Biodiversity hotspots on the Dutch Continental Shelf

A Marine Strategy Framework Directive perspective

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Summary

An important contribution to the achievement of good environmental status (GES) within the European Marine Strategy Framework Directive (MSFD) of 2008 can be formed by spatial protection measures, as described in Article 13.4 and Annex VI of the MSFD. In this report we focus on the potential for such spatial measures. The aim of this study was to analyse and present hotspots of biodiversity for several taxonomical groups and habitats on the Dutch Continental Shelf, based on the spatial application of GES descriptor 1: 'Biological diversity is maintained', one of the 11 descriptors of GES in the MSFD.

Data selection took place through a number of internal workshops. The main selection criterion was that data should have a spatial scale of at least the Dutch Continental Shelf to reveal large scale patterns (tens of kilometres). We therefore concentrated on data series for benthos (macrobenthos and megabenthos), fish, seabirds, marine mammals and habitats.

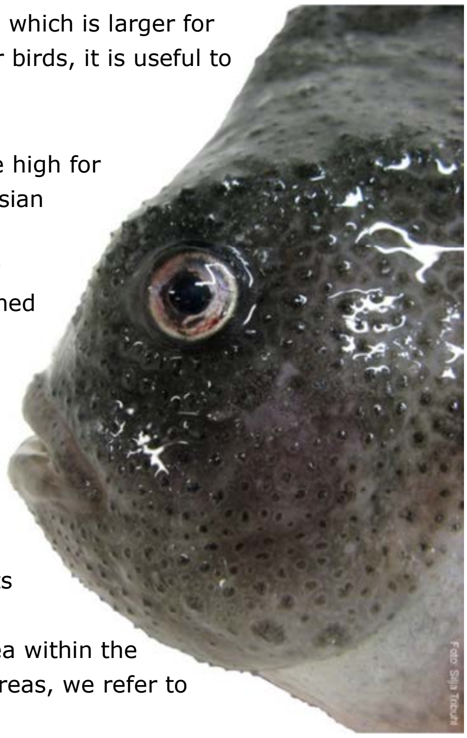
Next, we explored how the data could be used to provide biodiversity information on the three different levels (species, habitat and ecosystem) that are proposed in the 2010 Commission Decision on the criteria and methodological standards for GES-descriptor 1. Each level is divided in sublevels. For the species level information is required on species distribution (1.1), population size (1.2), and population condition (1.3). In this study, we do not show maps per species, but per taxonomical group. For the habitat level, information is asked for on habitat distribution (1.4) extent and (1.5) condition (1.6). Finally, for the ecosystem level, information on ecosystem structure is required (1.7).

Most data series contained absence/presence information per species. Usually also density information was present, and for benthos biomass information was available. For population condition, we focused on metrics that are informative on (maximum) length (for fish), maximum weight and maximum age (benthos), on trends (fish), on reproductive output (seabirds, marine mammals) and on rarity (or frequency of occurrence). The data were not only obtained from the selected datasets, but also from the literature (e.g. maximum ages). To estimate habitat distribution and extent, we constructed a map by combining abiotic characteristics (depth, grain size, absence/possible presence of summer stratification) and estimated the frequency of occurrence (or rarity) of each habitat type. For the ecosystem level, we concluded that mapping the ecosystem condition was not feasible, therefore, we did not consider this level. All in all, we defined a set of 13 metrics of biodiversity, covering the width of the Commission Decision criteria. Not all metrics were applicable to all datasets. We constructed maps per biodiversity metric and per taxonomical group.

To be able to compare and combine maps, we standardized them by rescaling the underlying values to a standard scale of 1-5 (low to high values). The aim was to combine different maps into a single map, by adding the maps and rescaling the obtained values again on a scale from 1-5. In order to be able to aggregate data at different spatial scales, we decided to use a grid of 5x5 km as the basis. We explored the usefulness of this method. When different metrics were combined in a map, by adding and rescaling, maps tended to lose information. Mapping of biodiversity hotspots on the level of individual biodiversity metrics within taxonomic groups proved to be useful. Separate maps of biodiversity metrics are therefore most informative. We therefore drew conclusions on the basis of separate maps per biodiversity metric per taxonomical group.

Spatial patterns of benthic biodiversity were more consistent than for other taxonomic groups. This is probably due to the sedentary lifestyle. For fish, spatial biodiversity patterns are less clear than for benthos, probably because fish are very mobile species. Although birds are mobile species as well, some areas have consistently higher bird values than others. In the coastal zone this is caused by the higher number of species present (coastal birds). For marine mammals, biodiversity patterns were difficult to

interpret. This is partly due to the data constraints and the low number of species. For this group, it is probably best to consider the species separately, as opposed to taxonomical aggregation for benthos, fish and birds.



Biodiversity patterns also have to be assessed at the relevant scale, which is larger for fish and marine mammals (greater North Sea) than for benthos. For birds, it is useful to determine temporal patterns.

For benthos, notably the Frisian Front and the Oyster Grounds score high for different biodiversity metrics. For birds, the coastal area and the Frisian Front stand out. For fish, no clear cluster of areas emerged as a biodiversity hotspot, although several areas have higher scores. For marine mammals the method is not suitable. For habitats, we obtained a map of frequency of occurrence of different habitat types, which shows how unique habitats are.

The aim of this report was to indicate areas that stand out in terms of biodiversity, and that may serve as a starting point for spatial protection measures within the framework of the MSFD, based on the criteria for GES descriptor 1 ‘Biological diversity is maintained’. The results of this study show that biodiversity hotspots can be identified on the DCS that can be a starting point for spatial management. For an overview of biodiversity characteristics per area within the Dutch part of the North Sea, and of the Natura 2000 status of the areas, we refer to Table 16 in the Conclusion chapter.

1 Introduction

1.1 Scope and purpose

In this report we present hotspots of biodiversity for benthos, fish, birds, marine mammals and habitats on the Dutch Continental Shelf. These hotspots are based on a spatial application of biodiversity metrics developed in this study for the GES-descriptor 1 'Biological diversity is maintained' of the Marine Strategy Framework Directive (MSFD) (EU 2008). The choice of the biodiversity metrics is based on the proposed indicators of biodiversity in the Commission Decision (EU 2010). The purpose of this study is to provide insight in possibilities for spatial protection measures in the framework of the MSFD. This report feeds information and ideas into further work for the MSFD in the Netherlands. IMARES has compiled this report for the Dutch Ministry of Economic Affairs, Agriculture and Innovation (Ministry of EL&I) and the Ministry of Infrastructure and the Environment (I&M).

1.2 Marine Strategy Framework Directive (MSFD)

The Marine Strategy Framework Directive (MSFD) came into force in 2008 (EU 2008). This directive promotes sustainable use of the European seas and conservation of marine ecosystems. To achieve this, the EU aims to apply an ecosystem based approach to the management of human activities while enabling a sustainable use of marine goods and services. Each Member State is required to develop a marine strategy for its marine waters that results in the execution of programmes of measures (deadline 2016) designed to achieve or maintain **good environmental status (GES)** by 2020.

In preparation of programmes of measures (deadline July 2015), Member States should deliver an initial assessment of the current environmental status including effects of human activities (July 2012), a determination of GES (July 2012), and series of environmental targets and associated indicators (July 2012).

An important contribution to the achievement of GES is formed by spatial protection measures, as described in Article 13.4 and Annex VI of the MSFD (see Box 1). In this report we focus on possibilities for such spatial measures, based on the spatial application of GES descriptor 1: 'Biological diversity is maintained', being one of the 11 descriptors of GES in the MSFD.

To consistently assess GES, the EU has developed criteria and methodological standards in 2010 (EU 2010). These criteria and standards are not very specific or concrete. Member States are required to elaborate on these criteria and standards and come up with workable indicators for their seas, for each of the 11 descriptors. In the Netherlands, the definition of these indicators for the Dutch government is carried out in a joint effort of Deltares and IMARES. The indicators of biodiversity developed in this project are therefore not by definition the ones that will ultimately be established and submitted to the EU in 2012. The function of this study is to provide basic information on biodiversity for the MSFD process in the Netherlands (see also article A.6 of the Commission Decision (EU 2010) in Box 3, which recommends to map ecosystem components). The development of biodiversity indicators is, at the moment of writing of this report, still under development in different countries. Therefore, we have not compared our approach to that of other countries.

Box 1. Description of spatial protection measures in article 13.4 and Annex VI of the Directive 2008/56/EC

CHAPTER III - MARINE STRATEGIES: PROGRAMMES OF MEASURES

Article 13.4. Programmes of measures established pursuant to this Article shall include spatial protection measures, contributing to coherent and representative networks of marine protected areas, adequately covering the diversity of the constituent ecosystems, such as special areas of conservation pursuant to the Habitats Directive, special protection areas pursuant to the Birds Directive, and marine protected areas as agreed by the Community or Member States concerned in the framework of international or regional agreements to which they are parties.

ANNEX VI
Programmes of measures
(referred to in Articles 13(1) and 24)
(1) Input controls: management measures that influence the amount of a human activity that is permitted.
(2) Output controls: management measures that influence the degree of perturbation of an ecosystem component that is permitted.
(3) Spatial and temporal distribution controls: management measures that influence where and when an activity is allowed to occur.
(4) Management coordination measures: tools to ensure that management is coordinated.
(5) Measures to improve the traceability, where feasible, of marine pollution.
(6) Economic incentives: management measures which make it in the economic interest of those using the marine ecosystems to act in ways which help to achieve the good environmental status objective.
(7) Mitigation and remediation tools: management tools which guide human activities to restore damaged components of marine ecosystems.
(8) Communication, stakeholder involvement and raising public awareness.

1.3 GES descriptor 1: biodiversity

For the assessment of the status of biodiversity in the Dutch North Sea (GES descriptor 1), biodiversity should be assessed at the species level, habitat level and ecosystem level (EU 2010). For the species level, we have to take into account the species distribution, the population size and the population condition. However, in this study, we decided to map aggregated information per taxonomical group and not per species (see 2.2.1). For the habitat level, we have to consider the habitat distribution, the extent and condition. Finally, for the ecosystem level, we need to evaluate the ecosystem structure. The full text on these criteria for good environmental status of biodiversity is provided in Box 2.

1.4 Structure of this report

In this report we first describe which data series were available on the scale of, at least, the Dutch Continental Shelf, for benthos, fish, birds, marine mammals and habitats, and we explore which biodiversity information could be obtained from these data, based on the GES descriptor 1 criteria (Chapter 2). Then we describe how such information can be mapped (Chapter 3). In Chapter 4 we explore each dataset in more detail, describe how biodiversity metric values are calculated and mapped, and show the maps. These results are discussed in Chapter 5 and we draw conclusions in Chapter 6. In the annexes we provide background information on the biodiversity metrics and background information for the different species groups. A scheme of the process is provided in Figure 1.

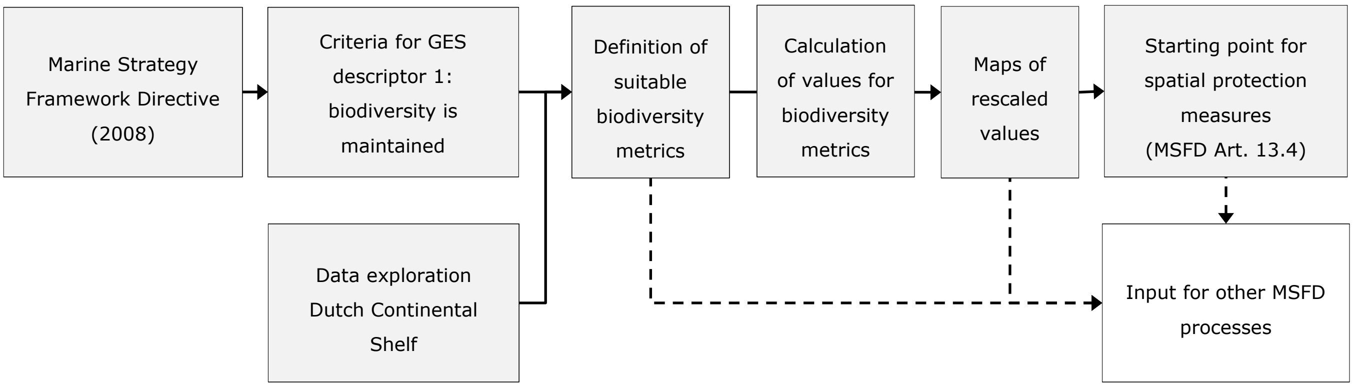


Figure 1. Set-up of this study.

1.5 Assignment

The Dutch Ministries of Economic Affairs, Agriculture and Innovation (Ministry of EL&I) and of Infrastructure and the Environment (I&M) have requested IMARES to make a spatial inventory of areas that could qualify for spatial protection measures under the MSFD, using the criteria and methodological standards for GES descriptor 1 'biological diversity is maintained' (EU 2010).

This research project is part of a bigger project aimed at identifying areas within the Dutch part of the North Sea that would qualify for spatial protection in the context of Natura2000 and/or the MSFD. This project has been announced in the National Water Plan (Min V&W et al. 2009) and the Policy Document on the North Sea (Dutch Central Government 2009).

Box 2. Criteria for good environmental status relevant to the descriptors of Annex I to Directive 2008/56/EC (EU 2010). Footnotes are left out of the text.

Descriptor 1*: Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climate conditions.*

Assessment is required at several ecological levels: ecosystems, habitats (including their associated communities, in the sense of biotopes) and species, which are reflected in the structure of this section, taking into account point 2 of Part A. For certain aspects of this descriptor, additional scientific and technical support is required. To address the broad scope of the descriptor, it is necessary, having regard to Annex III to Directive 2008/56/EC, to prioritise among biodiversity features at the level of species, habitats and ecosystems. This enables the identification of those biodiversity features and those areas where impacts and threats arise and also supports the identification of appropriate metrics among the selected criteria, adequate to the areas and the features concerned. The obligation of regional cooperation contained in Articles 5 and 6 of Directive 2008/56/EC is directly relevant to the process of selection of biodiversity features within regions, sub-regions and subdivisions, including for the establishment, where appropriate, of reference conditions pursuant to Annex IV to Directive 2008/56/EC. Modelling using a geographic information system platform may provide a useful basis for mapping a range of biodiversity features and human activities and their pressures, provided that any errors involved are properly assessed and described when applying the results. This type of data is a prerequisite for ecosystem-based management of human activities and for developing related spatial tools.

Species level

For each region, sub-region or subdivision, taking into account the different species and communities (e.g. for phytoplankton and zooplankton) contained in the indicative list in Table 1 of Annex III to Directive 2008/56/EC, it is necessary to draw up a set of relevant species and functional groups, having regard to point 2 of Part A. The three criteria for the assessment of any species are species distribution, population size and population condition. As to the later, there are cases where it also entails an understanding of population health and inter- and intra-specific relationships. It is also necessary to assess separately subspecies and populations where the initial assessment, or new information available, identifies impacts and potential threats to the status of some of them. The assessment of species also requires an integrated understanding of the distribution, extent and condition of their habitats, coherent with the requirements laid down in Directive 92/43/EEC and Directive 2009/147/EC, to make sure that there is a sufficiently large habitat to maintain its population, taking into consideration any threat of deterioration or loss of such habitats. In relation to biodiversity at the level of species, the three criteria for assessing progress towards good environmental status, as well as the metrics related respectively to them, are the following:

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).

Habitat level

For the purpose of Directive 2008/56/EC, the term habitat addresses both the abiotic characteristics and the associated biological community, treating both elements together in the sense of the term biotope. A set of habitat types needs to be drawn up for each region, sub-region or subdivision, taking into account the different habitats contained in the indicative list in Table 1 of Annex III and having regard to the instruments mentioned in point 2 of Part A. Such instruments also refer to a number of habitat complexes (which means assessing, where appropriate, the composition, extent and relative proportions of habitats within such complexes) and to functional habitats (such as spawning, breeding and feeding areas and migration routes). Additional efforts for a coherent classification of marine habitats, supported by adequate mapping, are essential for assessment at habitat level, taking also into account variations along the gradient of distance from the coast and depth (e.g. coastal, shelf and deep sea). The three criteria for the assessment of habitats are their distribution, extent and condition (for the latter, in particular the condition of typical species and communities), accompanied with the metrics related respectively to them. The assessment of habitat condition requires an integrated understanding of the status of associated communities and species, coherent with the requirements laid down in Directive 92/43/EEC (9) and Directive 2009/147/EC, including where appropriate an assessment of their functional traits.

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).

Ecosystem level

1.7. Ecosystem structure
— Composition and relative proportions of ecosystem components (habitats and species) (1.7.1).
In addition, the interactions between the structural components of the ecosystem are fundamental for assessing ecosystem processes and functions for the purpose of the overall determination of good environmental status, having regard, inter alia, to Articles 1, 3(5) and 9(1) of Directive 2008/56/EC. Other functional aspects addressed through other descriptors of good environmental status (such as descriptors 4 and 6), as well connectivity and resilience conditions, are also important for addressing ecosystem processes and functions.

Box 3. Article A.6 (EU 2010)

A combined assessment of the scale, distribution and intensity of the pressures and the extent, vulnerability and resilience of the different ecosystem components including where possible their mapping, allows the identification of areas where marine ecosystems have or may have been adversely affected. It is also a useful basis to assess the scale of the actual or potential impacts marine ecosystems. This approach, which takes into account risk-based considerations, also supports the selection of the most appropriate indicators related to the criteria for assessment of progress towards good environmental status. It also facilitates the development of specific tools that can support an ecosystem-based approach to the management of human activities required to achieve good environmental status through the identification of the sources of pressures and impacts, including their cumulative and synergetic effects. Such tools include spatial protection measures and measures in the list in Annex VI to Directive 2008/56/EC, notably spatial and temporal distribution controls, such as maritime spatial planning.

Glossary

Table 1. Glossary

Term	Explanation
BTS	Beam Trawl Survey
CBD	Convention on Biological Diversity
CEFAS	Centre for Environment, Fisheries & Aquaculture Science (in the UK)
DFS	Demersal Fish Survey
DCS	Dutch Continental Shelf (=NCP)
EEZ	Exclusive Economic Zone (see DCS)
EL&I	Dutch Ministry of Economic Affairs, Agriculture and Innovation
ESAS	European Seabirds At Sea database
EU metric	Metrics defined by the EU in the MSFD
EUNIS	European Nature Information System
GES	Good environmental status
GIS	Geographical Information System
Hamon grab	Havenmond grab: grab for benthic sampling
Hotspot	Area where biodiversity metric(or a combination of several metrics) has the highest value
IBTS	International Bottom Trawl Survey
ICES	International Council for the Exploration of the Sea
IMARES	Instute for Marine Resources and Ecosystem Studies, part of Wageningen University and Research centre
Metric	Metric of biodiversity
MIK	Methot Isaacs Kidd-net, named after its developers and used to sample herring larvae
MSFD	Marine Strategy Framework Directive (Kaderrichtlijn Mariene Strategie)
MWTL	Monitoring Waterkundige Toestand des Lands
Natura 2000	European network of protected areas under the Habitat Directive (SACs) and/or Bird Directive (SPAs)
NIOZ	Royal Netherlands Institute for Sea Research
NL	Netherlands
RWS	Rijkswaterstaat (implementing body of Dutch Ministry of Infrastructure and Environment
SAC	Special Area of Conservation (Natura 2000 Habitat Directive area)
SNS	Sole Net Survey
SPA	Spatial Area of Protection (Natura 2000 Bird Directive area)

2 Exploration of data for compatibility with GES descriptor 1

2.1 Data availability

Data selection took place through a number of internal workshops with researchers and data managers. The main selection criterion was that data should have a spatial scale of at least the Dutch Continental Shelf (DCS) to reveal large scale patterns (tens of kilometres). We thus concentrated on benthos, fish, birds, marine mammals, being faunal groups for which we have data available covering the DCS (Table 2). We did not select data series covering smaller parts of the DCS, since such small scale, higher resolution data cannot easily be compared to large scale, lower resolution data. Hence, dataseries such as those on coastal shellfish stocks (Goudswaard et al. 2010), marine mammal beach strandings (Camphuysen et al. 2008) and coastal seabird were not taken into account, just as dataseries resulting from local environmental impact studies of sand nourishment activities (e.g., Bos et al. 2009, Wijsman et al. 2009, Craeymeersch & Escaravage 2010), wind farm construction (Ter Hofstede 2008) or compensation measures for harbour enlargement (Tulp et al. 2006). We did, however, add a small scale dataset of benthos of the Cleaver Bank (Van Moorsel 2003) to the MWTL and Triple-D benthos data, to take into account the specific hard substrate benthos of the Cleaver Bank and its unique contribution to the DCS biodiversity, because this habitat type was otherwise not represented. For fish, also some smaller scale datasets were included, because sampling methods are standardized and data are comparable and readily available.

Although other groups such as phytoplankton, zooplankton (including jellyfish), bacteria or even viruses, also contribute to biodiversity we cannot present spatial data, since these groups are not regularly monitored on a DCS scale.

Table 2. Summary of datasets used in this study.

Data		Survey
Benthos		
	Macrobenthos (BIOMON)	This annual program of the Dutch government known as BIOMON or MWTL started in 1991 and includes 100 stations that are sampled with a boxcore of 0.074 m2. Fauna is sieved over 1 mm.
	Megabenthos (Triple-D)	The Royal NIOZ has sampled megabenthos (>7 mm) by means of a Triple-D-dredge between 2008-2010. The survey was set up to get data on long living molluscs, but samples include all taxa present, including some ‘benthic’ fish species. The survey covered the whole Dutch EEZ with over 360 samples (100 m x 20 cm x 20 cm) and gaps will be filled in the coming years.
	Macrobenthos & megabenthos (Cleaver Bank)	The Cleaver bank has been sampled in the 1990s to explore the area for sand extraction possibilities. Samples have been taken with a Hamon grab, which is more or less comparable to a boxcore
	Macrobenthos & megabenthos (BTS)	In annual fishery surveys (see below), the benthos bycatch is usually described as well. Spatial sampling units are ICES rectangles.
Demersal fish		Fish data are obtained from the annual fish surveys in the North Sea that designed for fish stock assessments. Besides the target species, also non-commercial fish and benthos are recorded. Since nets are selective, not all species are well presented. Surveys used in this study are BTS (since 1985), IBTS (since 1977) and DFS (since 1995). For this study, data of the different surveys are combined.
Seabirds		Bird data were obtained from the ESAS database (ship based counts) and from aerial counts (bimonthly, by RWS). Years analyzed span the period 1991-2008.
Marine Mammals		Cetacean data were collected during the bird surveys (see above). Seals were counted during dedicated surveys in the Wadden Sea. For seals, also satellite telemetry data are available.
Habitats		We constructed maps of habitat occurrence by combining GIS data of abiotic characteristics (depth, grain size, stratification).

2.2 Selection of biodiversity metrics

After the selection of data series, we assessed how the data could be used to provide biodiversity information on species, habitat and ecosystem levels as called for in the criteria and methodological standards for GES-descriptor 1 (EU 2010) (see Box 2). This was done in a number of workshops with specialists. We assessed if the spatial scales were comparable between datasets and how gaps in datasets could be filled in by e.g. combining datasets.

Not all types of biodiversity information is available or relevant for the different species groups that we concentrated on. Numbers of individuals are usually available in all datasets, while length or weight data are only available for fish and benthos, respectively. As a result, we came up with only partially overlapping sets of biodiversity metrics in the different workshops. Some of the biodiversity metrics could be calculated for all datasets, while others were only relevant for a few species groups.

