for	synthetic compound contamination (code P3)	According to Slijkerman & Tamis (2010) synthetic chemicals are by definition man-made and include, for example, organotins (tributyltin, triphenyltin), pesticides (lindane, atrazine, dichlorvos, DDT), organochlorides, organophosphates, solvents (carbon tetrachloride, chloroform) and polychlorinated biphenyls (PCBs) (Tyler-Walters et al. 2001). Pharmaceuticals and personal care products originate from veterinary and human applications comprises a variety of	Emissions from point and diffuse sources on land and in the sea

example, from losses from diffuse sources, pollution by ships, atmospheric deposition and biologically active substances)		products including over-the-counter medications, fungicides, chemotherapy drugs and animal therapeutics, such as growth hormones (OSPAR, 2011). Due to their biologically active nature, high levels of consumption, known combined effects, and their detection in most aquatic environments, they have become an emerging concern	
introduction of non-synthetic substances and compounds (e.g. heavy metals, hydrocarbons, resulting, for example, from pollution by ships and oil, gas and mineral exploration and exploitation, atmospheric deposition, riverine inputs),	Heavy metal & organo-metal contamination (code P1) Hydrocarbon & PAH contamination (code P2)	Slijkerman & Tamis (2010): This includes introduction of heavy metals (for example, arsenic (As), cadmium (Cd), mercury (Hg), lead (Pb), zinc (Zn) and copper (Cu)) and introduction of hydrocarbons (for example, oils (crude and fuel oils) and polyaromatic hydrocarbons (PAHs)). **Contamination by hormonally active agents**, i.e. natural occurring substances such as estroGES, androGES and progestins **are also included in this definition** (Karman & Jongbloed 2008).	Emissions from point and diffuse sources on land and in the sea
introduction of radio-nuclides.	radionuclide contamination (code P5)	This is defined as **"the introduction of isotopes of elements that emit alpha, beta or gamma radiation, raising levels above background concentrations" (OSPAR, 2011; Slijkerman & Tamis, 2010)**. Radio nuclides may occur naturally, but can also be artificially produced (Slijkerman & Tamis, 2010). Such materials can come from nuclear installation discharges, and from land or sea-based operations (e.g. oil platforms, medical sources).	land-based emissions (e.g. nuclear installation discharges, nuclear power generation) and land or sea-based operations (e.g. oil platforms, medical sources)
Systematic and/or intentional release of substances			
Introduction of other substances, whether solid, liquid or gas, in marine waters, resulting from their systematic and/or intentional release into the marine environment, as permitted in accordance with other Community legislation and/or international conventions	Introduction of other substances (solid, liquid or gas) (code P4)	The "systematic or intentional release of liquids, gases …" is considered [only] in relation to process water from the oil industry. It should therefore be considered in parallel with P1, P2 and P3	Oil and gas exploration and exploitation
Nutrient and organic matter enrichment			
inputs of fertilisers	Nutrient	This primarily relates to **increased**	Emissions from point and

and other nitrogen- and phosphorus-rich substances (e.g. from point and diffuse sources, including agriculture, aquaculture, atmospheric deposition	enrichment (code P6)	**levels of the elements nitrogen, phosphorus, and silicon in the marine environment.** Nutrients can enter marine waters by natural processes (e.g. decomposition of detritus, riverine outflows from areas of high natural productivity) or anthropogenic sources (e.g. waste water run-off, terrestrial/agricultural run-off, sewage discharges). Nutrient and organic enrichment may lead to eutrophication.	diffuse sources on land and in the sea
inputs of organic matter (e.g. sewers, mariculture, riverine inputs)	Organic enrichment (code P7)	This is defined as **increased levels of organic matter above background levels**. It relates to the degraded remains of dead biota & microbiota (land & sea); faecal matter from marine animals; flocculated colloidal organic matter and the degraded remains of: sewage material, domestic waste, industrial waste etc. Organic matter can enter marine waters from sewage discharges, aquaculture or terrestrial/agricultural run-off.	Emissions from point and diffuse sources on land and in the sea
Biological disturbance			
Introduction of microbial pathoGES	Introduction of microbial pathoGES (code B4)	In Slijkerman & Tamis (2010) this pressure is described by the UK Marine Monitoring and Assessment Strategy as (WRc & IECS 2008): “**introduction of microbial organisms that can cause minor illnesses in humans from exposure to seawater, or potential poisoning of shellfish, or affect the viability/health of other aquatic organisms**”. This pressure is associated with untreated effluent discharges & run-off from terrestrial sources & vessels. It may also be a consequence of ballast water releases. In mussel or shellfish fisheries where seed stock are imported there is a potential that ”infected” seed could be introduced, or there could be accidental releases in effluvia. Escapees, e.g. farmed salmon, could be infected and spread pathoGES in the indigenous populations. Aquaculture could release contaminated faecal matter, from which pathoGES could enter the food chain	untreated effluent discharge, ballast water releases, mariculture
introduction of non-indigenous species and translocations	Introduction or spread of non-indigenous species (code B3)	This pressure type relates to the **direct or indirect introduction of non-native species, where non-native species are organisms that are not indigenous to a given place or area and have been accidentally or deliberately transported by human activity**	Mariculture, maritime transportation