Although we aimed to use standardized calculation methods for each biodiversity metric, this was not always possible. The metric 'rarity', for example, is calculated differently between species groups. For benthos, a rare species is defined as a species with a low frequency of occurrence in the dataset, while for fish both numeric density and frequency of occurrence are taken into account to calculate the metric. We decided to use these different methods because they have been described and used before in other publications. The name 'rarity' for this biodiversity metric should therefore be considered as a generic term.

In this study we do not attempt to fully describe the ecological relevance of the proposed biodiversity metrics. Instead, we considered the MSFD and the associated criteria and methodological standards for GES-descriptor 1 as a given starting point. From there, we selected data and mapped the information that we thought would best represent what was asked for. In Chapter 4, some ecological relevance is provided.

Below we describe this exploration per dataset for benthos, fish, seabird, marine mammals and habitats. In Appendix A we describe the final set of 13 metrics of biodiversity and we explain for each species group which calculations were used. In Table 3 an overview is given of the metrics.

2.2.1 Species level

For the species level three criteria for the GES are defined: 1.1 Species distribution, 1.2 Population size and 1.3 population condition (see Box 2). We decided not to show species information for a selected number of indicator species, because that would result in a set of species distribution maps. Instead, we decided to map aggregated information per dataset for benthos, fish, birds and marine mammals.

Benthos

For benthos, 4 datasets were used (Table 2), which are described in more detail in section 4.1. We discussed these dataseries in an internal workshop with benthos experts and explored the compatibility with the criteria for GES descriptor 1. We estimated that for criterion 1.1 on species distribution we were able to provide information on the absence/presence per species, which results in a distribution map per species. For criterion 1.2 on population size, we were able to calculate biomass and density for three (BIOMON, Cleaver Bank, Triple-D) of the four datasets (biomass of benthos of the BTS (beamtrawl) is not determined).

A more difficult criterion was number 1.3 on population condition, which calls for demographic characteristics such as body size or age class structure, sex ratio, fecundity rates and/or survival/ mortality rates (1.3.1) and for population genetic structure (1.3.2) (Box 2). For benthos we did not have information on sex ratio, fecundity rates and survival/mortality rates, but there are some data on body size and age class structure. In the literature, however, it is possible to find part of the missing information. Following the concept used in the Genus Trait Handbook (Marine Ecological Surveys Ltd 2008) we wanted to express population condition as the resilience (or vulnerability) of a species, which indicates how well a species can recover after an impact, based on its reproductive capacity, dispersal, maximum age and age at maturity. Since the four datasets contain hundreds of species and since it was not possible to collect literature information on all of these species for the four traits within the timeframe of this project, we decided that we would only focus on maximum ages of benthos of one of the datasets (BIOMON). We think that maximum age could be a good proxy of resilience, since usually short living organisms are species that can recover quicker than long lived species. Another reason to focus on maximum ages is that they are well documented for a lot of species and that areas containing species with high potential maximum ages would probably have a higher potential in terms of spatial protection measures than areas where only short living species are found.

Finally, we added two very commonly used biodiversity indicators to our list: species richness and species evenness. Although the Commission Decision (EU 2010) does not mention these indicators of biodiversity, we decided to use them anyway, because they are the best most commonly used biodiversity measures. For each of the datasets, we also calculated the frequency of occurrence of a species within the total dataset, which we called the rarity of a species. In the maps, we show where the relatively rare species occur on the DCS. The rarity (or frequency of occurrence) is also a metric that is not asked for, but it provides some information on the composition of the benthic community that is not provide by other maps. An overview of the indicators (or metrics) for benthos biodiversity is given in Table 4.

Fish

For fish, a large standardized dataset is available, consisting of data of different surveys primarily collected for the stock assessment of a limited number of commercial fish stocks and life stages of these fish stocks. The datasets are discussed in detail in section 4.2 and an overview is given in Table 2. All species that are encountered in the nets are measured and counted however, so there is also information available on non-commercial fish species. For all fish species information on distribution is available in terms of presence/absence (criterion 1.1: species distribution), on numbers (criterion 1.2: population size), and on lengths. Also a maximum size is known per species (Lmax).

Criterion 1.3 on population condition calls for demographic characteristics such as body size or age class structure, sex ratio, fecundity rates and/or survival/mortality rates (1.3.1) and for information on the population genetic structure (1.3.2) (Box 2). In the fishery surveys, the lengths of all fish are measured. Therefore we can use information on length distribution, on length distribution in relation to the maximum length (Lmax) or on percentages of fish larger than a certain size as an indicator for population condition. For only a very limited number of commercial species, more detailed information is collected, such the maturity stage, the age (by collecting and reading otoliths) and sex ratios. We did not take this extra information into account, since it is not available for the whole assemblage of species we are interested in. We also determined population trends over time for a relatively large number of species. Although trends are not explicitly mentioned in the Commission Decision (EU 2010), we think that a long term negative or positive trends is indeed an indicator for population condition and we therefore included this as an indicator (or metric). Finally, only for a few species the genetic structure is known, but not for all. Therefore, we have not used any genetic information in this study. Finally, we also used species richness and species evenness as indicators for fish, and rarity. This was done for the same reasons as described in the benthos section above. An overview of the indicators (or metrics) for fish biodiversity is given in Table 3.

Seabirds

Compared to benthos and fish, the number of seabird species on the DCS is very limited. Therefore, species specific information is available for all species, in contrast to many benthic species for which almost nothing is known. Seabirds are counted every two months by a standardized aerial survey and during ship-based projects using standardized ESAS protocols. The two datasets (Table 2) are different in their set-up and therefore it takes a lot of effort to combine them. For that reason, it was not possible to make separate maps for each biodiversity metric that is described here. Instead, we expressed bird biodiversity in terms of Total Bird Values, following Leopold et al. (in prep.). More details can be found in section 4.3. Since seabirds are very mobile species that may use parts of the DCS only in certain seasons, and since temporal data are available, we decided to present the information per two month period. The seabird data allow us to calculate species distribution (criterion 1.1) and population size (criterion 1.2), expressed as species abundance (criterion 1.2). To estimate population condition (criterion 1.3), we use the method of Leopold et al. (in prep.). Based on literature research, they provided information on reproduction rate per species and combined that with information on the importance of the DCS for the species and some other factors into the so-called Specific Bird Value (SBV). An overview of the indicators (or metrics) for seabird biodiversity is given in Table 4.

Marine mammals

For marine mammals it is difficult to construct distribution maps that cover the whole of the DCS. Marine mammals are studied in several programmes on several scales and so far the data have not been fully combined. For the harbour porpoise, aerial surveys by Rijkswaterstaat (RWS) show different spatial patterns for different months. The densities are the highest between February and June (Arts 2008, 2011). A more detailed study covering half of the DCS (Scheidat & Verdaat 2009) shows different patterns with densities considerably higher than reported by RWS and in different months. When all knowledge on the spatial distribution of porpoises is put together, there is no evidence of areas with persistent hotspots (see Camphuysen & Siemersma 2011, in prep.). Keeping this in mind, we should assume an equal distribution of the harbour porpoise over the DCS, which is in harmony with the Harbour Porpoise Conservation Plan (Camphuysen & Siemersma 2011, in prep.). For seals, the estimate of the population distribution is based on satellite telemetry data of a limited number of individuals. Seals are easily overseen during ship-based and aerial surveys, which makes that only satellite tracks are reliable (Brasseur et al. 2008). Satellite tracking of seals and habitat modelling shows that they can swim large distances and that grey seals regularly migrate to Scottish waters. The minke whale is occasionally seen, but only in de deepest parts at the edge of the DCS (De Boer 2010), while the white-beaked dolphin is scarce at the western part of the DCS. All in all, since we needed combined distribution maps for all marine mammals species together, we decided to express species distribution (criterion 1.1) very roughly in terms of densities, ranging from 0 (vagrant), to 4 (common).

For criterion 1.2, population size, we used the population size estimates for the DCS of the above mentioned surveys and from the literature. We also obtained literature estimates of the biogeographical population size, which allowed us to estimate the relative importance of the DCS for the species and estimate the rarity of the species in terms of the total size of the biogeographical population.

For criterion 1.3, population condition, which calls for demographic characteristics such as body size or age class structure, sex ratio, fecundity rates and/or survival/ mortality rates (1.3.1) and for information on the population genetic structure (1.3.2), we wanted to use a measure that would be in line with those for the other faunal groups. We therefore use 'resilience' in accordance with the benthos and the seabirds. Resilience is a measure for how fast a species can recover from impact and is expressed as the number of offspring that a marine mammal can produce during its lifetime, based on literature data on the average number of calves per animal, the interval time, average age at first breeding and generation length. More details can be found in section 4.4. An overview of the indicators (or metrics) for marine mammal biodiversity is given in Table 4.

2.2.2 Habitat level

For the habitat level three criteria are defined: 1.4 Habitat distribution, 1.5 Habitat extent and 1.6 Habitat condition (see Box 2). To estimate habitat distribution and extent (criteria 1.4 and 1.5), we considered the different habitat classifications of the DCS. The Natura 2000 habitat types on the DCS (H1110 sandbanks and H1170 reefs) are very general and do not cover the whole of the Dutch seafloor, so we did not use them. The EUNIS habitat classification of De Jong (1999), as depicted in the Ecological Atlas of the North Sea by Lindeboom et al. (2008) only shows sediment types, and not depth or other abiotic characteristics. We therefore decided to construct a map by dividing the seafloor in units that are combinations of abiotic characteristics (depth, grain size, absence/possible presence of summer stratification), more or less following the EUNIS habitat classification level 3 (Davies et al. 2004, also see http://eunis.eea.europa.eu/habitats-code-browser.jsp?habCode=A%20-%20factsheet).

Criterion 1.6 on habitat condition is not easily addressed. The condition of the typical species and communities (1.6.1), is not known for the whole of the DCS, the scale at which we perform analyses in this study. Typical species and a favourable conservation status have been defined for the Natura 2000 areas (LNV 2008, Jak et al. 2009, Jak et al. 2010) (see also www.noordzeenatura2000.nl), but these were not taken into account in this study, since they apply only to the Natura 2000 areas and not to the whole of the DCS.
By using the habitat map described above, it was possible to calculate the relative occurrence of habitat types (criterion 1.6.2). Apart from the abiotic information on the habitat map, we have not explicitly mapped the physical, hydrological and chemical conditions.

2.2.3 Ecosystem level

For the ecosystem level, there is one criterion: 1.7 Ecosystem structure. We have considered different ways to map data on the ecosystem level, for example by plotting key habitats such as feeding, nursery and reproduction areas, or by mapping proportions between predators and preys or by mapping different feeding types, or the trophic level. Finally, we concluded that this was too difficult, given the knowledge on the ecosystem, and the timeframe of the project. Therefore, we did not consider this level.

Table 3. Short description of biodiversity metrics selected in this study. Not all metrics are used for each of the faunal groups (see Table 4).

Metric	Description
1.distribution	Describes the spatial distribution of a species
2.density	Describes total density
3.biomass	Describes total biomass
4.resilience (vulnerability)	The resilience metric indicates how fast a species can recover after impact. It is based on the reproductive capacity of a species. This metric can be used for benthos and birds.
5. dependence on marine environment (birds)	The marine species metric indicates to what extend a bird species depends on the marine environment.
6.breeding in NL (birds)	The breeding in NL metric indicates whether a bird species breeds in the Netherlands and if so, whether significant numbers of the breeding population depend on the Dutch North Sea for the provisioning of their chicks.
7.importance DCS (Dutch EEZ) for species	This metric indicates how important the Dutch Continental Shelf is to a species, compared to the biogeographical population. This metric is probably only applicable for birds and perhaps for mammals. It is expressed as the percentage of the population that occurs on the Dutch EEZ compared to the world population size.
8.trend	This metric shows whether a (fish) population is decreasing, stable or increasing. Mapping all species together should reveal areas where ‘threatened’ species occur.
9.rarity	Rarity is expressed as the relative abundance of a species or habitat compared to the other species or habitats.
10.large species (L-max)	This metric describes the occurrence of large species
11.large individuals within species	This metric describes the occurrence of large individuals (Body size within a species).
12.species richness	Species richness is expressed as the total number of species, optionally calculated separately per group (fish, benthos, birds, marine mammals).
13.evenness	The total number of species (species richness) metric only takes the presence and absence of species into account, whereas species evenness is about the evenness of the community.

Table 4. Overview of the spatially applied biodiversity metrics that were selected in this study (horizontal) and the criteria for GES descriptor 1 Biodiversity (vertical). In red is indicated which biodiversity information was available for which taxon. In blue is indicated the correspondence between the criteria of the Commission Decision (EU 2010) (see Box 2) and the biodiversity metrics defined in this study (see Appendix A).

				group	1.distribution	2.density	3.biomass	4.resilience (vulnerability)	5.marine species? (birds)	6.breeding in NL? (birds)	7.importance DCS for species	8.trend	9.rarity	10.large species (L-max)	11.large individuals within species	12.species richness	13.evenness
				benthos	x	x	x	x	*	*	NA	NA	x	x	NA	x	x
				birds	x	x	*	x	x	x	x	NA	x	*	*	x	NA
				fish	x	NA	NA	NA	*	*	NA	x	x	x	x	x	x
				mammals	x	x	*	x	*	*	x	NA	x	*	*	x	*
				habitat	x	*	*	NA	*	*	*	*	x	*	*	*	*
	SPECIES LEVEL																
1.1	Species distribution	1.1.1	Distributional range		x								x	x			
		1.1.2	Distributional pattern		x								x	x			
		1.1.3	Area covered by the species		x												
1.2	Population size	1.2.1	Abundance/biomass			x	x										
1.3	Population condition	1.3.1	Demographic characteristics					x	x	x	x	x	x	x	x		
		1.3.2	Population genetic structure, where appropriate														
	HABITAT LEVEL																
1.4	Habitat distribution	1.4.1	Distributional range										x				
		1.4.2	Distributional pattern		x								x				
1.5	Habitat extent	1.5.1	Habitat area		x												
		1.5.2	Habitat volume		x												
1.6	Habitat condition	1.6.1	Condition typical species/communities														
		1.6.2	Relative abundance and/or biomass, as appropriate		x						x			x	x	x	x
		1.6.3	Physical, hydrological and chemical conditions		x												
	ECOSYSTEM LEVEL																
1.7	Ecosystem structure	1.7.1	Composition & relative proportions of ecosystem components (habitats and species)														

NA = not available
* = not relevant

3 Mapping

In this chapter we shortly explain the general procedures for the production of maps in this study.

3.1 Scaling

As described in the previous chapter, we defined a set of biodiversity metrics for each taxonomical group (see Table 4 and Appendix A). To be able to compare and combine the different maps, we plotted them on a relative scale. Here we describe the general process. First, we first calculated values per sampling point (benthos) or per spatial unit (1/9 ICES rectangle for fish and marine mammals or 5x5 km cells for birds). Next, we rescaled the values on a scale of 1-5 to obtain 5 classes, from low values to high values. The result is a set of maps, one for each biodiversity metric per dataset, which all present data on a standardized scale of 1-5. Detailed information on time-scales and spatial resolution can be found in Chapter 4 and in Appendix A.

3.2 Classes

The choice for 5 classes is arbitrary but useful to keep the maps simple and make them readable. Using 5 classes makes that about 20% of the area on each map, or 20% of the data points, is considered to fall in the highest class, forming the 'hotspot'. The first class therefore corresponds to the 20th percentile, the second class to the 40th percentile, and so on. In the case of species richness, this means that the 20% of the stations with the highest species numbers are given 5 points, and the 20% of the stations with the lowest species numbers were given 1 point. These values were plotted on a map. For benthic data, the data were then interpolated between points to cover the whole of the DCS. This procedure is explained below. The result of this method is that the 'hotspot' area is the area with the 20% highest values.

In some cases, when more sampling points are taken in a specific area than outside that area, this may lead to more concentrated hotspots than otherwise would have been obtained: this is notably the case for the Triple-D data.

Another way of mapping would be to divide data by equal breaks, in which case the data range is divided in equal classes. For example, if species richness varies between 10 and 60 species per sampling point, we would make classes containing 10 species each (10-19, 20-29, etc.). The result of that choice would be that in the case of outliers (very high or very low values) such values would form the only value in their class and hence the hotspot on the map. In general, maps obtained with a lot of data points in a few classes and only a few in the highest and lowest class. The advantage is that real high values show up better. In general, there is no good or bad way, it just has to be consistently done.

3.3 Combining maps

Next, we wanted to combine different maps of different biodiversity metrics, within a dataset, into a single map, to see if certain areas would score high values for several biodiversity metrics. To combine different maps into a single map, we added the maps and rescaled the obtained values again on a scale from 1-5. In order to be able to aggrate data at different spatial scales, we decided to use a grid of 5x5 km as the basis, which is the resolution of the birds map (see section 3.5).

To combine different maps into a single map, one could use weighing factors. We chose to give each map of a single biodiversity metric the same weight as the maps of the other metrics, since they represent different aspects of biodiversity that do not have a certain logical hierarchy. However, not weighting the different metrics implies that we assume that all metrics have the same importance (see discussions in

ICES 2011).We therefore advice to keep in mind the separate maps at all times. Moreover, the more information is combined in this way, the more information tends to get lost. We present the overview of hotspots therefore in the form of a table with characteristics per area. In Figure 2 we have summarised the general procedure.

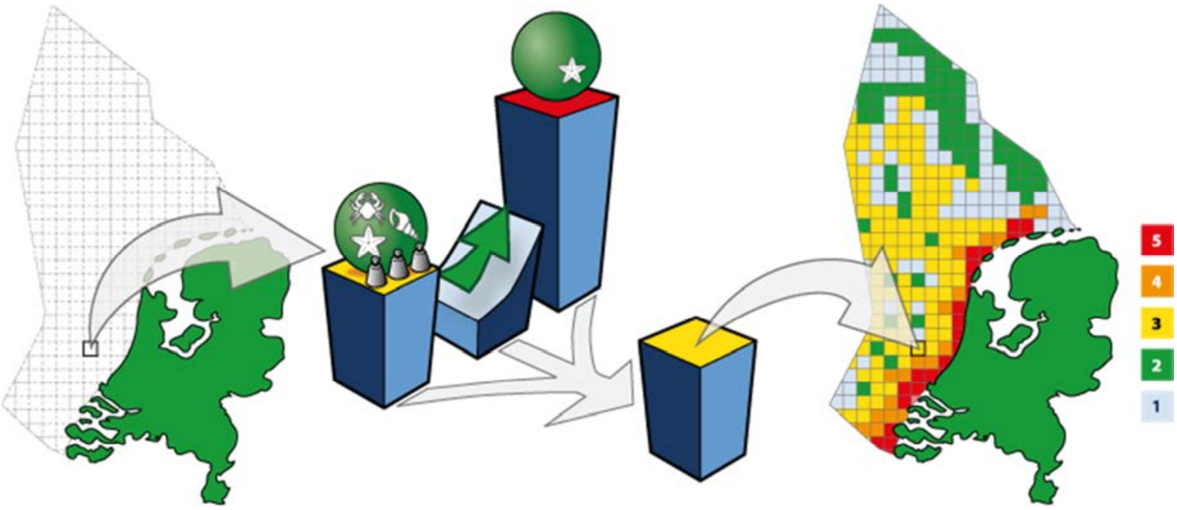


Figure 2. Schematic representation of combining different values for several different biodiversity metrics into a single value.

3.4 Interpolation (kriging and cokriging)

Kriging is a method to spatially interpolate between values. Kriging was used for the benthos maps (BIOMON, Triple-D in combination with Cleaver Bank). The appearance of the map and the value of the interpolated cells on the map can be varied by a number of factors. To interpolate, neighbouring points are taken into account. To obtain clear patterns, we have used 4 neighbouring points, or less if there were not 4 points available. Increasing the number of neighbouring points would yields more averaged maps, with less clear patterns. Extending the interpolation distance (lagsize) determines to what distance gaps in the spatial coverage are filled in. Changing the interpolation from a circular shape (same interpolation in all directions, used in this report) into an oval shape (larger interpolation distance in a certain direction) would change the patterns in a map.

The benthos maps were cokriged with the EUNIS habitat type map of De Jong (1999) (Figure 3), following the method used in the Ecological Atlas of the North Sea by Lindeboom et al. (2008). Cokriging with this habitat map results in restrictions for interpolation between habitat types, and no restrictions within a habitat type. This means that the interpolation is partly steered by the boundaries of the habitat type, which is done to obtain more realistic distribution patterns, since benthic assemblages are more similar within a sediment type than between sediment types, at least on a local scale. To prevent misinterpretation of the kriged maps, we always show the (scaled) data points in a separate map. The kriged maps show a continuous color range, to make it look smooth. However, for further calculation, the interpolated values are divided in 5 classes on a 5x5 km grid, similar to what is done for the other maps. We did not use the habitat map (Figure 35) made within this project for cokriging purposes, because it is not only based on sediment characteristics, but also on 10-m depth classes, which may not correlate to benthic distribution patterns.

The range of kriging on the maps is determined by the most northern, western, eastern and southern sampling points. Therefore white parts on the kriged maps are visible, for example in the Northern part of the Dogger Bank.

3.5 Scale of maps

We mapped all data on the scale of the DCS, although for some datasets we have also information on the scale of the larger North Sea. We chose to plot the data on the scale of the DCS because the GES initially has to be assessed on a national level, and only after that on a regional level (greater North Sea). Biologically, this scale is however not always appropriate.

3.6 Temporal coverage of maps

The maps presented in the report always cover a period of several years, which usually means that year-to-year variation is averaged. An overview of the used dataseries is given in Table 2. For analysis of year-to-year variation and trends, we refer to other reports (benthos: Craeymeersch et al. (2008); fish: (Heessen & Daan 1996, Daan 2006a, Tulp et al. 2008, Meesters et al. 2009); Birds and marine mammals: e.g. Arts et al. (2011) Camphuysen (2004))

3.7 Resolution of maps

We converted all maps and cokriged maps to the spatial unit used for the bird maps: a 5x5 km grid. The conversion from 1/9 ICES rectangles to 5x5 km blocks may look a bit unfamiliar (Figure 4), but was the only way to aggregate information.

3.8 Accuracy of maps

The maps in this report are the result of a set of choices, based on the available data, the spatial and temporal data coverage, the set of criteria defined for GES-descriptor 1 (EU 2010), the set of biodiversity metrics that were derived from these criteria, the choices made to calculate these metrics, and the available time. These choices are explained in Chapter 2 and are all logical and not random. These choices are all driven by the possibilities of the data, given the criteria and given the budget of the project. A frequently asked question within this project was: are these maps the best ones we can get or do we miss important areas by the choices we have made? The answer is that although some variation in maps may occur when some choices are made differently, this will not affect conclusions on the level of larger areas (i.e. on the scale of tens of kms). The spatial level at which conclusions are drawn (see Chapter 6) is much larger than the resolution of our maps (5x5 km or 1/9 ICES rectangle). Adding or leaving out certain maps will also not change the main conclusions, since for example for benthos, different maps of different dataseries point to similar patterns.

The perceived accuracy of the maps is another issue and can be determined by the choice of colours, of symbol sizes, but also by the choice of kriging parameters. In general, we have tried to make maps as neutral as possible, by avoiding colours that have certain meanings (blue for depth, red/ green for good/bad, etc.), by using symbol sizes that do not overlap to much on a map, but are still readable, and by using ‘moderate’ kriging parameters (see section 3.4). Also the number of classes and the way classes are made (see section 3.2) influence the maps. Of course, maps may be more suggestive than we intended them to be, but we have tried to avoid that.

In general, the basic maps show the clearest information, and are the easiest to understand, while any aggregated map will reveal less clear information. We therefore advice to not just look at the final table, or at aggregated maps, but also at the individual maps.

3.9 Additional maps

For each of the biodiversity metrics we have produced maps. The maps that are used for further calculations are tagged with coloured dots (see Table 5). In some cases we show additional maps that contribute to the discussion, but that are not used for further calculations. These maps are not tagged with a coloured dot.

3.10 Choices per data set

Benthos
For all benthos maps, the scaled data points are shown in the left panel and the interpolated maps (see section 3.4) are shown in the right panel. For some of the macrobenthos maps, the upper maps (extra maps) show the value in individual numbers, while the lower maps (used for further calculation) show the map for species numbers.

To be sure that both soft sediment and hard substrate habitattypes would be well represented we added a dataseries on the Cleaver Bank (stony area) to the BIOMON and Triple-D datasets (soft sediment). The result is that biodiversity is better covered than in earlier work.

In the Triple-D data, data density in the south is lower than elsewhere, but these gaps will be filled in the coming years. Comparable IMARES data are available for that region, and could have been used, but they do not cover the rest of the DCS and will probably not alter any large scale pattern. The whole Triple-D survey is an one-off event, that is the survey is not conducted annually or multi annually. Some temporal variation may therefore influence the maps, but in general, the combined data provide consistent information. For now, we have interpolated between the available datapoints (see section 3.4). Future sampling of these areas may reveal patterns that could be different than the patterns presented here.

For the benthos maps we have made ‘rarity’ maps, which show the distribution of species with a frequency of occurence within the dataset below a certain threshold level, ranging from 5 to 15%. The choice for the threshold level or percentage is arbitrary, but the maps would probably not change much if the percentage is slightly lowered or highered, because changing this level means that a certain extra number of species will be included or left out, while the others are still in the selection and thus largely determine the pattern. In general, the rarity maps resemble the species richness maps and increasing or decreasing the threshold level will therefore not change the pattern. The rare benthic species are therefore in the areas with high species richness. Although testing these relationships is beyond the scope of this study, this observation supports the idea that the exact threshold level is not crucial for the patterns on the maps.

For BTS benthos, we were faced with the difficulty that a large number of hauls is needed to reach the ‘plateau’ of the sampling effort versus species richness curve. For fish, a number of 20 hauls (see Figure 21) is suggested to get a representative estimate of the total number of species, for benthos this number is estimated to be much larger. Hence, for BTS benthos, we chose to present the average number of species per haul, which is comparable to the way the Triple-D data are treated.

For BTS benthos we decided to split the data according to vessel (RV Isis, RV Tridens II) and keep the analysis separate. The reason for this is the different catchability which can be expected between the two vessels and also the fact that sorting/identifying the benthos on the Isis cannot be carried out to the same level/certainty as on the RV Tridens II. Only the Isis benthos was used to construct a final maps, since the spatial coverage of the RV Tridens II was considered too small.

Fish

Fish maps have a basic resolution of 1/9 ICES rectangle. These rectangles follow the curves of the longitudes and latitudes. When we standardised them to the 5x5 km grid cells, which is another grid system, the 1/9 ICES grid cells were redistributed which may lead to slightly different shapes (Figure 4).

We did not include all species found in the surveys, but used a selected number of species (Daan 2000). This is a logic choice, since surveys do not catch all species in a representative way.

To represent the current distribution of fish, it is not possible to only select the data of 2010 or of the last few years. We selected a time series of 10 y to obtain enough data to allow for a spatial resolution of 1/9 ICES rectangle, since each year, only 1 or 2 hauls are made in a single ICES rectangle. A consequence is that the species richness maps include recent increases of species due to climate change (Ter Hofstede et al. 2010).

For the fish maps (except for trends, see below), a number of 20 hauls at each 1/9 ICES rectangle is used (see Figure 21). This is done by randomly selecting neighbouring 1/9 ICES rectangles to increase the number of hauls to 20. This may lead to greater resemblance between areas, but is necessary to allow for comparisons between areas. If 20 hauls could not be selected from the cell itself or its neighbouring cells then it was left black, even thou some hauls could have been made in this cell.

For trend analysis the time period should be long enough to cover fluctuations caused by a variable environment (such as temperature etc.) or by fluctuating populations (i.e. populations with cyclic behaviour). On the other hand, we also want to know how the population trends are at present, since populations that are increasing may not need additional protection. For the temporal scale, we used a 25 y period (1985-2009), where 1985 is more or less the start of the time series, which however is not a reference for the desired population size. Before that year, there was no BTS survey. One could choose for a shorter period (10 y), but then trends are less well detectable. As a spatial scale for the trend analyses we chose the area between 51 and 56° N, since above and below these latitudes, the fish community changes. Using data only for the DCS, could indicate a negative trend while the species on North Sea scale is increasing. Because we set the minimum of hauls in which the species had to be sampled at 5%, the majority of species was excluded from the analysis. Consequently, these species were assigned neutral trends, but in reality we do not have enough information to determine their trends.

Birds

The general approach for birds was slightly different than for the other groups (see section 2.2.1): first each bird species was given a final score by summing different biodiversity metrics, next maps per season were made based on bird values multiplied by bird abundance. For the final bird map, the highest value per 2-month period per 5x5 km area was taken (more details in section 4.3).

Due to time constraints and data availability, we chose not to make separate maps for each biodiversity metric, but we made integrated maps for each 2 month period, aggregated over indicators and over species. The effect of this choice is that the results are less comparable to the other maps, but the advantage is that the seasonal dynamics are better visible.

Expressing biodiversity by ‘specific bird values’ – the summation of species-specific products of abundances and metric values – is in line with earlier studies that aimed to scale marine areas according to the vulnerability of their avifauna to oil pollution (Camphuysen 1998), disturbance by shipping (Camphuysen et al. 1999) and offshore wind farms (Garthe & Hüppop 2004). Specific Bird Values differentiate areas that harbour elevated densities of seabirds with specific characteristics, such as a low resilience, a high denpedence on the DCS or a small biogeographical population size.

Marine mammals

For marine mammals, estimated density classes (section 4.4.) were used as basis for further maps that were plotted on a 1/9 ICES rectangle scale to express the uncertainties. For further details, see section 4.4.

For marine mammals, we chose not to use density data or modelled data, but instead use estimates of densities, based on data and models, since the measured data would always be biased due to higher local monitoring effort (e.g. for wind farms, etc.) or not cover the whole DCS.

Habitats

The habitat map was composed by combining 3 abiotic maps. The rarity map was then plotted on a 5x5 km scale.

One of the aims of the habitat map is to show the distribution of habitats, expressed as combinations of abiotic parameters. We felt that existing maps did not fully take into account the uniqueness of some part of the DCS, e.g. the shallow coastal zone. We therefore chose to combine abiotic characteristics into a habitat map. One issue is that it is possible to use different basic maps, e.g. depth distribution maps are available with different levels of detail and sediment maps can be divided into a few or a lot of classes. We chose the level in such a way that we ended up with habitat classes that express the diversity of habitats well.

Table 5. Maps are tagged with the symbols in this table to indicate how they are processed.

Symbol	Meaning
No symbol	Map serves as illustration
Grey circle	Map of biodiversity metric used for further calculations
Blue circle	Semi-final map (e.g. per survey or subgroup)
Red circle	Final map per species group

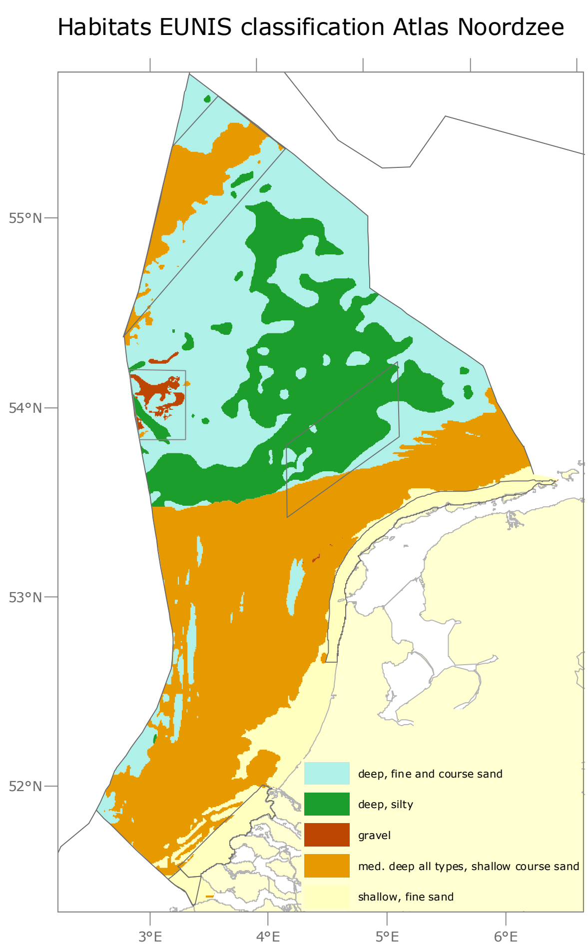


Figure 3. EUNIS habitat classification map, used for cokringing in the benthos maps.

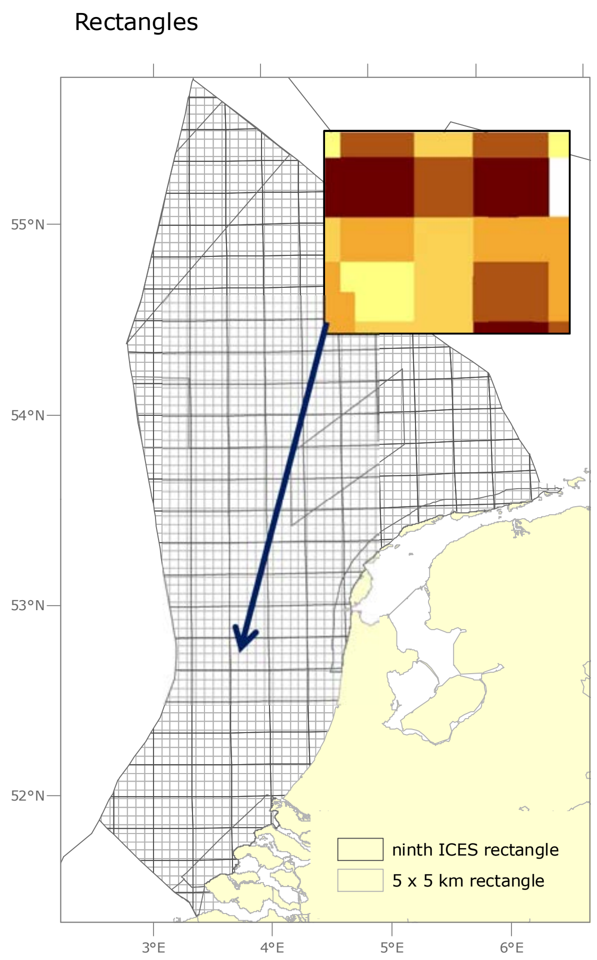


Figure 4. Effect of dividing 1/9 ICES rectangles into 5x5 km units.

4 Data description and results

In this chapter we describe the selected datasets in detail, including sampling techniques, the calculation of the biodiversity metrics, the procedures for rescaling the values of the biodiversity and the choices that were made during these processes. For each of the biodiversity metrics we have produced maps. In some cases we show additional maps that contribute to the discussion.

4.1 Benthos

4.1.1 Small macrobenthos (MTWL/BIOMON and the Cleaver Bank)

4.1.1.1 Data and sampling methods

We used two datasets on macrobenthic fauna for the analyses and identification of potential hotspots within the Dutch Continental Shelf (DCS): (1) MWTL and (2) Cleaver Bank data. The first data set has been collected within the MWTL (also known as BIOMON) monitoring program of Rijkswaterstaat (RWS) and covers most of the DCS. The MWTL data set is composed of a set of 100 boxcore samples (0.078 m^2) taken annually. The fauna is sieved over 1 mm mesh size. For practical reasons, we selected the period 1991-2006 (Daan & Mulder 2009). The sampling stations are distributed over the DCS in such a way that different sediment types are well represented. The Cleaver Bank (Klaverbank) area was not covered in this dataset, because the stony sediment does not allow sampling with a boxcorer. Therefore, a second data set collected by Bureau Waardenburg en Ecosub has been added. The Cleaver Bank dataset covers the years 1989, 1990 and 2002 and comprises 103 samples, and is described by Van Moorsel (2003).

Combining MTWL and Cleaver Bank data

The setup of MWTL is such that average densities over a period of years can be determined. For the Cleaver Bank such time series were not available. Instead, sampling took place in a limited number of years and stations were strongly clustered. Because the number of species encountered in benthic samples is proportional to the bottom surface area sampled, treatment of individual samples would give results incomparable to the MWTL samples. To overcome this problem we treated the clustered Cleaver Bank stations as if they were replicate samples over time. With that, we reduced the bias in species number due to differences in total sampled surface. For MWTL and the Cleaver Bank a total of 1394 benthos samples were available. From these samples, over 450 taxa have been identified (see Appendix A) of which 63 were unique for the Cleaver Bank. We excluded records that were not determined to the species level. However, if several of such records were found that could be grouped into a higher taxon (genus, family, order), these records were given the higher taxon name and treated as if they were a species.

To determine the uniqueness of the species assemblage at each of the above 112 stations the method outlined by Lavaleye (2000) was followed, i.e. information on species is brought back to rank numbers on which in the end, station classification is made possible. Attention focussed on three species attributes (or biodiversity metrics in the context of this report): (1) longevity (potential maximum age), (2) maximum attainable weight (potential maximum weight, AFDW) and (3) species rarity. Especially the attributes "weight" and "longevity" give information about their mode of life; i.e. being either a K- or r-strategist. Communities with high proportions of K-strategists reflect long-term environmental stability with high survival changes, while benthic communities which are dominated by short lived species point to dynamic and disturbed conditions. Thus by looking at the benthic communities in terms of potential maximum species longevity (Metric 4. Resilience), potential maximum species weight (Metric 11. Large species) or species rarity (Metric 9. Rarity) gives another way of looking at the station's species composition especially when compared to more traditional ways of looking at biodiversity. By following this method, it becomes feasible to incorporate MSFD criteria for macrobenthos into the judgement of the environmental status at the DCS.

Table 6. Macrobenthos. Ranking of density and biomass classes and number of stations per class.

Class	Density n/m²	Nr of stations	Biomass g AFDW/m²	Nr of stations
1	<750	23	<10	28
2	750-1500	29	10-15	23
3	1500-2500	33	15-20	16
4	2500-3000	12	20-30	21
5	>3000	14	>30	24

Table 7. Macrobenthos. Ranking of longevity (maximum age) classes and number of species per class (see Appendix B).

Class	longevity class	Nr of species
1	0-1 yr	190
2	2 yr	77
3	3-5 yr	110
4	5-10 yr	70
5	>10 yr	19

Table 8. Macrobenthos. Ranking of rarity classes and number of species per class.

Rank	Category	Nr of species
1	>5.4% station year combinations	101
2	1.2-5.4 station year combinations	80
3	0.4-1.1% station year combinations	69
4	0.2-0.3% station year combinations	93
5	<.1 of station year combinations	123

Table 9. Macrobenthos. Ranking of species richness and evenness (Shannon-Wiener) in classes and number of stations per class.

Class	Species richness	Nr of stations	Evenness (Shannon wiener)	Nr of stations
1	<60	26	<2.5	17
2	60-75	23	2.5 - 2.75	18
3	76-85	18	2.75 – 3	24
4	86-95	27	3.00 - 3.25	29
5	>95	19	>3.25	24

Table 10. Ranking of weight classes and number of species per class.

Class	log2 class	Weights (mg AFDW)	Nr of species
1	<0	<1	139
2	0-5	1-3	173
3	5-10	33-1000	126
4	10-12.5	1000-5000	21
5	>12.5	>5000	7

4.1.1.2 Maps

Metrics 2 and 3. Density and biomass

Average total density (N individuals /m^2) and average total biomass (g AFDW/m^2) were calculated per sampling station as described in the previous section.

The maps in Figure 8 give the average distribution of biomass and density classes over the area for the period 1995-2006. Data for the Cleaver Bank area cover the period between 1989-2002. For the latter area biomass data were only partly available. Macrobenthos density and biomass is low in the south-western part of the DCS. The coastal area locally has high densities of animals. Distribution of biomass shows an even more extreme distribution with high biomass along the coast, illustrating the high productivity of the area. The Frisian Front area is characterised by intermediate biomasses, similar to those along the southern flank of the Dogger Bank.

Metric 4. Resilience

Resilience maps for benthos show the number of species that can attain a maximum age that exceeds 10y. To prepare maps, first maximum ages were determined on basis of literature and internet sources (Appendix B). Especially for crustaceans, it was hard to find maximum ages as reliable methods for age determination of this fauna group not really exist. Similar problems existed for a large proportion of the polychaete species. Therefore, the available species specific information has been extrapolated to closely related species for which such information was not available. If no information was available on related species, extrapolation took place on basis of similarity based on higher taxonomic levels such as genus, family or order. For a minority of species this approach neither worked. We estimated their ages on basis of expert judgment. An overview of the age-species frequency distribution is given in Figure 5. Species were ranked on basis of the maximum obtainable age with highest maximum longevity getting highest rank (5) and species with lowest longevity got lowest rank. Most of the species fall within the age category of less or equal to 1 year. Highest rank (5) contained 19 species with a longevity surpassing 10 years (see Appendix B). We wanted to prepare maps that showed the distribution of old growing species and we therefore selected the species that can grow older than 10y.

In Figure 9 two maps are presented that show the distribution of the BIOMON and Cleaver bank stations, (a) ranked according to the individual observations of old growing species (1995-2006) (several observations of one species may be included) and (b) ranked according to the number of old growing species (and not the number of individuals). A clear spatial distribution is evident from both maps. Both maps show that species or numbers of individuals with a maximum longevity greater than 10 y are found north of the 30 m depth contour, the thermally stratified, deeper part of the Dutch Continental Shelf. In the southern coastal and off-shore area neither the number of species, nor the number of observations of long living species is high.

Metric 9. Rarity

The underlying question is whether there are areas within the DCS, which are characterised by a disproportional high number of rare species. This means that rarity of a species has to be determined. Here the rarity of a species in the DCS samples was determined by ranking them according to the frequency of occurrence in all sample-year combinations (n=1394) which were available. The ranked species were divided into 5 groups of approximately similar size (number of species) as far as rank distribution permitted. Ranks were assigned in such a way that the rarest species (incidental finds) got the highest rank (
Table 8). The distribution of species over the observed abundance categories is given in Figure 6. About 325 species belong to the rarest category, i.e. are found in less than 5% of the samples.

Figure 11 gives (a) the number of observations of rare species and (b) the total number of rare species in the study period (1995-2006). A rare species is a species that occurs in less than 5% in the total number of samples. A distinct pattern is not evident except that both the individual observations of rare species, as well as the number of rare species at the Cleaver Bank is higher than in the surrounding area. Except for the Cleaver Bank, the figure illustrates that the chance to find a rare species over the rest of the continental shelf is rather equally distributed. The high number of rare species found at the Cleaver Bank is linked to the deviating substrate types found in the area when compared to the remainder of the DCS. An effect of the methodological approach followed is minimized because the "stations" in the Cleaver Bank are based on averaged replicated samples as if they were a time series. The percentage contribution of any of the Cleaver Bank stations to the total number of samples (1394) is equal to the contribution by any of the MWTL samples. The Cleaver Bank thus shows a real higher abundance of rare species.

Metric 11. Large species (number of species with a 'large' (>1 g AFDW) maximum weight)

Maximum weights per species were obtained from the MWTL dataset. For those species for which this method evidently underestimated maximum weight, other data sources were explored. The species were ranked by maximum weight. Weight classes were determined on basis of 2Log(weight) distribution to obtain an rank classification with as much as possible equal numbers of species within each rank. From Figure 7 it is evident that the weight distribution of species is strongly skewed. Species with individual weights below 1 mg dominated the fauna sampled within the monitoring program. We used those species falling in the two highest weight classes (4 and 5) for the analyses. Hence, we have produced a map of the distribution of species with a maximum potential weight of > 1g.

Most 'heavy' species (Weight max >1000 mg) are found in the northern part of the DCS and represent molluscs and echinoderms (Figure 10). The pattern in number of species parallels partly the pattern observed in the number of observations. The higher number of observations and species along the Dutch coast is related to the occurrence of molluscs such as *Ensis* spp. The maps give potential maximum weight distribution over the DCS and not necesarily reflect actual ash free weight distributions of this class of heavy species. It however could be of value to compare potential weights and actual weights at the sampled stations.

Metrics 12 and 13. Species richness and species evenness

Species richness (average total number of species) and species evenness, expressed as the Shannon wiener index (see Chapter Appendix A) were calculated for the MWTL and Cleaver Bank stations on basis of the average species densities. The calculated indices were ranked over the stations (Table 9).

Figure 12 gives two measures of diversity: (a) species richness, expressed as the number of taxa (species) that has been found between 1995 and 2006 and (b) species evenness, expressed as the

Shannon-Wiener index per station. The figure illustrates that the number of species found in the southern part of the Dutch Continental Shelf is much lower when compared to the central part (Oyster Grounds) or Dogger Bank. The Shannon Wiener index incorporates besides the number of species also the numerical distribution of individuals over the species. Thus this index gives a slightly better idea to what extent the fauna is dominated by a few abundant species or that individuals are spread equally over the species. The Dogger Bank and Cleaver Bank show up as diverse areas. Although the Frisian Front is species rich, the Shannon Wiener index shows that there is numerical dominance of some species. The area north of the Frisian Front has both a high number of different species as well as a high Shannon Wiener index, suggesting a rather even distribution over the different species.

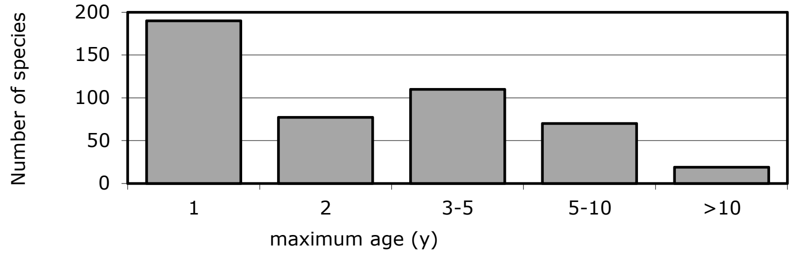


Figure 5. Macrobenthos (BIOMON+ Cleaver Bank). Species distribution over longevity classes.

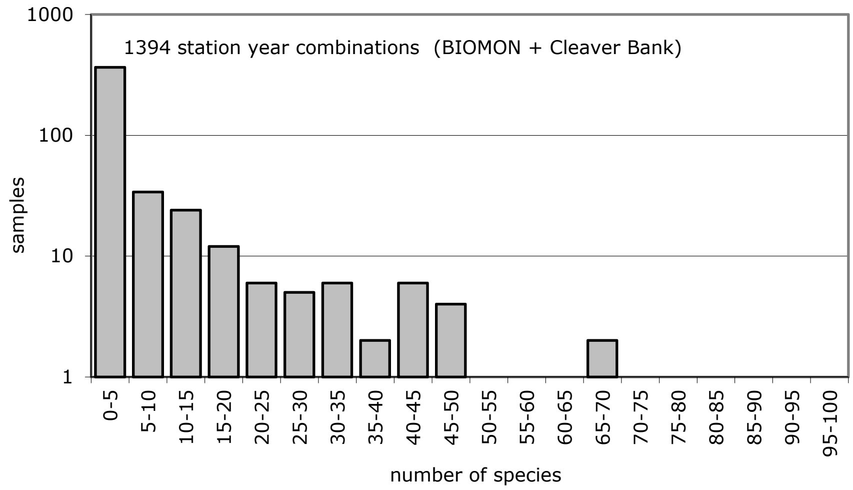


Figure 6. Macrobenthos (BIOMON + Cleaver Bank). The distribution of species numbers over the abundance categories. Most samples (or station year combinations) contain 0-5 species, only a few samples contain >65 species.