		(OSPAR, 2011; Slijkerman & Tamis, 2010)**.** Other terms for non-indigenous, but with a slightly different emphasis regarding their introduction to an area, are “invasive species” or “exotic species”. Definitions are sometimes used interchangeably. Examples of such species are Chinese mitten crabs, Crepidula sp., and Pacific oysters and their subsequent spreading and out-competing of native species. Ballast water and stepping stone effects (e.g. offshore windfarms) may facilitate the spread of such species. This pressure could be associated with mussel or shellfish fisheries where seed stock is imported, or with accidental releases.	
selective extraction of species, including incidental non-target catches (e.g. by commercial and recreational fishing)	Removal of target species (code B5) Removal of non-target species (code B6)	According to Slijkerman & Tamis (2010) the UK Marine Monitoring and Assessment Strategy describe this pressure as (WRc & IECS 2008): “**The selective removal of target species for human consumption (e.g. shellfish and fish), as part of a recreational activity or for other commercial purposes (e.g. bio-prospecting)**”. Accidental non-target catches **relates to by-catch associated with commercial fishing activities** and is included in the driver selective extraction of species**.**	fishing
genetic modification**	Genetic modification & translocation of indigenous species (code B2)	Genetic modification can be either deliberate (e.g. introduction of farmed individuals to the wild, GM food production) or a by-product of other activities (e.g. mutations associated with radionuclide contamination) (OSPAR, 2011). Former related to escapees or deliberate releases e.g. cultivated species such as farmed salmon, oysters, scallops if GM practices employed. Scale of pressure compounded if GM species "captured" and translocated in ballast water. Mutated organisms from the latter could be transferred on ships’ hulls, in ballast water or “natural” migration. Movement of native species to new regions can also introduce different genetic stock.	mariculture This pressure is currently not a concern on the Dutch Continental Shelf,

*not mentioned in MSFD Annex III, Table 2
** not mentioned in MSFD Annex III, Table 2; not included in Table 3.3

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D Analysis of contaminants in fish and seafood

Table D.1 Contaminants analysed in flounder and mussel samples from the Dutch coast (JAMP programme). Mussels were collected in October, flounder were caught in September.

Chemical group	Analysed in flounder	Analysed in mussels
Metals	cadmium, copper, zinc, lead in liver, and mercury in filet	cadmium, copper, chrome, zinc, lead, nickel, mercury and arsenic
Organotin		TBT, DNT, MBt and TPhT, DPhT, MPhT
PBDEs	47, 99 and 100	47, 99 and 100
PCBs/OCPs	28 PCBs and HCB, HCBD, β-HCH, γ-HCH), p,p-DDE, p,p-DDD, dieldrin (also in liver)	7 indicator PCBs and QCB, HCB, α-HCH, β-HCH, γ-HCH), p,p-DDE, p,p-DDD, dieldrin
PAHs	-	Acenaftylene, acenaftene, phenantrene, fluoranthene, pyrene, benz[a]anthracene, chrysene, benzo[b+j]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, indeno[123cd]pyrene, dibenzo[ah]anthracene

Table D.2 Contaminants analysed in the LNV monitoring programme “Monitoring NL”, 2004-2008.

Chemical group	Specific
Metals	Cadmium, mercury, lead, zinc and selenium
Dioxins, furans and dioxin-like PCBs	17 dioxin- and furan congeners plus 12 non- and mono-ortho PCB congeners (total -TEQ)
OCPs	p,p’-DDE, p,p’-DDD, p,p’-DDT, o,p’-DDT, HCB, HCBD, α-HCH, β-HCH, γ-HCH, pentachlorobenzene
PCBs	Indicator PCBs: CB-28, 52, 101, *118*, 138 (+163), 153, 180
TCPM(e)	Tris(4-chlorofenyl)methane (TCPMe), tris(4-chlorofenyl)methanol (TCPM)
PAHs	Acenaftylene, acenaftene, phenantrene, fluoranthene, pyrene, benz[a]anthracene, chrysene, benzo[b+j]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, indeno[123cd]pyrene, dibenzo[ah]anthracene
PBDEs (only in 2008)	PBDE17, 28, 47, 49, 66, 71, 75, 77, 85, 99, 100, 119, 138, 153, 154, 183, 190, 203, 205, 206, 207, 208, 209