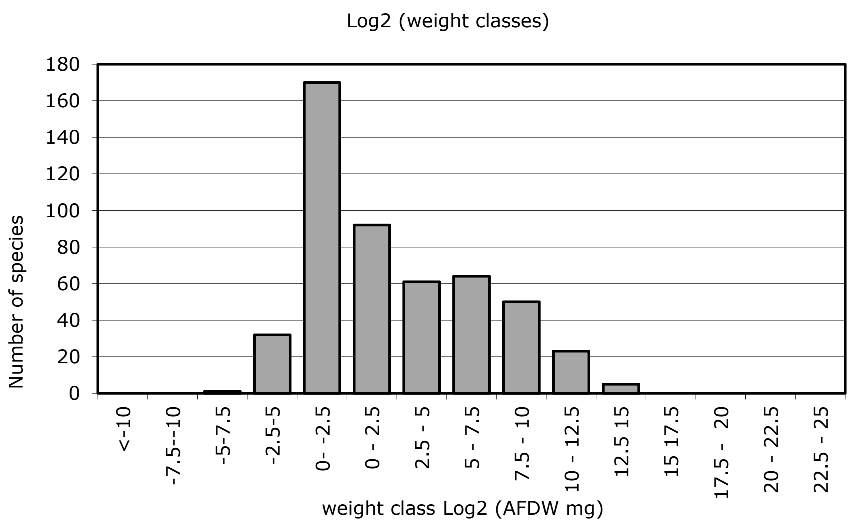


Figure 7. Macrobenthos (BIOMON+Cleaver Bank). Number of species per weight class (log2 transformed).

Figure 8 Macrobenthos (BIOMON + Cleaver Bank). (a) Density classes based on total densities of all species together and (b) Biomass classes based on total biomass of all species together.

Figure 9 Macrobenthos (BIOMON + Cleaver Bank). (a) Number of individual observations of potentially old growing species (>10y) (b) Number of potentially old growing species (>10y)

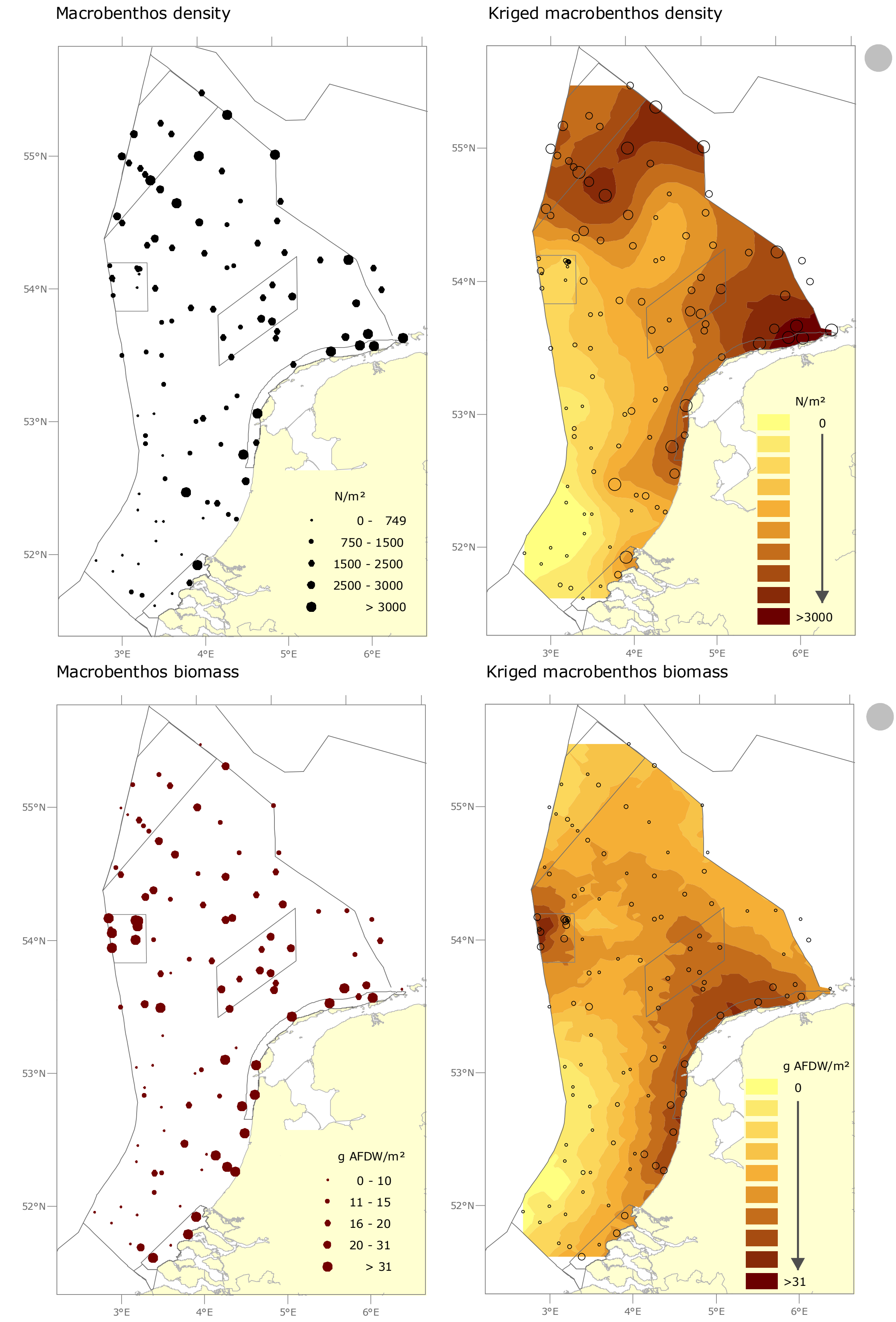
Figure 10 Macrobenthos (BIOMON + Cleaver Bank). (a) Number of individual observations of heavy species(g AFDW) and (b) Number of heavy species (g AFDW).(Several individuals within one species are represented as a single observation in the second map).

Figure 11 Macrobenthos (BIOMON + Cleaver Bank). (a) Number of individual observations of rare species and (b) Number of rare species.

Figure 12. Macrobenthos (BIOMON + Cleaver Bank). Species richness and (b) Evenness (Shannon Wiener)

Symbol	Meaning
No symbol	Map serves as illustration
	Map of biodiversity metric used for further calculations
	Semi-final map (e.g. per survey or subgroup)
	Final map per species group

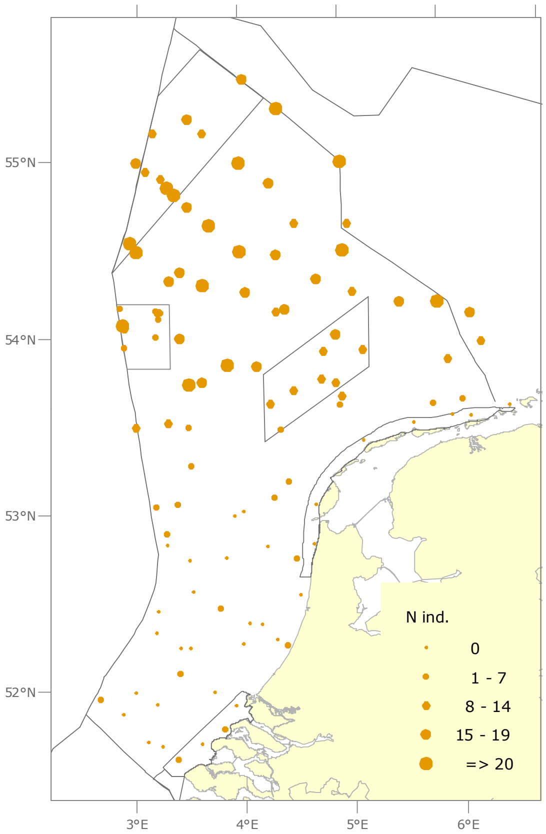
Figure 8



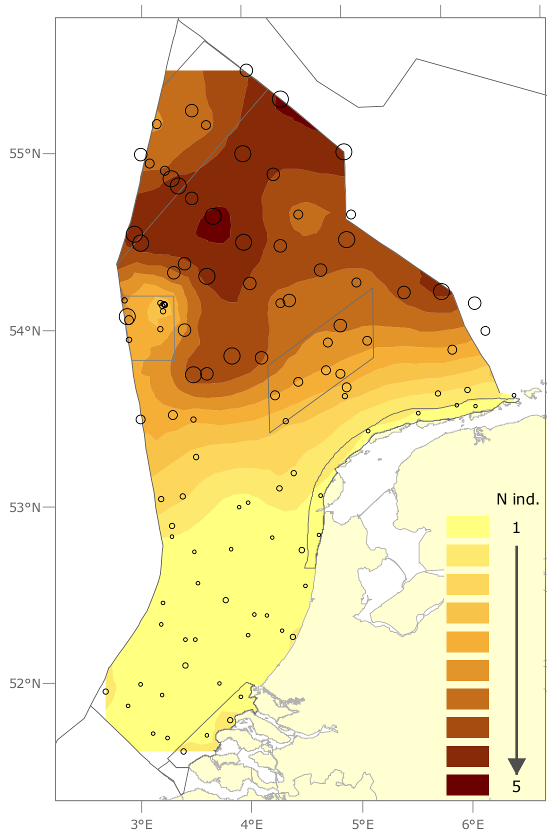
Macrobenthos density
Kriged macrobenthos density
Macrobenthos biomass
Kriged macrobenthos biomass
55°N
54°N
53°N
52°N
3°E
4°E
5°E
6°E
N/m²
0 - 749
750 - 1500
1500 - 2500
2500 - 3000
> 3000
N/m²
0
>3000
g AFDW/m²
0 - 10
11 - 15
16 - 20
20 - 31
> 31
g AFDW/m²
0
>31

Figure 9

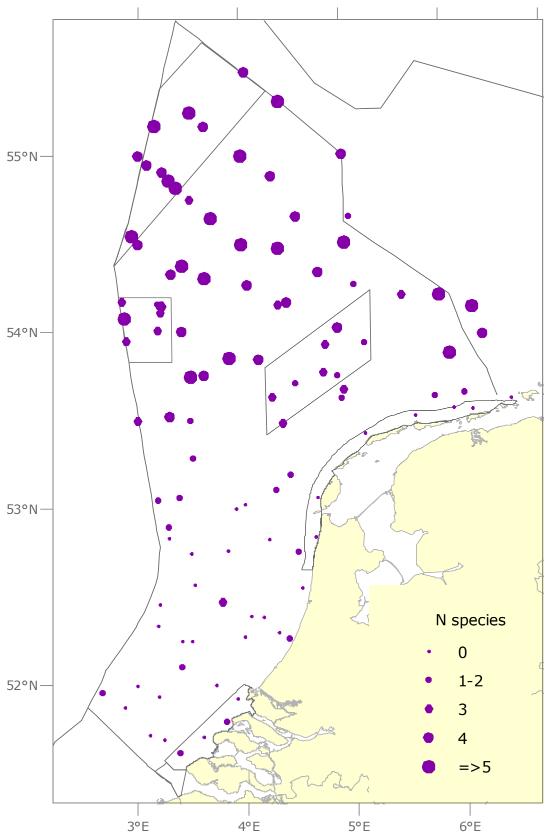
Macrobenthos resilience (longevity > 10 y)



Kriged macrobenthos resilience (l. > 10 y)



Macrobenthos resilience (longevity > 10 y)



Kriged macrobenthos resilience (l. > 10 y)

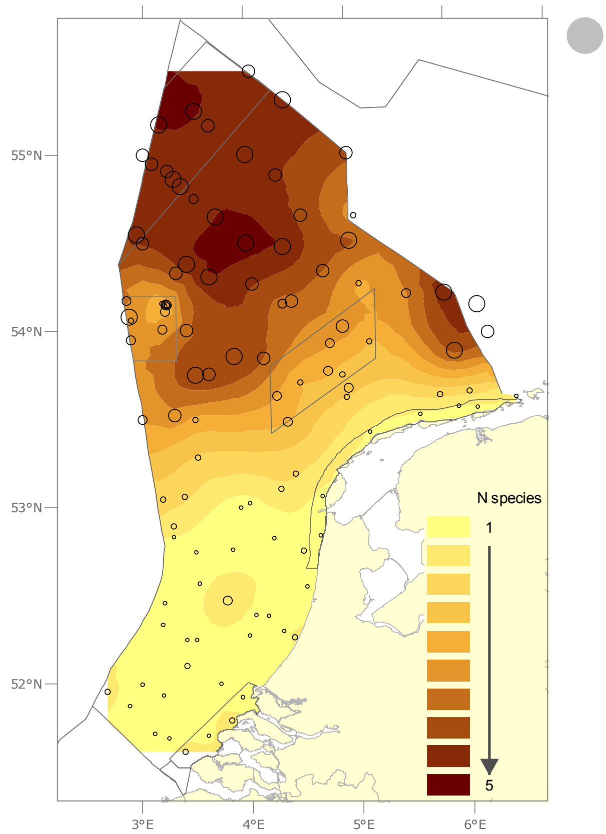
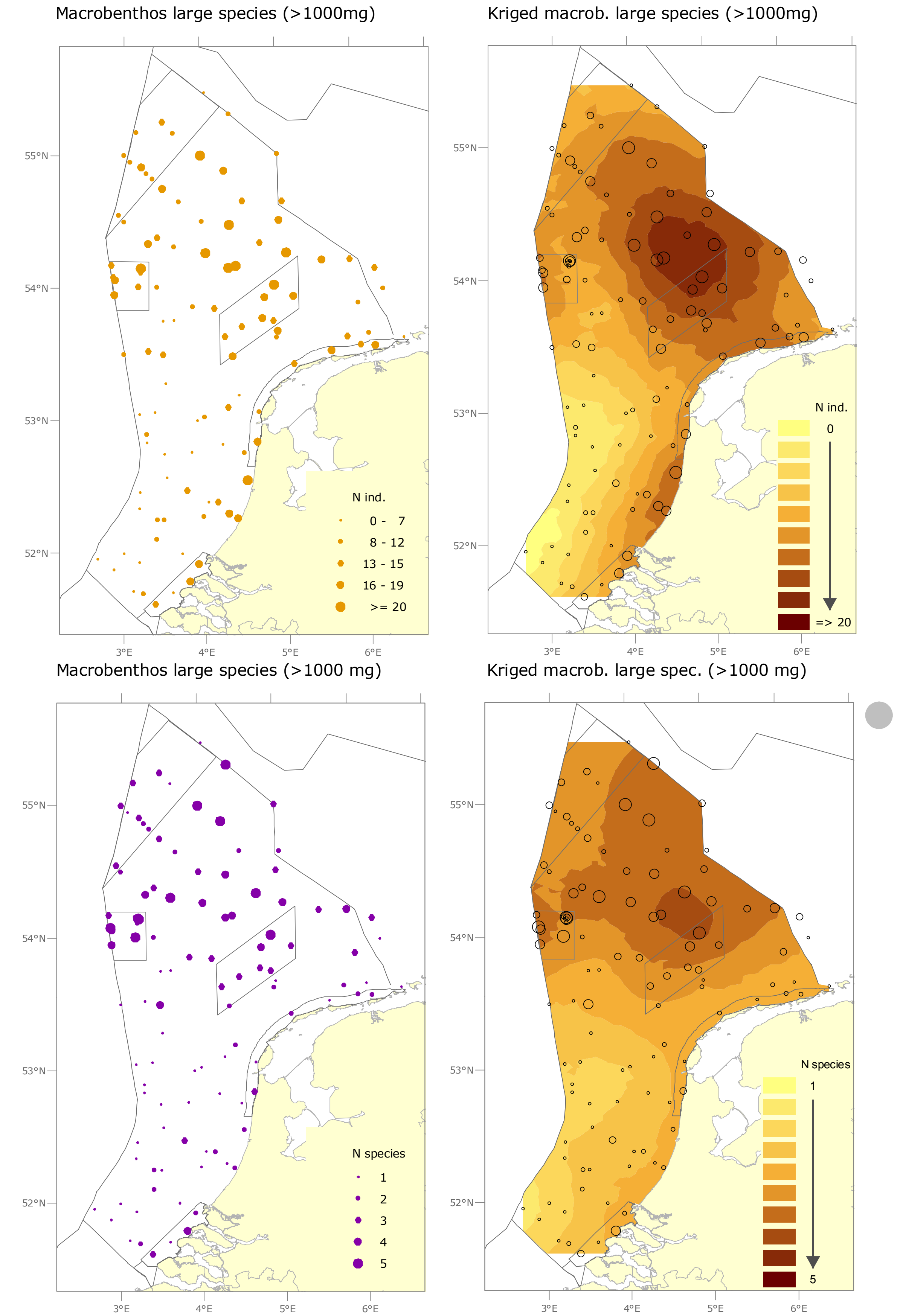


Figure 10



Macrobenthos large species (>1000mg)
55°N
54°N
53°N
52°N
3°E
4°E
5°E
6°E
N ind.
0 - 7
8 - 12
13 - 15
16 - 19
>= 20
Kriged macrob. large species (>1000mg)
N ind.
0
=> 20
Macrobenthos large species (>1000 mg)
N species
1
2
3
4
5
Kriged macrob. large spec. (>1000 mg)
N species
1
5

Figure 11

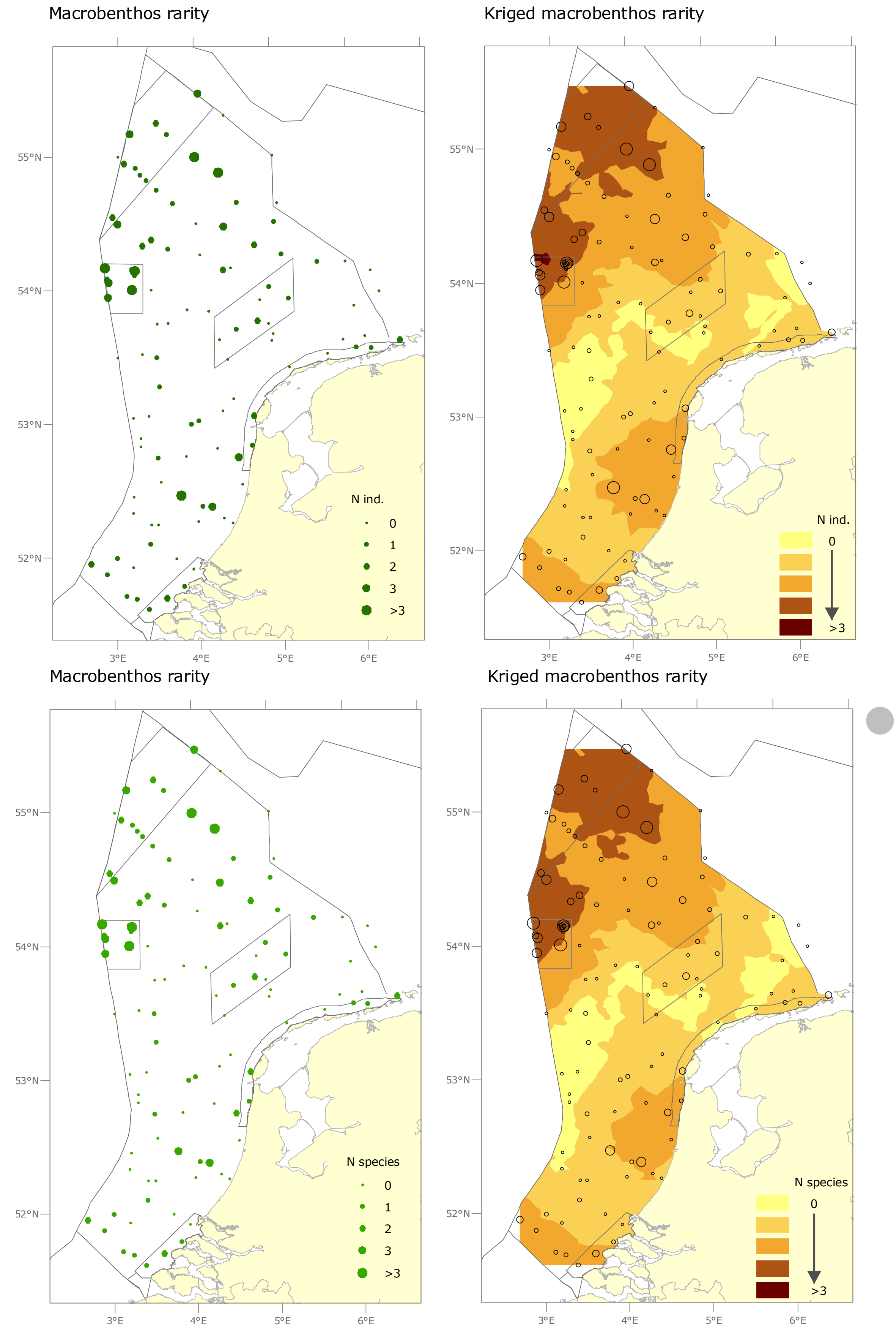
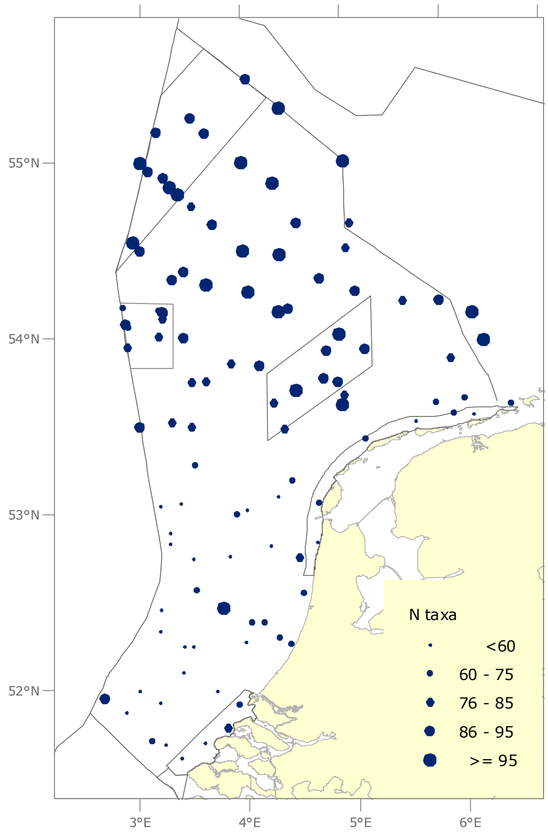
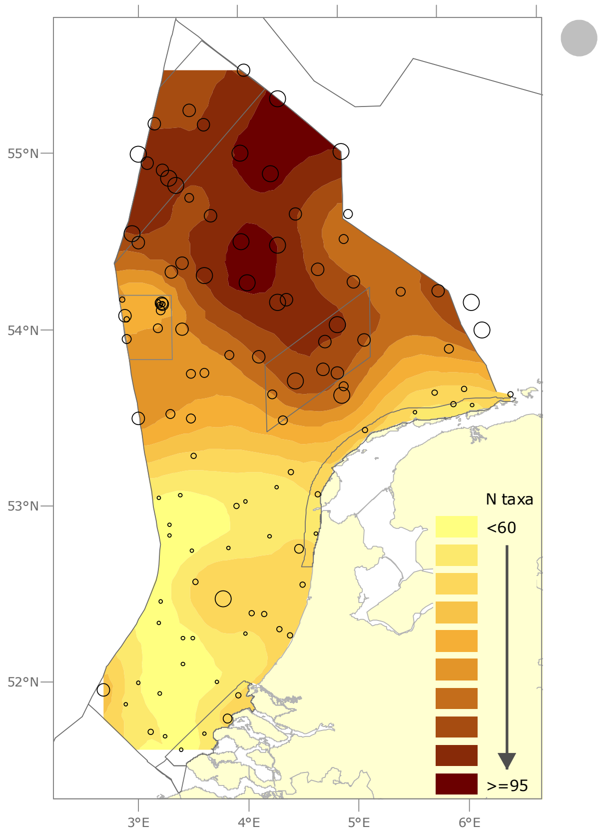

Macrobenthos rarity
Kriged macrobenthos rarity
55°N
54°N
53°N
52°N
3°E
4°E
5°E
6°E
N ind.
0
1
2
3
>3
Macrobenthos rarity
Kriged macrobenthos rarity
N species
0
1
2
3
>3

Figure 12

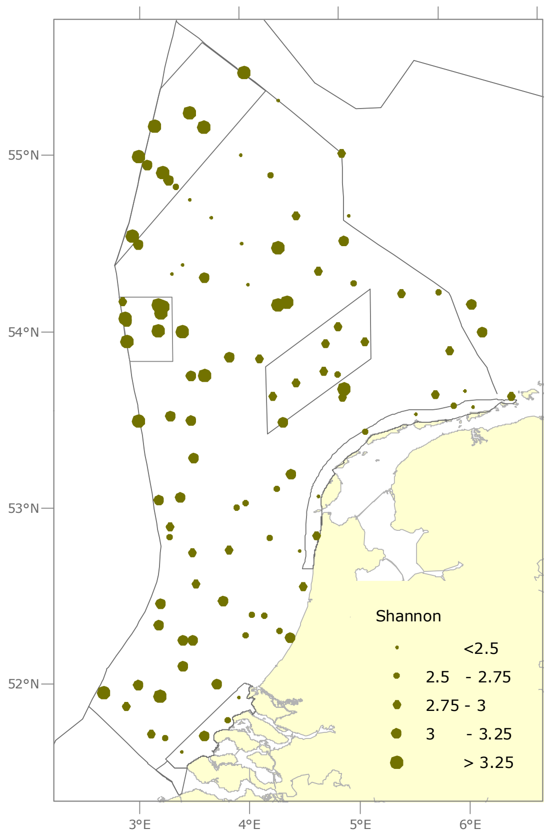
Macrobenthos richness



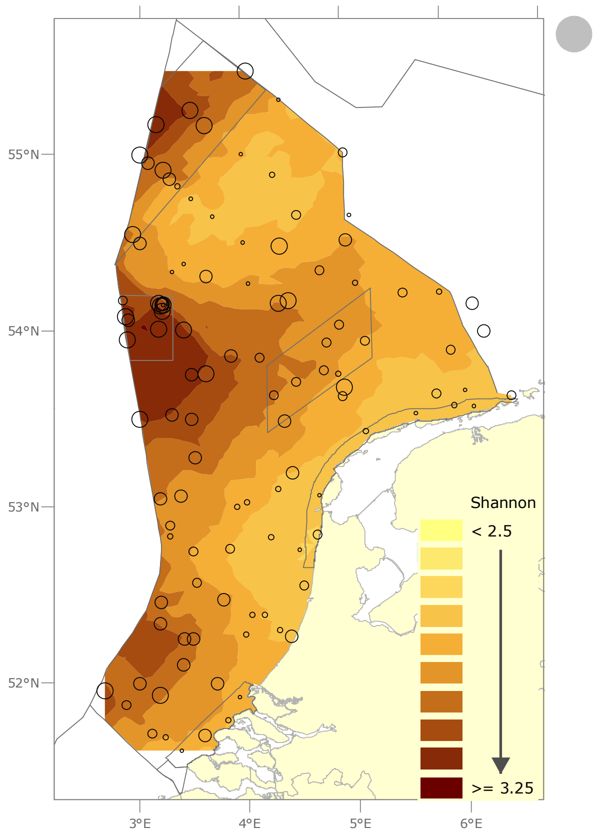
Kriged macrobenthos richness



Macrobenthos evenness



Kriged macrobenthos evenness



4.1.2 Megabenthos (Triple-D dredge fauna)

By Marc Lavaleye (NIOZ), Magda Bergman (NIOZ), Rob Witbaard (NIOZ/IMARES, Gerard Duineveld (NIOZ) & Godfried van Moorsel (Ecosub)

4.1.2.1 Data and sampling methods

The megabenthos data are based on recent sampling surveys by Royal NIOZ in 2006, 2007 and 2008 with a special dredge, the Triple-D on the Dutch Continental Shelf (DCS). With a boxcorer the smaller infauna (macrobenthos) can be sampled quantitatively very well. However, this is not possible for the larger infauna, such as the large bivalves like the Quahog (*Arctica islandica*) and the Knotted gaper (*Mya truncata*), as their density is much lower than most of the smaller infauna. This means that the probability of collecting these animals with a boxcore is very small. The same applies for the epifauna. The non-mobile epifauna is only rarely present in the Dutch Continental Shelf (DCS) of the North Sea, as intense fishing with bottom trawls plough and rake the sea-bed on a regular basis, removing hard substrate and destroying most epifauna. The mobile epifauna, like crabs and bottomfishes, is still quite abundant on the DCS, but has a density much lower than most of the infauna. Besides, these animals can move relatively fast, and in this way mostly escape the boxcore.

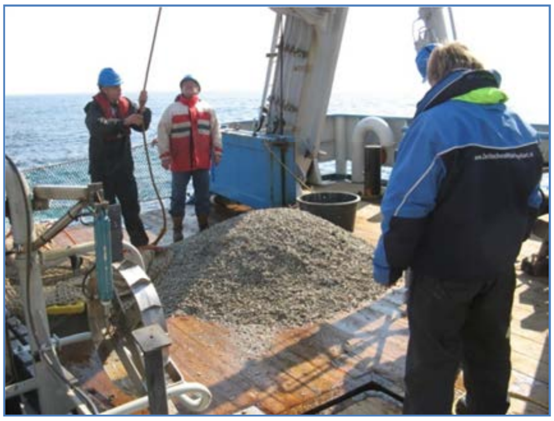
To sample the larger infauna and the epifauna in a quantitative way a so-called Triple-D dredge (Figure 13) was designed at NIOZ. This special dredge cuts a square groove of about 20 cm deep and 20 cm wide out of the bottom over a distance of 100 m (in special cases this pre-programmed distance can be altered). The sediment extracted from this groove is collected in a very sturdy net with a meshsize of 7 x 7 mm. The knife that cuts the groove can be opened and closed quickly with air hydraulics. This closing mechanism is triggered by two odometers, which calculate exactly the distance travelled over the bottom by the dredge. The catch is first flushed with seawater by towing it behind the ship for a few minutes and is then immediately analyzed afterwards on board. Analysis involves identification, counting, measuring and/or weighing. The Triple-D provides reliable density estimates of e.g. (sub)adult molluscs, echinoderms, larger polychaetes, crustaceans and some smaller fish species. Although more complex in construction than many other dredges (see above), the capacity for accurate quantification of the targeted fauna is a notable advantage (e.g. Duineveld et al. 2007).

The Triple-D dredge has been used often by NIOZ in the past, especially to study the impact of bottom fishing on the bottom fauna (De Groot & Lindeboom 1994, Lindeboom & De Groot 1998, Bergman et al. 2005). For surveying the larger bottom fauna of the DCS it was first used in 1996. In total 60 stations were sampled. This survey was repeated the following year (1997) with an improved version of the dredge at the same stations and at 7 additional stations (Bergman & Van Santbrink 1998). On the basis of these surveys the first distribution maps of the larger bivalves, echinoderms, crustaceans and the smaller bottom fish species could be made (Bergman & Van Santbrink 1998). These maps were not very detailed, and especially in the fauna-rich coastal zone that is of special interest, a much denser grid of stations would be preferred. For the projects Klimaat voor Ruimte and We@Sea, both in the framework of BSIK (Besluit Subsidies Investeringen Kennisinfrastructuur), NIOZ has carried out 8 different Triple-D cruises on the DCS over the past 3 years (2006-2008). In total 360 different stations were sampled: specifically the coastal zone was sampled intensively. As the fieldwork for a complete megabenthos survey of the DCS will only be finished in June 2011 some gaps still need to be filled. For this project we filled these gaps (mainly offshore Zeeland) with older data from the survey in 1997 and a research in and around the windpark offshore Egmond aan Zee. These extra data were also collected with the same dredge. As there is some overlap in the surveys the final number of plotted stations is 361.

The Triple-D stations covered the whole DCS, except for the Cleaver Bank. This special area contains bottom sediments with gravel and cobbles that are unsuitable for the dredge. To fill this last gap we used data from a Hamon grab survey on 10 transects in the Cleaver Bank area done by van Moorsel in 1989, 1990 and 2002 (Van Moorsel 2003). These grabs fortunately were also sieved over 8 mm, and the fauna of this large fraction was recorded separate from the finer fractions. As this 8 mm fraction corresponds rather well with the meshsize of the Triple-D dredge (7x7 mm) we used these data to fill the Cleaver Bank gab. As the Hamon grab stations were distributed much closer than the Triple-D dredge survey over the DCS we condensed the data into 5 stations. Because the Hamon grab data lack data on the mobile epifauna we adjusted the data by expert judgement so that they are more or less comparable to the Triple-D dredge data.

Figure 13. Megabenthos: Deep Digging Dredge (Triple-D: 2008 version: ~ 1500 kg).

(A) Front view showing the 20 cm wide funnel in the middle that with its cutting blade (now retracted) digs a square groove in the sediment over a fixed distances (normally set at 100 m); the triangular leading edge of the gear prevents the lateral escape of epifauna in front of the cutting blade.



(B) The catch on deck. In the right corner one of the odometers is visible.

(C) Immediate sorting, identification and measuring of the catch on board (source: M.J.N. Bergman, Royal NIOZ, the Netherlands).

4.1.2.2 Maps

Metrics 2 and 3. Density & biomass

For density (N/m^2) and biomass (g $AFDW/m^2$) all data from the Triple-D dredge surveys in 2006, 2007 and 2008 were used. There is some overlap in stations between years, the data of these stations was averaged. As a result the number of stations point on the DCS was reduced to 328. Twenty stations were added from the 1997 survey, and another 13 stations were added from the North Sea Windpark survey in 2007. So in total 361 stations were used to make the maps. For the density 5 extra stations could be added for the Cleaver Bank, from Hamon grab surveys in 1989, 1990 and 2002. Unfortunately biomass data for the Cleaver Bank were only available for one station.

In Figure 15 the density and biomass of megafauna are shown. 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. Since the data points each represent one sampling point, and since each sampling point has the same surface sampled, correction for effort was not needed.

Metric 9. Species rarity

For species rarity all Triple-D stations could be used, but not those of the Cleaver Bank, as the data are incomparable due to the fact that they are based on completely different size of sampled surface area. As definition for a rare species of the dredge fauna we used that it was found in less than 15 % of the total stations. The data for the 5 biodiversity metrics (density, biomass, richness, Shannon-Wiener, number of rare species) were each divided over 5 classes, in such a way that each class contained more or less the same number of stations. Table 11 shows the actual borders for the 5 classes of each of the 5 parameters.

Figure 16 shows the number of rare species, i.e. the species with a frequency of occurrence < 15%, encountered per sample. As for density and biodiversity, the Frisian Front and Oyster Grounds again stand out in terms of numbers of infrequently encountered species. The southern part of the DCS, although not yet as intensively monitored as the rest, shows a much lower chance to encounter rare species. The Dogger Bank has intermediate values.

Metrics 12 and 13. Species richness and species evenness

For species richness and evenness (the Shannon-Wiener biodiversity index, see Chapter Appendix A) all Triple-D stations could be used, but not those of the Cleaver Bank, as the data are incomparable due to the fact that they are based on completely different size of sampled surface area.

The lower part of Figure 16 shows species richness, expressed as the number of taxa (species) that has been found per sample and the upper part of Figure 17 shows species evenness, expressed as the Shannon-Wiener index per station. The figure illustrates that in general the species richness is higher in the northern part than in the southern part of the North Sea. The species richness is highest in the Frisian Front and in the Oyster Grounds and much lower in the coastal zone. The northern part of the DCS has an high species evenness, with highest values in the Frisian Front area. The Cleaver Bank seems to have a lower megabenthos species richness and evenness, but this is due to the fact that the Cleaver Bank data could not be used (see above).

Table 11. The actual borders for the 5 classes for each of the 5 parameters as used for the Triple-D dredge megabenthos data.

	from	to
Density class (N/m^2)		
1	1.8	9.8
2	9.9	15.7
3	15.9	29.4
4	29.7	60.1
5	60.5	878.6
Biomass class (g $AFDW/m^2$)		
1	0.68	4.41
2	4.45	6.06
3	6.14	8.99
4	9.04	14.93
5	14.99	315.93
Richness class		
1	4	19
2	20	23
3	23.4	27
4	28	32
5	33	48
Shannon Wiener class (H^1 log e)		
1	0.535	1.666
2	1.669	1.804
3	1.805	1.909
4	1.91	2.012
5	2.014	2.275
Number of Rare species		
1	0	2
2	2.1	3.9
3	4	5
4	6	7
5	8	14

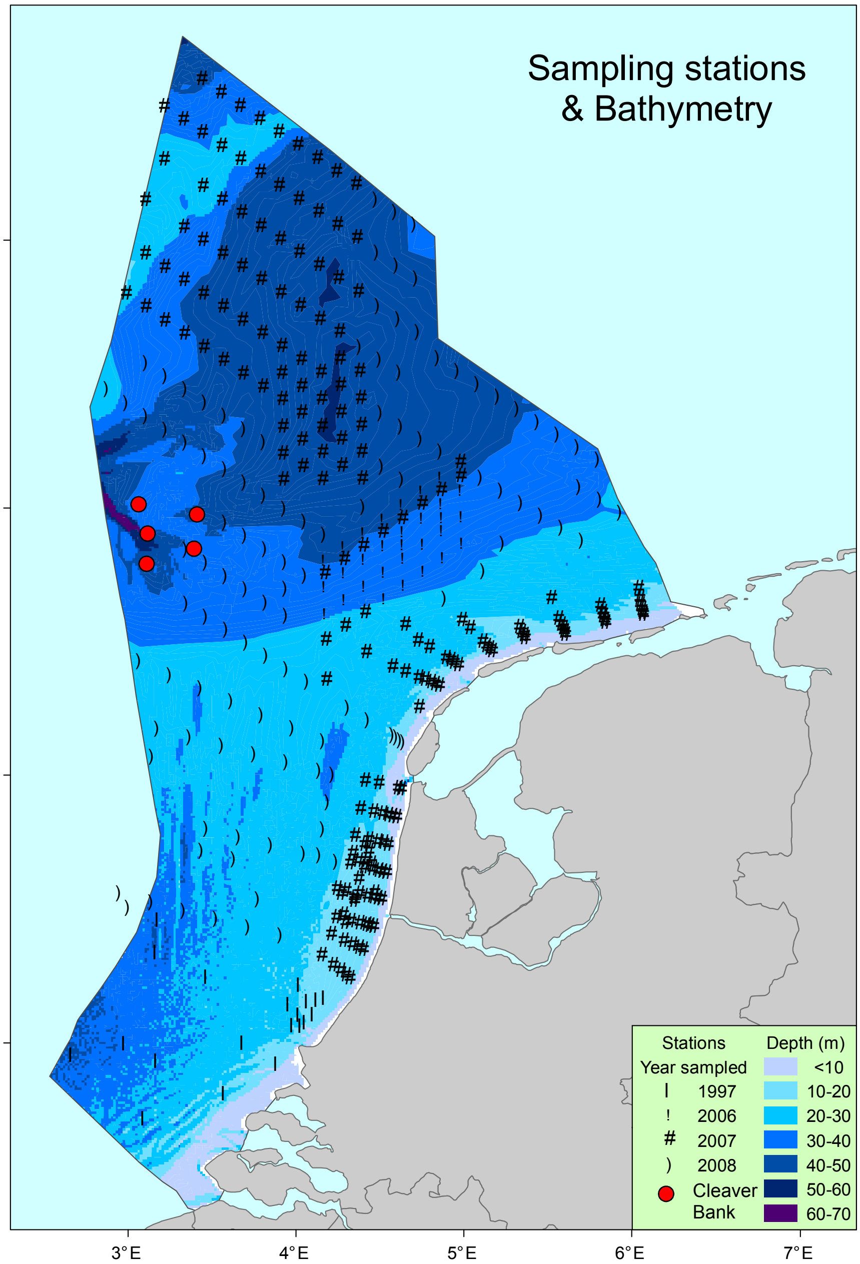


Figure 14. Bathymetric map of the DCS with the distribution of the 361 Triple-D dredge stations were data on megabenthos was available. Comparable fauna data for five extra stations on the Cleaver Bank were extracted from Hamon grabs (map: NIOZ).

Figure 15. Megabenthos (Triple-D) density and biomass. For the Cleaver Bank, density was available for 5 stations, but biomass was only available for 1 station (see 4.1.2.1).

Figure 16. Megabenthos (Triple-D). (A) Rarity: number of species/sample occurring in less than 15% of all samples and (B) species richness: number of species per Triple-D sample of 100 x 0.2 x 0.2 m). Data: NIOZ. Note that for both maps the Cleaver Bank data could not be used.

Figure 17. Megabenthos (Triple-D). (A) Evenness (Shannon-Wiener index). Note that the Cleaver Bank data could not be used for this map.

Symbol	Meaning
No symbol	Map serves as illustration
	Map of biodiversity metric used for further calculations
	Semi-final map (e.g. per survey or subgroup)
	Final map per species group

Figure 15

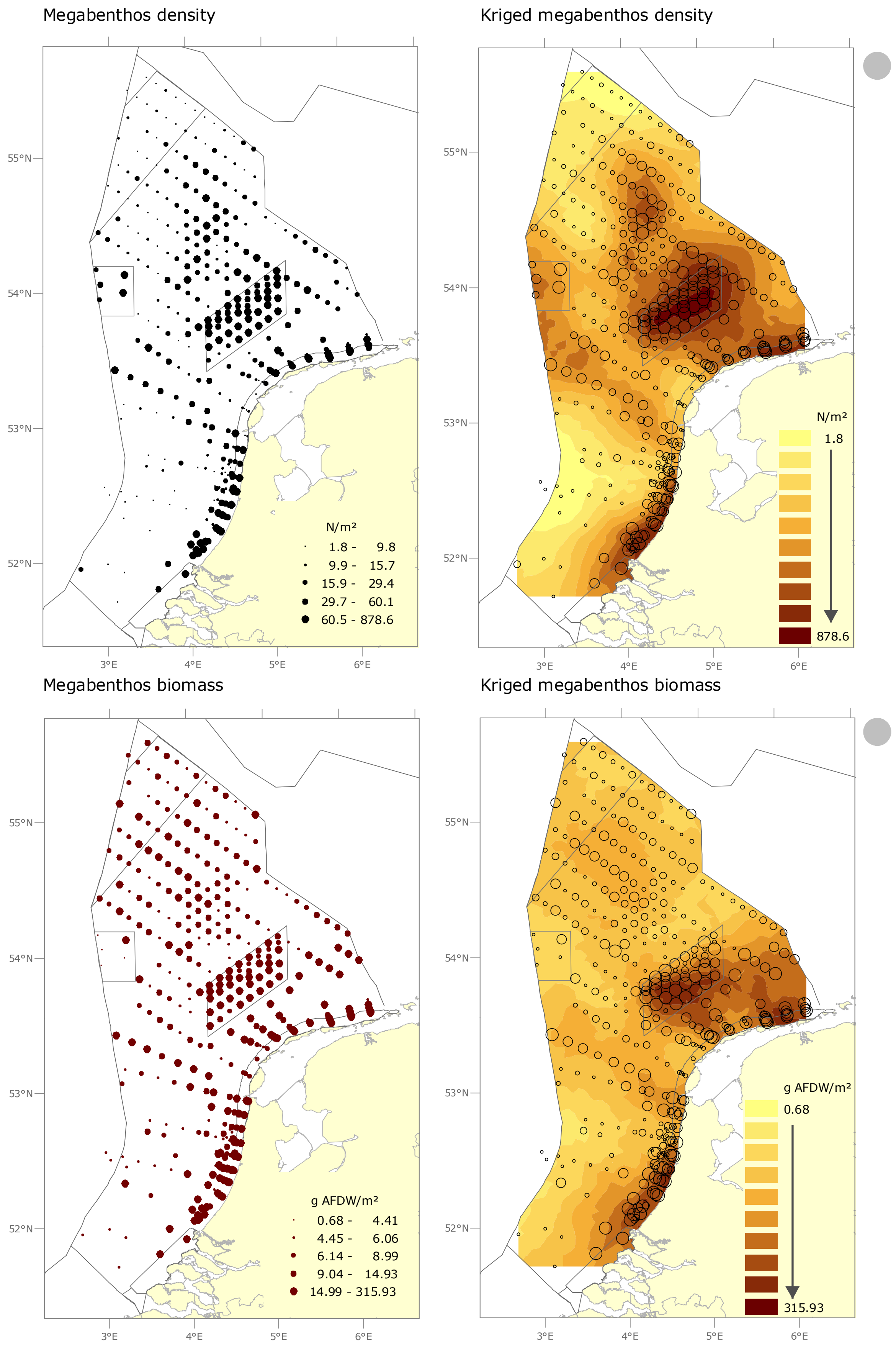
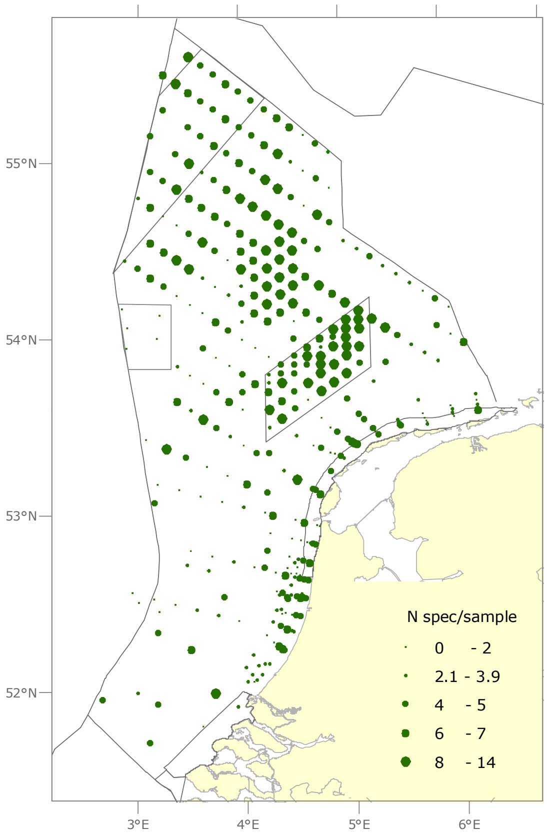
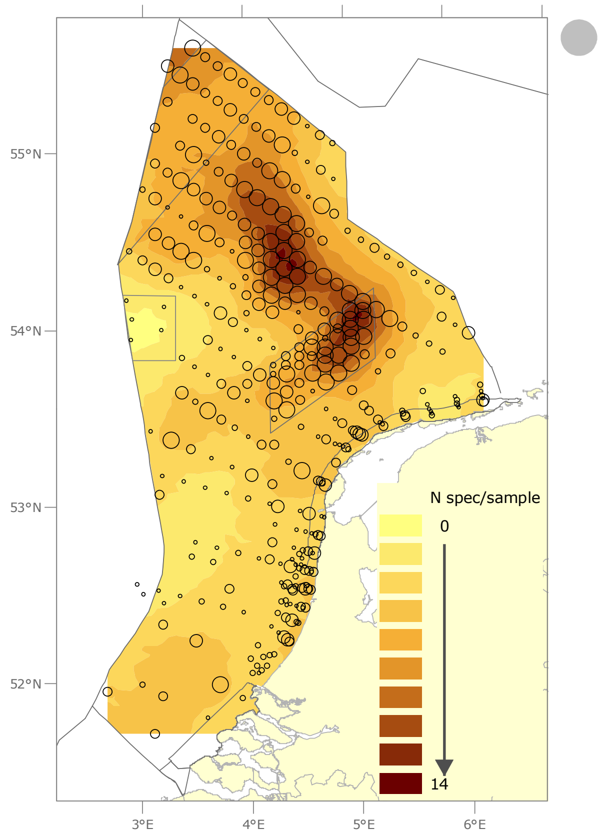

Megabenthos density
Kriged megabenthos density
Megabenthos biomass
Kriged megabenthos biomass
N/m²
1.8 - 9.8
9.9 - 15.7
15.9 - 29.4
29.7 - 60.1
60.5 - 878.6
1.8
878.6
g AFDW/m²
0.68 - 4.41
4.45 - 6.06
6.14 - 8.99
9.04 - 14.93
14.99 - 315.93
0.68
315.93
55°N
54°N
53°N
52°N
3°E
4°E
5°E
6°E

Figure 16

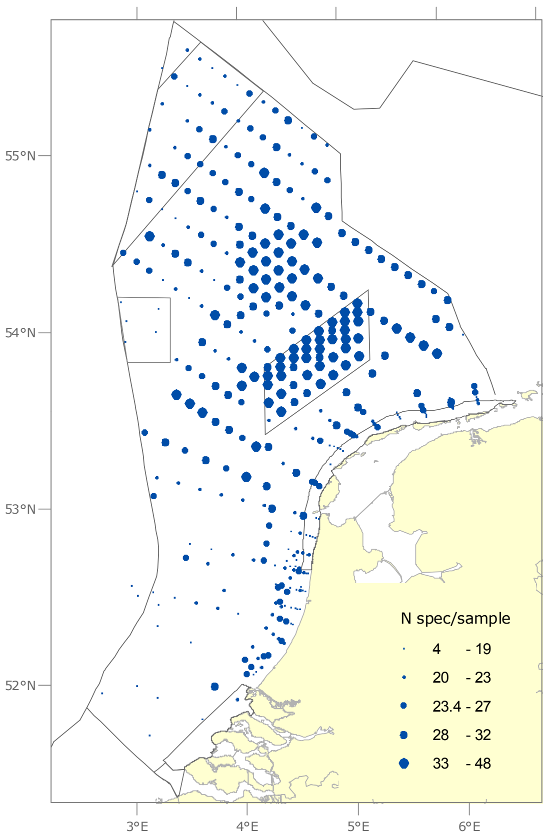
Megabenthos rarity



Kriged megabenthos rarity



Megabenthos richness



Kriged megabenthos richness

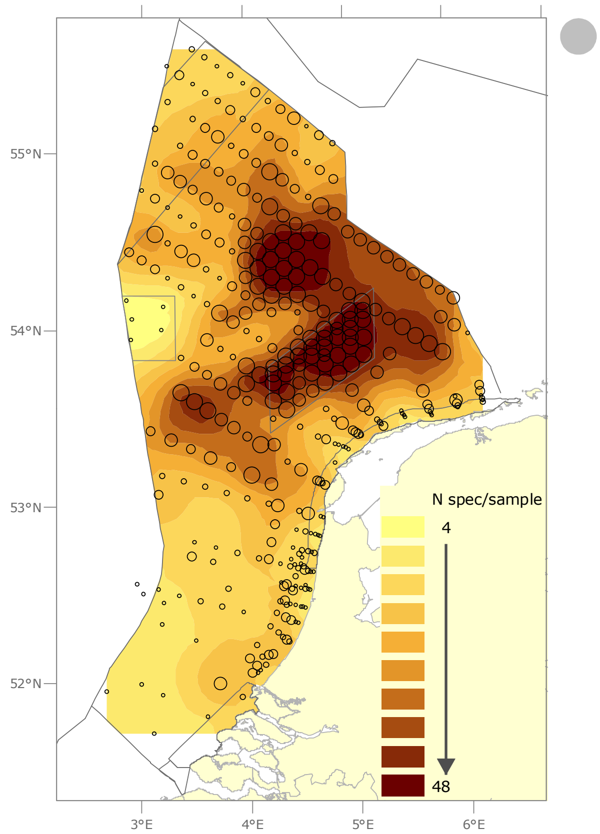
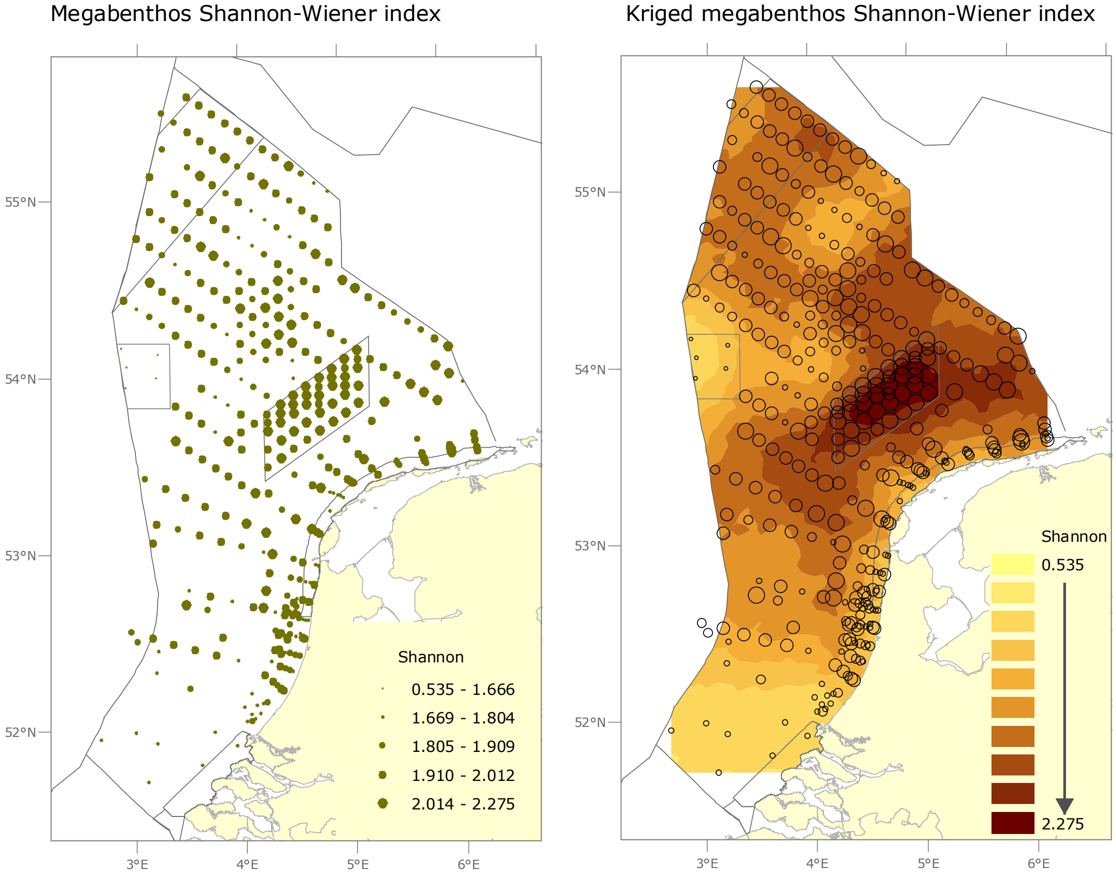


Figure 17


Megabenthos Shannon-Wiener index
Kriged megabenthos Shannon-Wiener index
55°N
54°N
53°N
52°N
3°E
4°E
5°E
6°E
Shannon
0.535 - 1.666
1.669 - 1.804
1.805 - 1.909
1.910 - 2.012
2.014 - 2.275
Shannon
0.535
2.275

4.1.3 Megabenthos (BTS)

4.1.3.1 Data and sampling methods

Data of the two vessels (RV Tridens II, RV Isis) participating in the BTS (more information: see paragraph 4.2.1) was treated separately due to slight differences in catchability and differences in the ability to identify benthic species on board (the RV Isis being less well equipped for on board identification). As the BTS covers the whole North Sea, we selected data from ICES rectangles within the DCS.

All species were included in the analysis. Those not identified to species level are assumed different species to those, which are identified to species level.

4.1.3.2 Maps

Metric 9. Rarity

A species was defined as "rare" if it was present in less than 10% of all hauls, which is an arbitrary level, just as for the other datasets. Considering that the beam trawl is not designed for sampling benthos, the BTS data includes many species which are caught on occasion and therefore classified as rare. The absence of species (consider the small size of many in relation to the mesh size of the net) does not mean that they are absent in reality. The percentage occurrence in hauls was calculated for each species to determine whether or not the species can be considered "rare" (within the BTS sampling program and split by vessel). Rarity was calculated per $1/9^{th}$ ICES rectangle based on the mean value of the sums of "rare" species occurring per haul within the respective rectangle.

Metric 12. Species richness

Richness was defined as the number of species per haul. This was to avoid the problem of unequal numbers of hauls within different blocks assigned to points. In this way, the method is comparable to the one used for the other benthos datasets, where richness was also defined as number of species per sample. The selection of species used is therefore crucial to this parameter and should be taken into account in any interpretation. Points were assigned to each $1/9^{th}$ ICES rectangle based on the mean value of species richness per haul within the respective rectangle.

For the BTS-benthos, we show data per haul, similar to the Triple-D Data. The data of the RV Isis are shown in Figure 18. The map of rare species or species with a frequency of occurrence < 10% shows that rare species are most frequently encountered in the central and northern Dutch North Sea, although their frequency is also locally high in other part of the DCS. The map of species richness shows the same patterns. Since datapoint represent only 1 haul, it is clear that the sampling takes place at the steep part of the effort-species curve, that is, during fishing, only a small part of the total number of species present is sampled, so that many species occur in low frequencies.

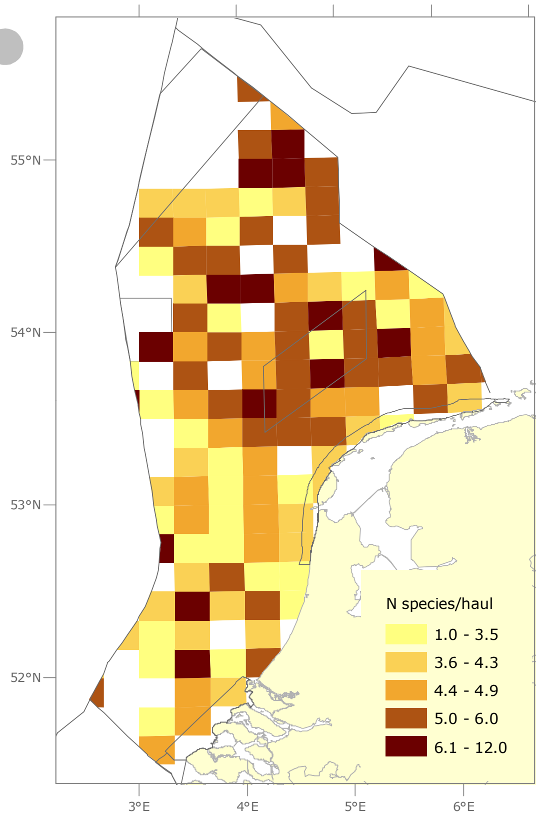
The data of the RV Tridens II are shown in the lower graphs of Figure 18. This survey covers only the northern part of the DCS, since the RV Isis and RV Tridens II perform complementary surveys, which however differ slightly in the gear they use, which is a reason to show the data separately. We show the data here, but the maps are not used for further calculation, since they cover only part of the DCS. Both evenness and species richness show larger values in the northern stations, which corresponds more or less to the findings of the RV Isis.

Figure 18. Upper graphs: Rarity (frequency of occurrence) and species richness of BTS Isis benthos.This survey covers the whole of the Dutch Continental Shelf. Lower graphs: Rarity (frequency of occurrence) and species richness of BTS Tridens II benthos. This survey covers only part of the Dutch Continental Shelf.

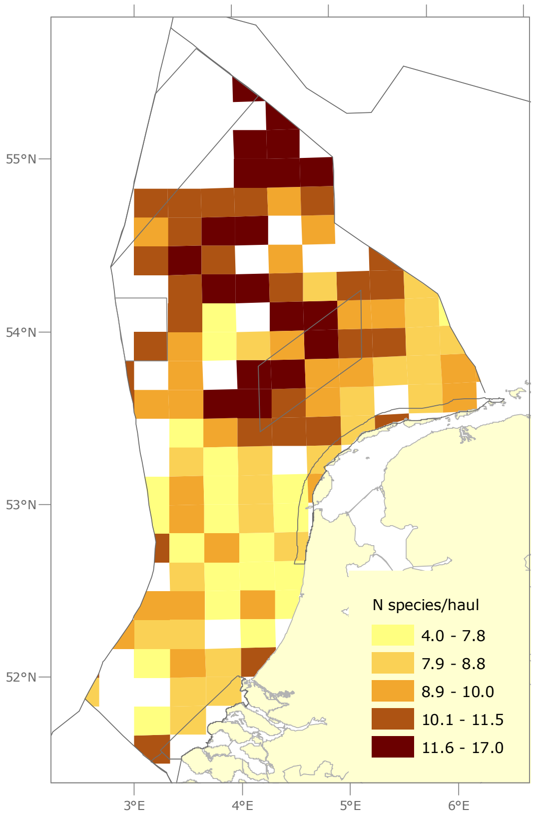
Symbol	Meaning
No symbol	Map serves as illustration
	Map of biodiversity metric used for further calculations
	Semi-final map (e.g. per survey or subgroup)
	Final map per species group

Figure 18

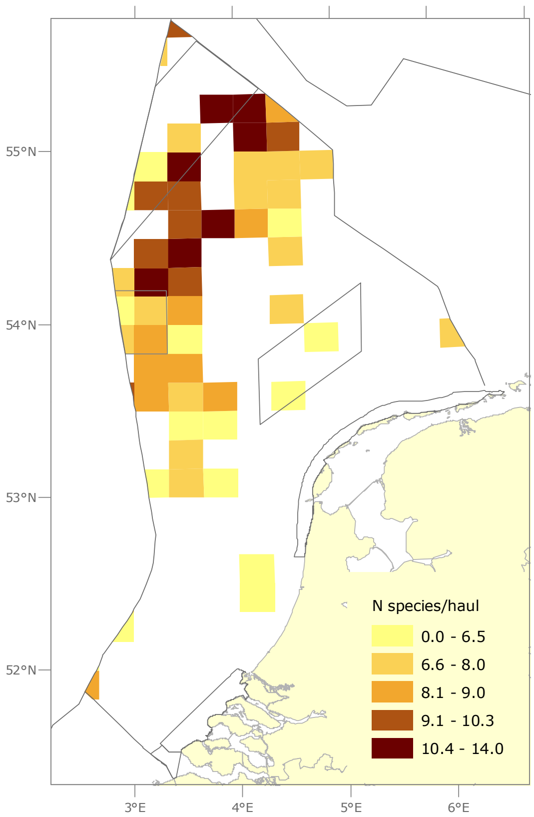
Benthos R.V. ISIS BTS rarity



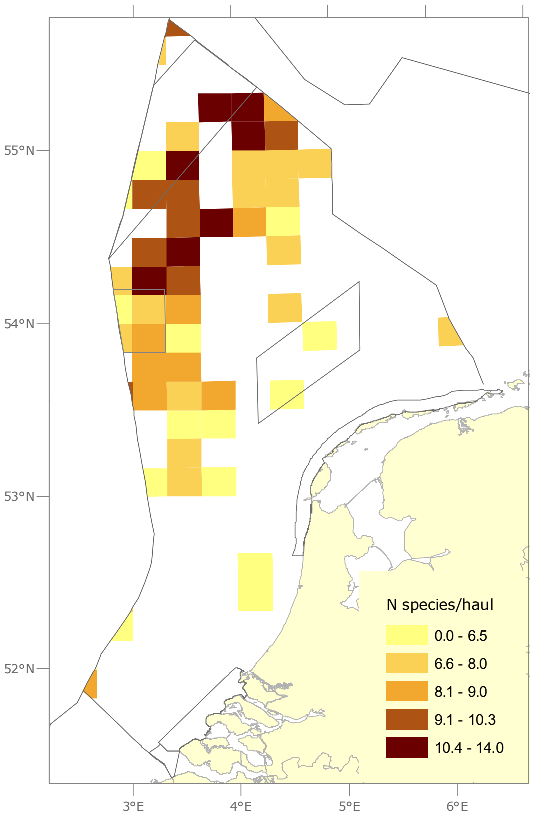
Benthos R.V. ISIS BTS richness



Benthos R.V.Tridens II BTS rarity



Benthos R.V. Tridens II BTS richness



4.1.4 Total benthos

Macrobenthos (BIOMON)

The final map for macrobenthos was constructed by combining 7 different biodiversity maps (those maps indicated with a grey dot) into a single metric as depicted schematically in Figure 2. The Frisian Front, Oyster Grounds and the whole northern part of the Dutch North Sea have the highest combined biodiversity metric values. The Cleaver Bank also forms part of high valued areas.

Megabenthos (Triple-D)

The Triple-D final map, based on 5 different metrics, indicated with grey dots, shows biodiverse areas east, southwest, north and in the Frisian Front, and less diverse areas on the Dogger Bank, the Cleaver Bank and the Southern North Sea. Note that Cleaver Bank data only contribute to one underlying map (density), and not to the other maps that contribute to the final map for megabenthos.

Megabenthos (BTS)

The BTS final map is only based on 2 maps, indicated with grey dots, which already are quite similar, yielding a pattern of somewhere in-between those of the two previous maps.

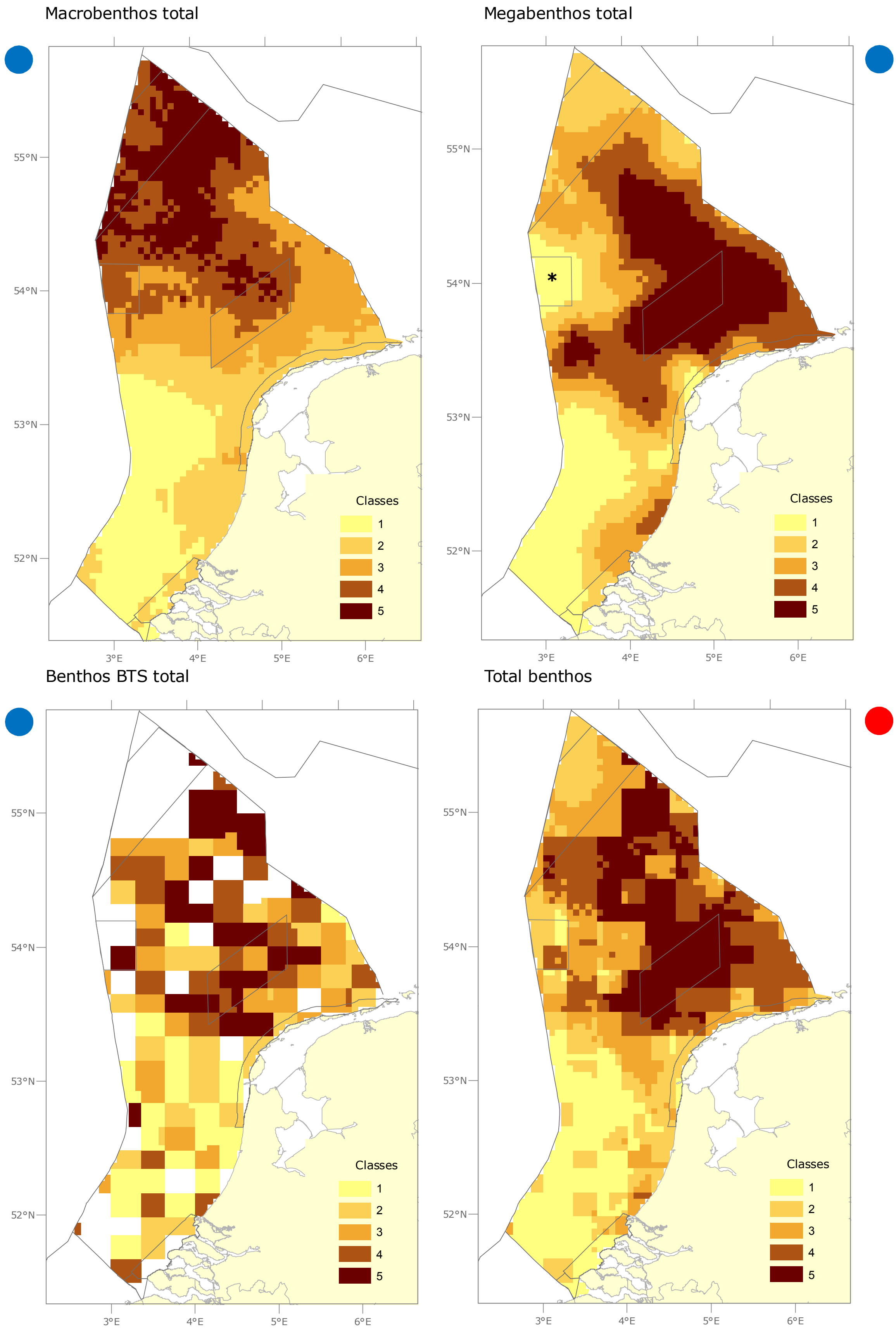
Total benthos map

The final map, all three final benthos maps combined, emphasises the importance of the Frisian Front area and north thereof, towards the Dogger Bank.

*Figure 19. Benthos Averaged biodiversity metrics for (A) macrobenthos (BIOMON + Cleaver Bank), (B) megabenthos (Triple-D + partly Cleaver Bank), (C) BTS and (D) the grand total, in which the three benthos maps have been combined. *Note that in figure B data for the Cleaver Bank could only partially be used (see section 4.1.2)*

Symbol	Meaning
No symbol	Map serves as illustration
	Map of biodiversity metric used for further calculations
	Semi-final map (e.g. per survey or subgroup)
	Final map per species group

Figure 19


Macrobenthos total
Megabenthos total
Benthos BTS total
Total benthos
55°N
54°N
53°N
52°N
3°E
4°E
5°E
6°E
*
Classes
1
2
3
4
5

4.2 Fish

4.2.1 Data and sampling methods

To calculate metrics of biodiversity, we used a number of ICES fish surveys (Table 2) performed by IMARES and foreign institutes. The scale of these surveys is the greater North Sea and they are designed for monitoring certain parts of commercial fish stocks, delivering tuning series for stock assessments. Hence, the spatial and temporal distribution of the surveys only allow to a certain extend for the study of fish biodiversity, due to selectivity and catchability issues (see below) of the non-commercial fish species.

In this study, we excluded fish data of surveys with limited spatial (some tens of kms) and temporal scales (few years), such as those for monitoring of offshore wind farms (MEP-NSW) or of the extension of the Rotterdam Harbour (Maasvlakte II). Other data that we did not use were those of observer programmes on board of commercial ships. Although such data provide information on both commercial sizes and smaller sizes and non-commercial species, sampling is irregularly in terms of temporal and spatial coverage.

4.2.1.1 Demersal trawl surveys

IBTS

The International Bottom Trawl Survey (IBTS) is executed yearly to produces recruitment indices for 8 species (herring *Clupea harengus*, cod *Gadus morhua*, whiting *Merlangius merlangus*, haddock *Melanogrammus aeglefinus*, saithe *Pollachius virens*, Norway pout *Trisopterus esmarkii*, mackerel *Scomber scombrus* and sprat *Sprattus sprattus*). The goals of the IBTS are:

- Produces the recruitment indices for the commercial species
- Fisheries independent monitoring of changes in commercial fish
- Monitoring of changes in non-commercial species
- Collecting hydrological data (Salinity and Temperature)

The spatial distribution of the survey in the North Sea is from 51° to 62°N. This area is fished by France, England, Scotland, Norway, Sweden, Denmark, Germany and the Netherlands.
The temporal distribution of the survey has changed over the years. The survey started in 1966 as the International Young Herring Survey and was executed in February. In 1981, the name was changed into the Young Fish Survey but was still executed in February. In 1990, the name changed into the IBTS and from 1991 to 1996 the survey was executed each quarter of the year. Since 1997, the survey is executed in the 1st and 3th quarter. The Dutch contribution is limited to the first quarter.

The design of the survey has also slightly changed. Since 1977, the survey is performed in a standardized way. However before 1998, not all participating countries used the same Grande Overture Vertical (GOV) trawl gear, and tow durations varied (Fraser et al. 2007). The GOV-trawl is a kind of ottertrawl that is kept open by two otter boards. This is different from a beamtrawl, where the beam is fixed and determines the spread of the net. The spread of the GOV differs and is affected by the depth and the speed. The door spread varies between 60 and 100 m and net height is around 5 m. This height makes it suitable for fishing on pelagic species and species that swim just above the bottom. The gearing is much lighter than a beam trawl, which makes it less suitable for catching flatfish species. The GOV geared with a net with a stretched mesh size of 16mm in the codend. The standardized duration of a haul is 30 min and the fishing speed is 4 knots, all hauls are done during day time.

The sampling design is stratified over so-called ICES-rectangles (1 degree longitude x 0.5 degree latitude). In each rectangle, two different countries perform at least 1 haul. Yearly about 600-700 hauls are executed in the whole North Sea. The IBTS does not catch small fish (< 10 cm), neither is the catchability great for the largest fish. The survey is limited in catching flatfish species or other species that can burry themselves into the sediment.

Due to the variable door width the surface fished cannot accurately be calculated. Therefore the analyses on the IBTS are done based on number per hour fished.

MIK

During evenings and nights of the IBTS in the first quarter of the year herring larvae are sampled. The larvae are caught with a plankton net, the so called MIK-net (Methot Isaacs Kidd-net, named after its developers). It is a dark net with a meshsize of 1.6 mm, the last meter of the net there is a meshsize of 500 µm. The opening of the net is a circle with a diameter of 2 m. The fishing speed is 3 knots. The net samples from the surface to 5 m above the seafloor and back. The sampling design follows the grid of the IBTS, 2 to 3 hauls are made in each ICES-rectangle.

Due to the oblique movement of the net, the MIK catches pelagic species, but due to the low speed and the small mesh size it is not a real pelagic fish net. In this study, MIK data on three pelagic fish species are used: the transparent goby (*Aphia minuta*) and two species of pipefish grouped together in *Syngnathus* sp. (*Syngnathus acus* and *Syngnathus rostellatus*).

Table 12. Characteristics of fish surveys.

	IBTS	MIK	BTS	DFS	SNS
Net	GOV	MIKnet	8m beam trawl	6m beam trawl	6m beam trawl
Width (m)	20		8	6	6
Height (m)	5		1	1	1
Meshsize (mm stetched)	16	1.6 mm to 500 µm	40	20	40
Duration (min)	30	10-20	30	15	15
Speed (knots)	4	3	4	2-3	3,5-4
Period (months)	Q1 & Q3	Jan-Feb	Aug-Sept	Sept-Oct	Sept-Oct
Area	Total North Sea		Southern and central North Sea	Coastal area	Transects in front of the Dutch to Danish Coast.
Target species	Whiting, Cod, Haddock, Herring, Sprat	Herring larvae	Plaice, Sole, Dab	Plaice, Sole, Dab, Shrimp	Plaice, Sole, Dab

4.2.1.2 Beam trawl surveys

We used data of three annual North Sea beam trawl surveys executed by IMARES. The target species of the beam trawl surveys are flatfish, mainly plaice *Pleuronectes platessa* and sole *Solea vulgaris*. Compared to the GOV used in the IBTS, the beam trawl moves tighter over or even in the bottom, leaving little space for flatfish to escape. The gear has however a lower height, making it easier for species living close to the bottom to escape over the net. Because the exact width of the gear is known, the total area trawled can be calculated, and hence the abundance in numbers per fished area.
Per haul all individuals (or a known fraction) per species are measured up to the cm (or 0.5 cm for herring *Clupea harengus* and sprat *Sprattus sprattus*). Age, weight and maturity are only determined for target species.

SNS

The Sole Net Survey (SNS) is designed for catching 1 to 4 year old sole and plaice. The SNS has been carried out in September–October from 1969 to the present (except in 2003). Hauls (stations) are situated on approximately fixed transects which run parallel or perpendicular to the continental coast. The survey uses two 6-m beam trawls with a standard ground rope and four tickler chains with a cod-end stretched mess size of 40 mm, haul duration of 15 min and a towing speed of approximately 4 knots.

BTS

The BTS has been carried out in August and September since 1985 and aims for the older year classes of plaice and sole. It covers the south-eastern North Sea using the RV Isis. Since 1996, the BTS has been expanded to the western, central and northern North Sea using RV Tridens II, which has gear similar to that on RV Isis with the exception of a flip-up rope to allow fishing on rougher grounds. The gear is a 8 m beam trawl with 4 chains from the shoes and 4 tickler chains from the ground rope. The duration per haul is approximately 30 minutes and the towing speed is around 4 knots.

The sampling design of the BTS is similar to that of the IBTS. A specified number of hauls is executed per ICES-rectangle. The number of hauls in each rectangle covered by the RV Isis is larger (1 to 4 hauls) than in the area covered by the RV Tridens II (1 haul).

In this project benthic data of the BTS is also used. Benthic species are identified and counted, but not measured or individually weighed. Benthos is weighed in total (or a known part) on board of the RV Tridens II.

DFS

The Demersal Fish Survey (DFS) is executed in the Dutch to Danish coastal area of the North Sea since 1969. Target species are 0 and 1 year old sole and plaice as well as brown shrimps and it takes place in October/November. The survey uses two 6-m beam trawls with a cod-end stretched mess size of 20 mm, a haul duration of 15 min and a towing speed of approximately 3 knots.
The sampling design is stratified by depth and the locations of the hauls are fixed over the years.

4.2.1.3 Selectivity and Catchability issues

Overall limitations of fish surveys are that the gear and speed of the vessel are designed for target species. In contrast to commercial fisheries that target larger individuals of a species, the surveys are developed for earlier life stages. Therefore, they use smaller mesh sizes and a lower speed. All fish surveys (except the MIK) used in this study are targeting demersal species, e.g. species that are located on or close to the bottom. The GOV also targets pelagic species (see above). The species higher up in the water column, pelagic species, are only caught when the net is hauled or cleaned on the surface.

Each gear has its own catchability for a specific length of a certain species. With a high catchability this means that a large part of the specific length class of that species is caught. In Figure 20 it can be seen that even for the target species this catchability differs enormously between length classes and fish species, ranging from not even catching 10% of the present fish to catching 80-90% of the present fish. With a catchability of 10%, there is a high change of not catching these fish while they are there. In 90% of the hauls they will not be caught even though they are present. This means that if you do not catch a species this does not mean it is not there. With high abundant species, like most commercial species, this is not a big issue. They are so abundant that even with a low catchability they will be recorded in a haul. However, for low abundant species, the rare species that determine the total biodiversity and often the difference in biodiversity indices, this is a much bigger issue. A large number of hauls is needed before all species in an area are caught, let alone all length classes of all species (Figure 21).

The catchability of fish species is not constant. It depends amongst others on the sediment type, hydrological conditions, and behaviour of species. The gear behaves differently on different sediment types, affecting the catchability. When fishing takes place along the current, fish can easier outswim the gear and escape. Similarly, under warmer conditions, fish can swim longer/faster. The behaviour of the fish also affects the catchability: when fish are more active they are easier to catch. Also when fish aggregate for to spawn they are easier to catch.

The surveys are limited to locations where they can fish. The sampling is often such that the hauls are randomly distributed within a stratified grid. However, obstacles and seafloor conditions make the design less random. There are restricted areas, e.g. around oilrigs and wind farms and there is a high risk of losing gear due to shipwrecks. In addition, most gear is not suited for fishing in very rocky areas or on biological structures like musselbeds. For example, only a very limited number of fishing hauls is done on the Cleaver Bank. Biologically rich areas, such as ship wrecks and rocky areas will therefore be underrepresented.

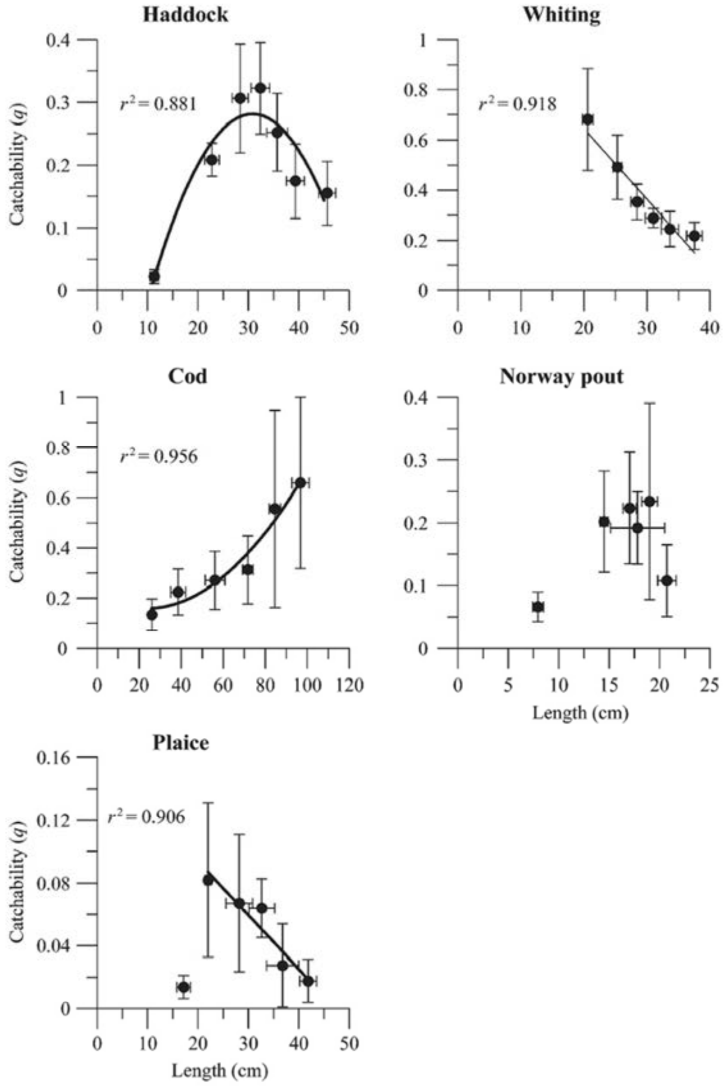


Figure 20. Fish. Catchability (q) at length of some of the target species of the IBTS (Fraser et al. 2007).

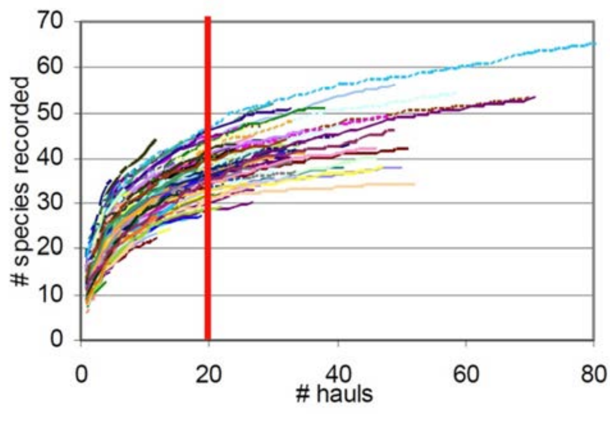


Figure 21. Average number of species recorded after 1… n hauls within a rectangle (based on 20 sequences of randomly selected hauls, based on the IBTS (Daan 2006b).

4.2.1.4 Identification of species

Due to difficulties in species identification, it is not done identically in all surveys or by all countries, so that errors may occur. Furthermore, some taxa were found to consist of more than one species. This is another complication in determining species richness.

When possible we used the species-level, however in some cases species identification is considered so problematic that only genus-level is reported or considered valid. This is done for two sandeel species, Raitt's sandeel *Ammodytus marinus* and lesser sandeel *Ammodytus tobianus*, that are grouped in the genus Ammodytus. The species greater sandeel *Hyperoplus lanceolatus* and Corbin's sandeel *Hyperoplus immaculatus* are grouped in the genus Hyperoplus. The species *Salmo trutta trutta,* trout *Salmo trutta* and salmon *Salmo salar* are grouped in the genus *Salmo*. The species Nilsson's pipefish *Syngnathus rostellatus* and Greater pipefish *Syngnathus acus* are grouped in the genus *Syngnathus* and the species Sand goby *Pomatoschistus minutus*, Common goby *Pomatoschistus microps* and Lozano's goby *Pomatoschistus lozanoi* are grouped in de genus *Pomatoschistus*.

4.2.1.5 Species selection

In this study we followed the species selection by Daan (2000) who excluded fresh water fish, vagrant species and species from the shelf slope (present in the Norwegian Trench). Furthermore, he selected species with a clear affinity with the North Sea, e.g. spawning in the North Sea. Species with a really low catchability*,* eel *Anguilla anguilla*, three Labridae species, Crystal goby *Crystallogobius linearis* and Two-spotted clingfish *Diplecogaster bimaculata* were excluded.
In contrast to Daan (2000), we decided on including Sand sole *Pegusa lascaris*, Blue whiting *Micromesistius poutassou* and John Dory *Zeus faber* in the analysis. This is done based on their higher occurrence in the last ten years.

4.2.1.6 Combining surveys

For the calculation of some of the metrics, we have combined the data of the different fish surveys. This is tricky due to the differences in timing and the differences in catchability. In case where abundance is used the combination of data is avoided. In case of the occurrence of species or sizes of fish the surveys are combined.

4.2.2 Maps

Metric 8. Trends

Trend analyses are based on data from the IBTS (quarter 1 & 3) and BTS (quarter 3) for the period 1985-2009 and in the area between 51 and 56 °N. For the BTS only the data from the RV ISIS where used, which covers most of the DCS. Data is only included in the analysis for the ICES rectangles if at least 20 years out of 25 were sampled. Species are included if they were sampled in at least 5% of the hauls and if they are on the list proposed by Daan (2000). Data consist of estimated number of fish caught per hectare (BTS) or the number fish caught per hour (IBTS).

For most species the fraction of hauls in which the species was not caught is high. By hauls we mean the total number of hauls used for the analysis (see above). Therefore, the analysis is based on (a) presence/absence of the species if it was sampled in 5% - 90% of the hauls and (b) if the species was sampled in more than 90% of the hauls the analysis was based on abundance. The last occurred for plaice (*Pleuronectes platessa*), sole (*Solea solea*), dab (*Limanda limanda*) and whiting (*Merlangius merlangus*) in the BTS data. In the first quarter of the IBTS this occurred for plaice, sprat (*Sprattus*

sprattus), herring (*Clupea harengus*). and whiting and in the BTS data from quarter three, this occurred for plaice, dab and whiting. Two methods were chosen to estimate the current trends for each species:

1) GAMs (generalized additive models) where used to fit the trends. A significant effect of year means that there are significant trends. However, because of the non-linear nature of this model, significant trends can be both positive and negative within a species. Therefore the graphs resulting from this analysis are judged visually. See Figure 22 for an example of GAM trends for cod *Gadus morhua* and plaice *Pleuronectes platessa*.
2) A linear trend was fitted through the data.

In this way trends were estimated for 40 species, of which 38 were analysed with a presence absence model, and 51 were excluded from the analysis because they were caught in less than 5 % of the hauls in each survey.

The assignment of classes to trends was done as follows: if only positive flags where assigned to the trend, or if the positive flags outnumbered the neutral flags, the species trend was considered positive. The same method was applied for negative and neutral flags. If a species was given both negative and positive flags the trend was also considered as neutral. If a species was caught in less than 5 % of the hauls in all the datasets, it was assigned a neutral trend, because of lack of information. All other (including those for which no analysis was performed) species were considered to have a neutral trend.

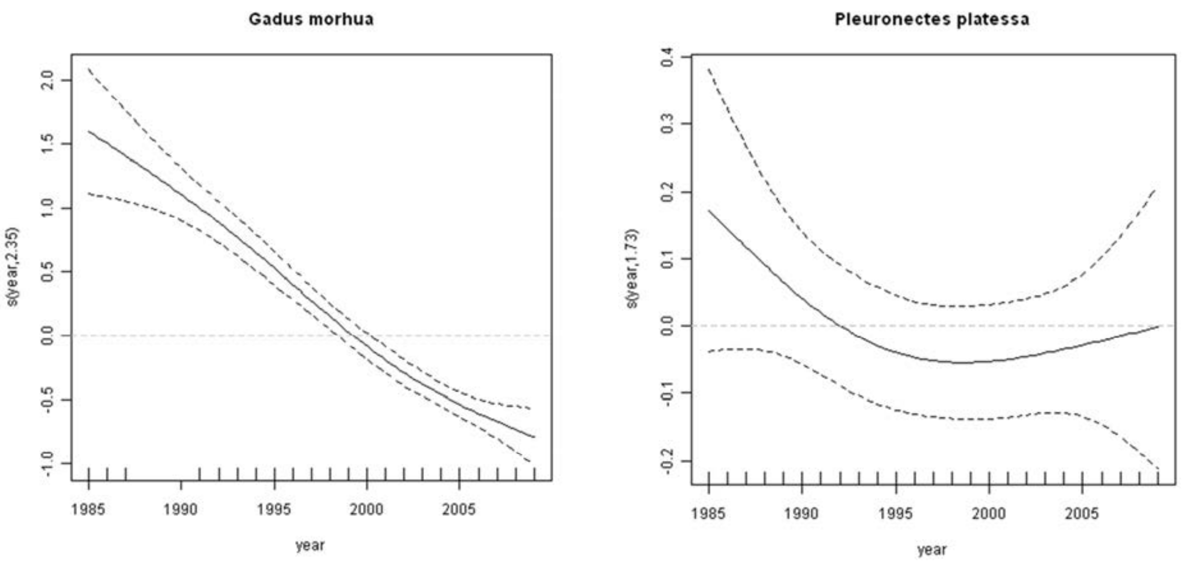


Figure 22. Example of estimated smoothing curves from GAMs. the left graph is for cod data in the IBTS survey (quarter 3) and the graph on the right is for plaice in the BTS survey. The y-axis shows the contribution of the smoother to the fitted values. The solid line is the smoother and the dotted lines 95% confidence bands. The value of the y-axis indicates the amount of smoothing (1 = linear). In this example, cod has a significant negative trend and plaice is not significant.

We estimated trends for 43 species in at least one of the three datasets for a 25 year period (1985-2009). 55 Species were excluded from the analysis because they were caught in less than 5 % of the hauls in all three datasets. Twelve species had a positive trend (*Agonus cataphractus, Arnoglossus laterna, Buglossidium luteum, Callionymus lyra, Callionymus reticulatus, Echiichthys vipera, Enchelyopus cimbrius, Microstomus kitt, Mullus surmuletus, Myoxocephalus scorpius, Pomatoschistus sp. and Sprattus*

sprattus) and 7 species had a negative trend (*Cyclopterus lumpus, Gadus morhua, Gasterosteus aculeatus, Merlangius merlangus, Sardina pilchardus, Squalus acanthias, Trisopterus minutus*). All other species where considered neutral. In Appendix C (Table 20) the full list is provided with the assigned trend per species for each survey and quarter.

In Figure 23 we plotted the number of species with a negative trend in the period 1985-2009, present per 1/9 ICES rectangle, using presence/absence data from 2000-2009, as used for estimating species richness. Towards the western fringe of the DCS, there appear to be more species with a negative trend, but this pattern is not very clear. Note that this map is based on presence/absence of species and not on densities, which could alter the results.

Metric 9. Rarity

For fish, we use the index of rarity as described in Daan (2000), in which two aspects play a role: numeric density and geographic distribution. Numeric density is not always a straight forward measure for rarity. Smaller species on the base of the foodweb are more numerous than those at the top, which is not directly relevant for rarity. Numeric density fluctuates in natural situations. A 50% change in density in a small population is similar to a 50% change in a large population, however the absolute numeric change in a large populations is much larger. Therefore, it is relevant to give less weight to large values, which is done by log-transformation or square root transformation. Rarity in distribution is easier. An area can be divided in smaller blocks, and the number of blocks in which the species occurs can be counted.

Both aspects are combined in the index of rarity, which is described in Daan (2000). The index for rarity of fish is therefore different from that for benthos, in which only the frequency of occurrence is taken into account, following Lavaleye (2000). Hence, we chose to follow existing methods. For the fish calculations we choose a grid size of 1/9 ICES-rectangle. For each grid cell the mean density is calculated per species (j). Rarity per species (j) is then calculated as:

$$z_j = (\frac{n}{n_j * \sqrt{N_j}}) / \sum_{j=1}^{j} (\frac{n}{(n_j * \sqrt{N_j}})$$

Where n is the total number of grid cells fished, n_j the total number of cell in which species j is found and N_j an index of the total density (sum of all densities) of species j. By dividing by the summation the index is normalised, such that the sum of all z_j is 1. The rarity of species j in cell k is:

$$z_{jk} = \left(\frac{N_{jk}}{N_j}\right) * z_j$$

The rarity-value of the whole cell is then calculated as:

$$z_k = \sum_{j=1}^{j} z_{jk}$$

The sum of all z_k is again 1 (Daan 2000).

For these calculations the data of all fish surveys described are used. The calculations are done based on the list of selected species (Appendix C) and we only used the data of the last ten years (2000-2009).

The distribution of rare fish on the Dutch North Sea appears to follow no clear pattern. Areas with high values border areas with low values, leading to a checkerboard like distribution of rarity (Figure 23).

Metric 10. Large specimens

Fisheries for consumption target most often the bigger species, especially the larger individuals of these species.
The selectivity of most fishing techniques, is such that mainly larger individuals are caught, and then not only those of the target species. The effect of fishing pressure on the size structure of fish communities has been shown in numerous empirical studies (Bianchi et al. 2000, Daan et al. 2005). Reducing the larger individuals of species will reduce the spawning stock biomass (SSB) of a species and thus the reproductive capacity of the population. For commercial species there is management to keep stocks above a threshold level of SSB (metrics SSBba or SSBmsy).For other species this is just as important for ensuring reproduction and thus survival of the species.

Of almost all North Sea fish species the maximum length (Lmax) is known. We have used maximum length as reported in Engelhard (2011). For each species maps of presence/absence per 1/9 ICES rectangle were made for individuals larger than 75% of Lmax of the specific species. The occurrence maps are based on all data collected in the last 10 years (2000-2009) from all fish surveys.

Note: large individuals of a species can mean that they are only about 5 cm in length (*Amphia minuta*), while other individuals have to be larger than 225 cm (*Dipturus batis*) to be included in the map.

Figure 24A shows where individuals of species occur with a length of at least 75% of the maximum length (Lmax). The highest numbers appear to be at the soutwestern part, the coastal zone and northeastern part of the DCS. Note that such individuals include small species as well.

Metric 11. Large species

The large species metric focuses on species with a large maximal length. The resulting map shows areas where potentially large growing species (Lmax >90 cm) presently occur.

Fisheries for consumption target most often the bigger species, especially the larger individuals of these species. The selectivity of most fishing techniques, is such that mainly larger individuals are caught, including those of non-target species.

The effect of fishing pressure on the size structure of fish communities has been shown in numerous empirical studies (Bianchi et al. 2000, Daan et al. 2005). This pressure is highest on the larger species, that are not only caught better, but often take a longer time to reach maturity and if they are able to reach maturity, they have a lower productivity. For example, the composition of rays and skates in the North Sea changed in such a way that the species with the lowest length and/or age at maturity, in this case the starry skate, dominates the community. The length–frequency patterns have changed accordingly, and illustrate the paucity of individuals larger than 79 cm. This means that all the breeding females, and a large majority of the juveniles, of Common skate *Dipturus batis*, Shagreen skate *Leucoraja fullonica* and Thornback ray *Raja clavata* have disappeared, whilst the other species may have lost only the very largest individuals (Walker & Hislop 1998). To reach good environmental status (GES), by maintaining biological diversity, it is important that these larger species get the possibility to reach length at maturity and contribute to the sustainability of the population.

The data used is the presence/absence of species per 1/9 of an ICES-rectangle, of the data set of all surveys combined. Only the occurrence in the last 10 years is used (2000-2009). We selected species with a Lmax>90 cm and used the presence/absence data on these species to produce a map with summed numbers of species per 1/9 ICES rectangle. Choosing a higher Lmax of 100 cm would leave out some important elasmobranch species such as starry skate *Amblyraja radiata* and thornback ray *Raja clavata.*

Figure 24B shows the distribution of species that could potentially grow large (Lmax>90 cm). Again this is not a map of large individuals, but of species that potentially can grow large. Larger growing species appear to occur mostly in the northern part of the DCS.

Figure 27 shows the number of fish caught per hour larger than 40 cm. This is an extra map to provide some more information on distribution of larger fish.

Metric 12. Species richness and species evenness

Species richness is calculated as the number of species in 20 hauls per 1/9 ICES rectangle. With 20 hauls, most species are represented (see Figure 21). If less than 20 hauls were available, we randomly choose one or more hauls from adjacent 1/9 ICES rectangles. In this way, we tried to include as many fish species as possible. Species evenness is calculated as the Shannon-Wiener index, using the same dataset (see Chapter Appendix A).

Figure 24C and D show the species richness in Quarter 1 (Q1) and Quarter 3 (Q3) of the IBTS data. The difference between the two maps is intriguing. In the area around the Cleaver Bank, the maximum species richness in winter (Q1) is 39-50 species (out of the selected 95 species), while in summer (Q3) it decreases till average values of around 30 species. In the Southern North Sea, the species richness appears to be low in Q1, but higher in Q3. Hence, there is a clear temporal difference in patterns. Note that the scales of both maps are not the same. In Figure 28D the combined map is shown for which the highest values per area were taken from the other two maps. The western part of the central North Sea and the area in front of the Voordelta appear to contain the highest number of species based on these two quarters.

The patterns in species evenness in Q1 and Q3 (Figure 25A+B) are more or less similar, with higher values in the southern and northern part and lower values in the central part of the North Sea. In Figure 28D) a combined map is shown, for which the highest values per area of each map were taken. This map also shows the pattern described above.

Figure 23. Fish (A) Number of species per 1/9 ICES rectangle showing a negative trend in the period 1985-2009 (B), rarity calculated according to Daan (2000)

Figure 24. Fish. (A) Number of fish species per 1/9 ICES rectangle of which individuals >75% of Lmax were present. NB These include also small fish species. (B) Number of species per 1/9 ICES rectangle that have a Lmax >90 cm. (C) Species richness in the first quarter and (D) in the third quarter.

Figure 25. Fish. (A) Species evenness in the first quarter, (B) species evenness in the third quarter, (C) Species richness: highest value (Q1 and Q3) per 1/9 ICES rectangle (D) Species evenness: highest value (Q1 and Q3) per 1/9 ICES rectangle.

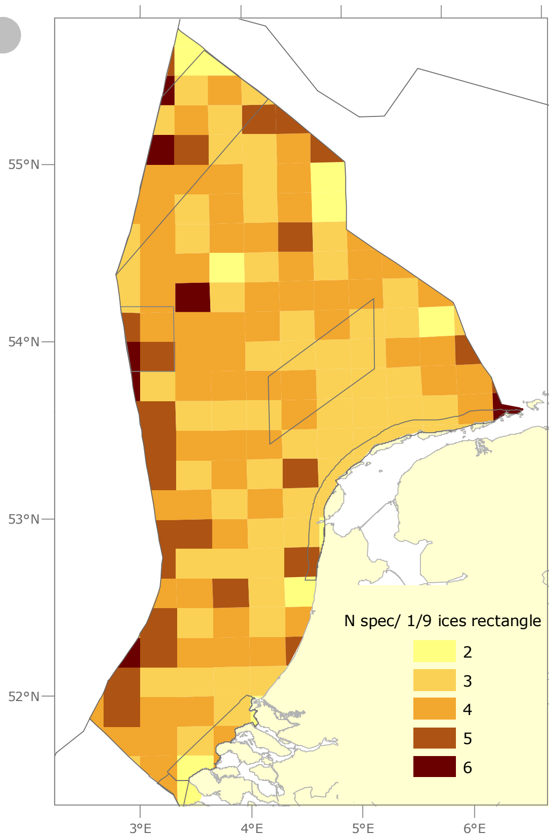
Figure 26. Fish. Combined biodiversity metrics

Figure 27. Fish (A) Number of individuals >= 40 cm/h per 1/9 ICES rectangle, for different surveys. This is an extra map, as input for the discussion.

Symbol	meaning
No symbol	Map serves as illustration
	Map of biodiversity metric used for further calculations
	Semi-final map (e.g. per survey or subgroup)
	Final map per species group

Figure 23

Fish negative trends



Fish rarity

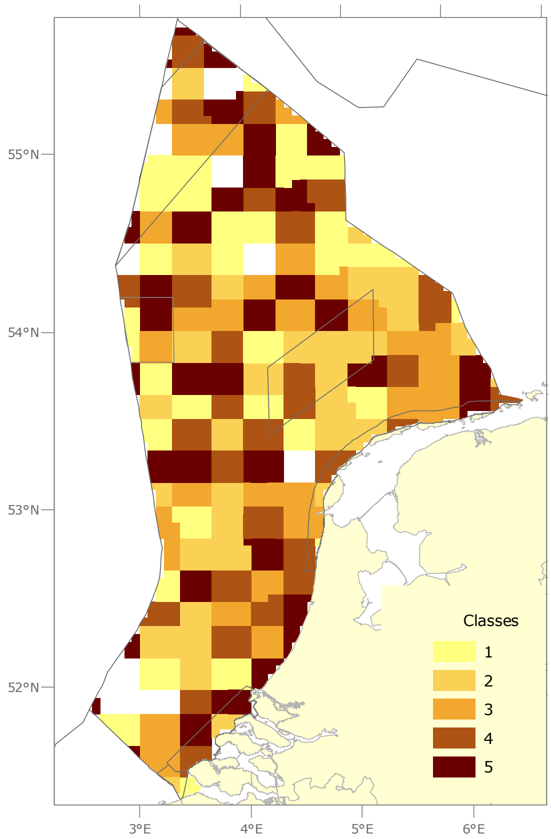


Figure 24

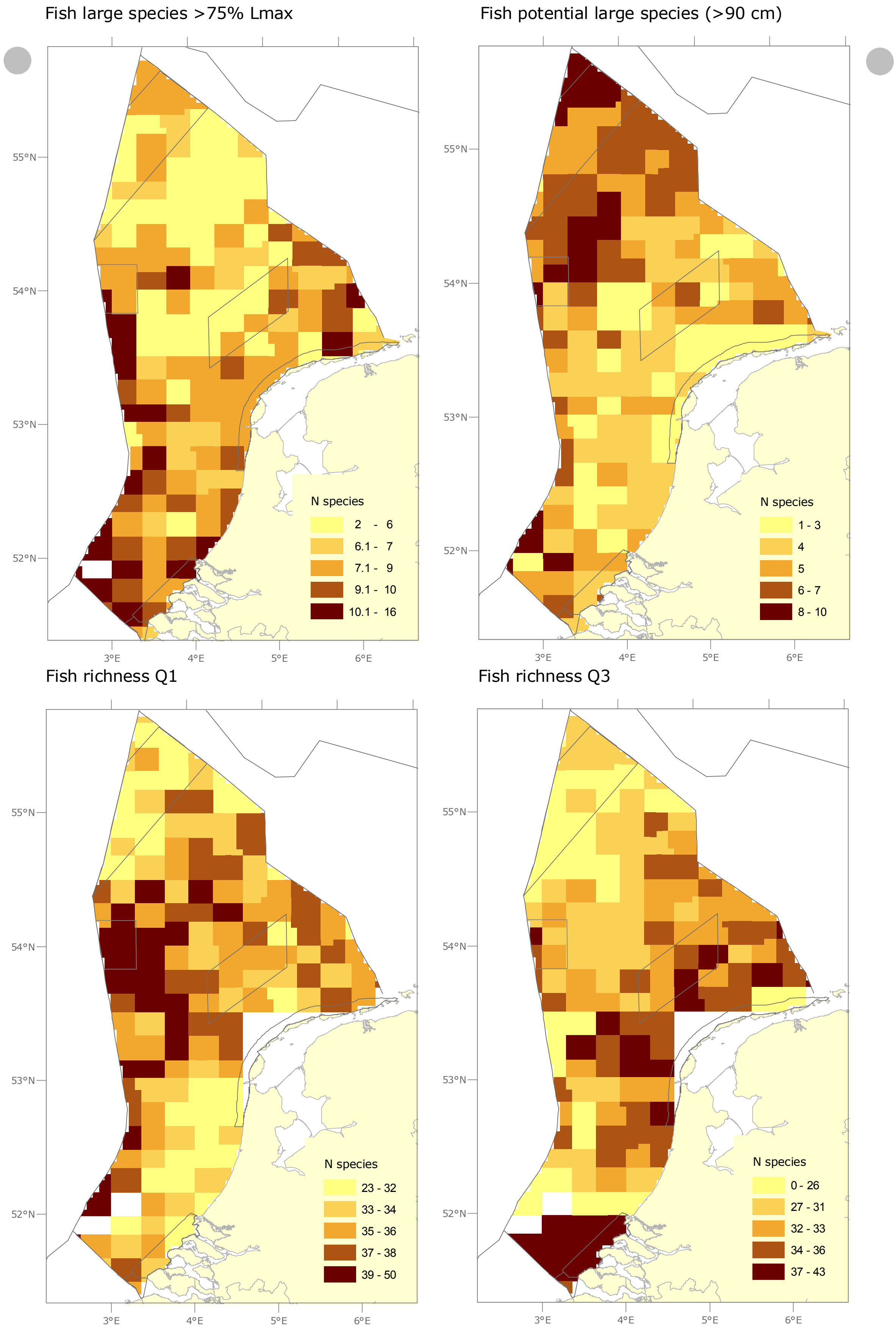
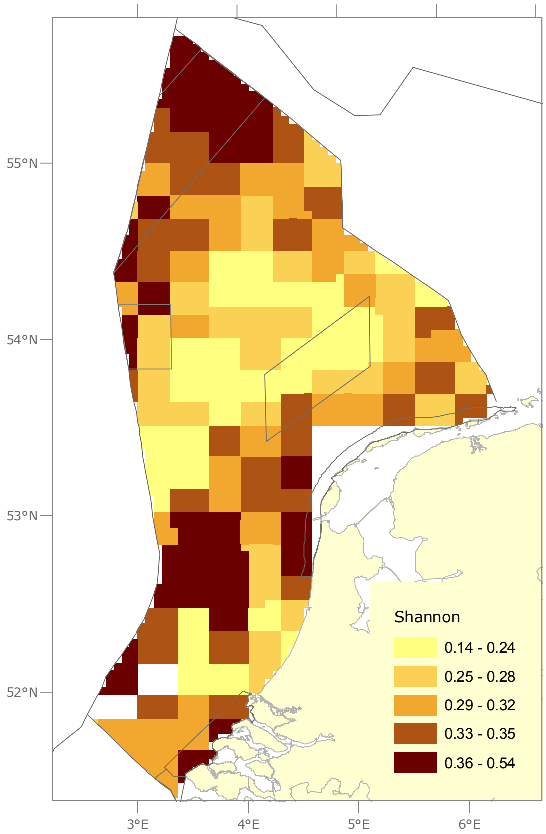
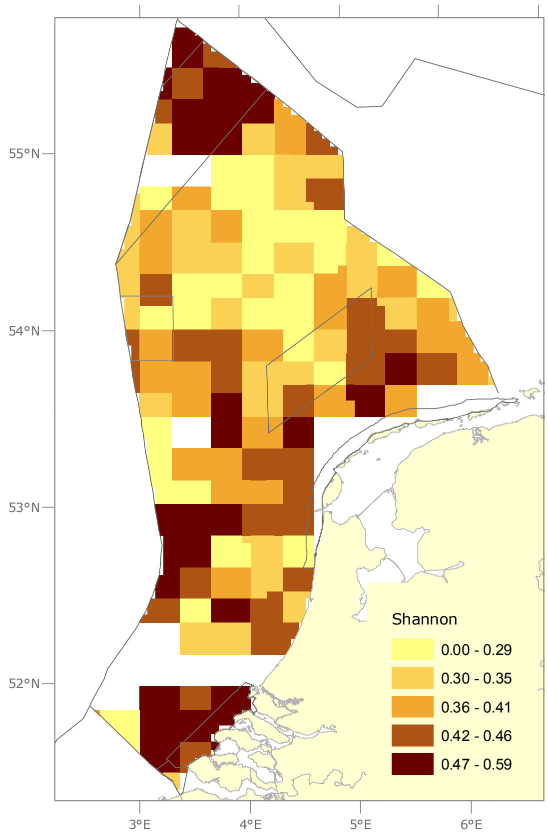

Fish large species >75% Lmax
55°N
54°N
53°N
52°N
3°E
4°E
5°E
6°E
N species
2 - 6
6.1 - 7
7.1 - 9
9.1 - 10
10.1 - 16
Fish potential large species (>90 cm)
N species
1 - 3
4
5
6 - 7
8 - 10
Fish richness Q1
N species
23 - 32
33 - 34
35 - 36
37 - 38
39 - 50
Fish richness Q3
N species
0 - 26
27 - 31
32 - 33
34 - 36
37 - 43

Figure 25

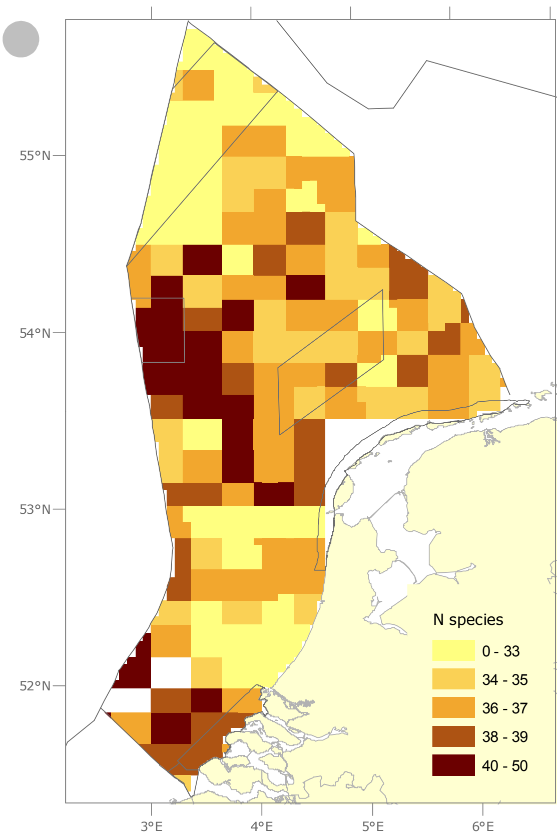
Fish evenness Q1



Fish evenness Q3



Fish richness Q1Q3



Fish eveness Q1Q3

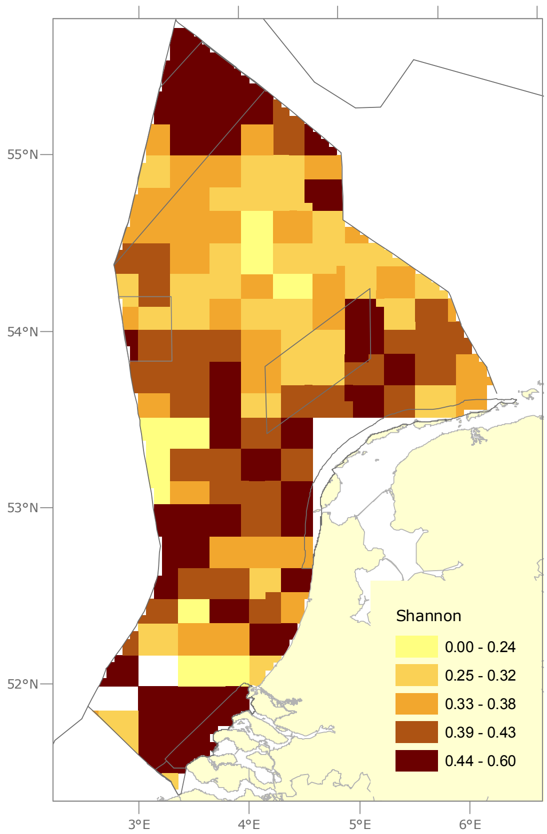


Figure 26

Fish total ecopoints

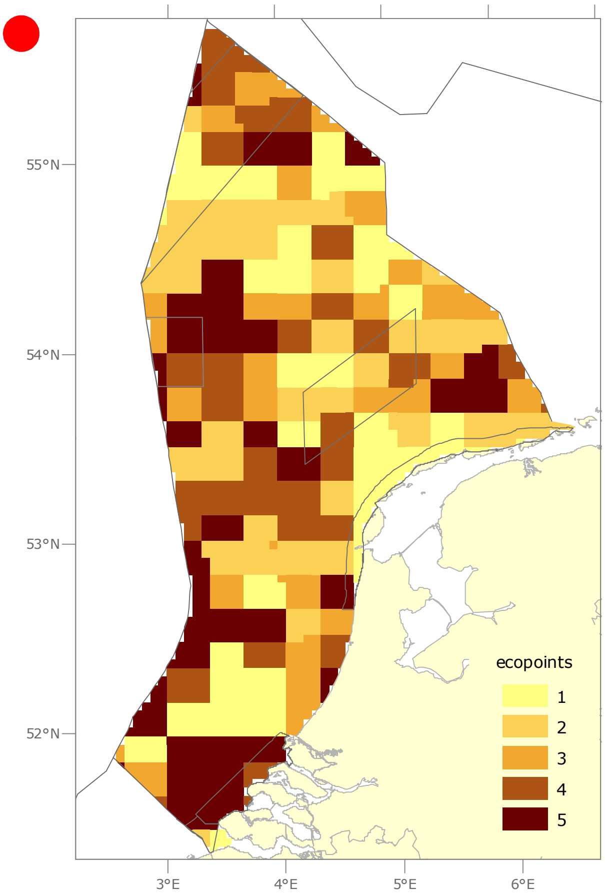
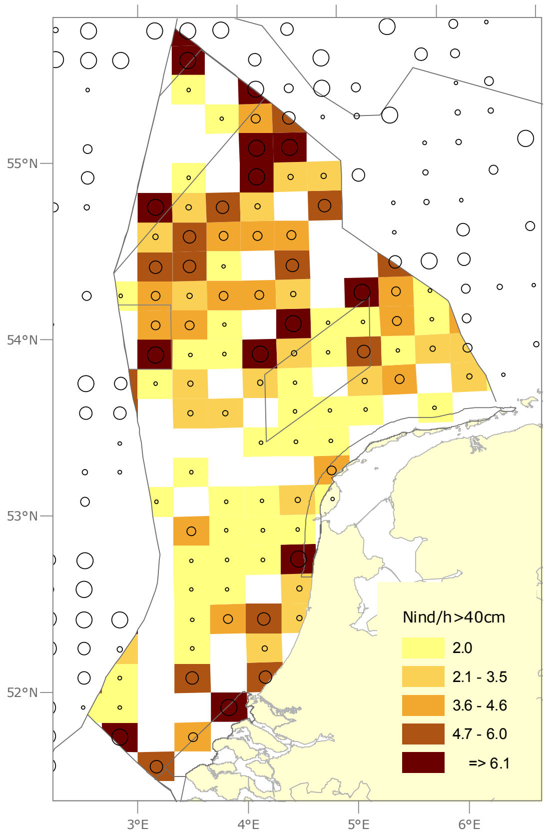
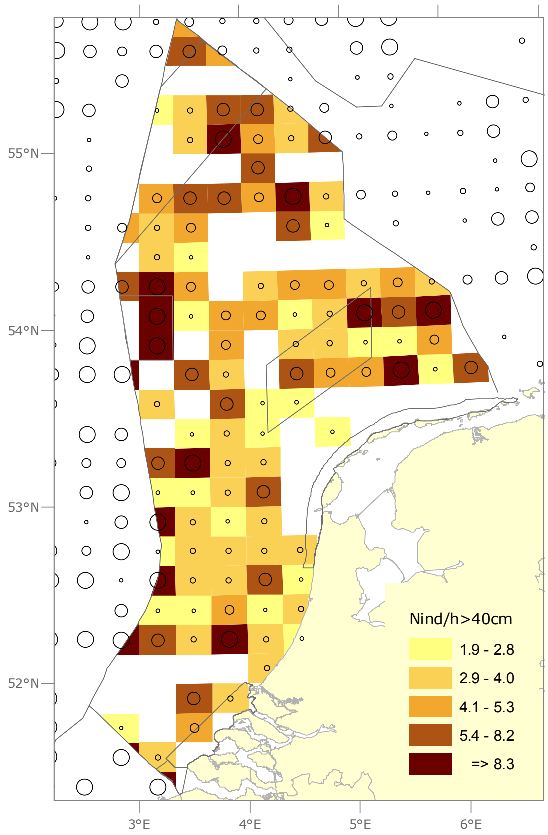


Figure 27 (Extra maps)

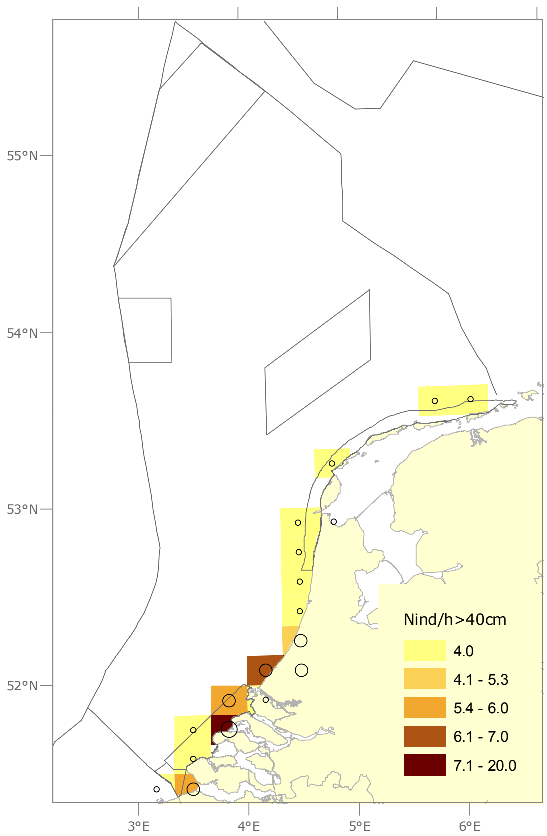
Fish BTS mean Nind/h >40 cm



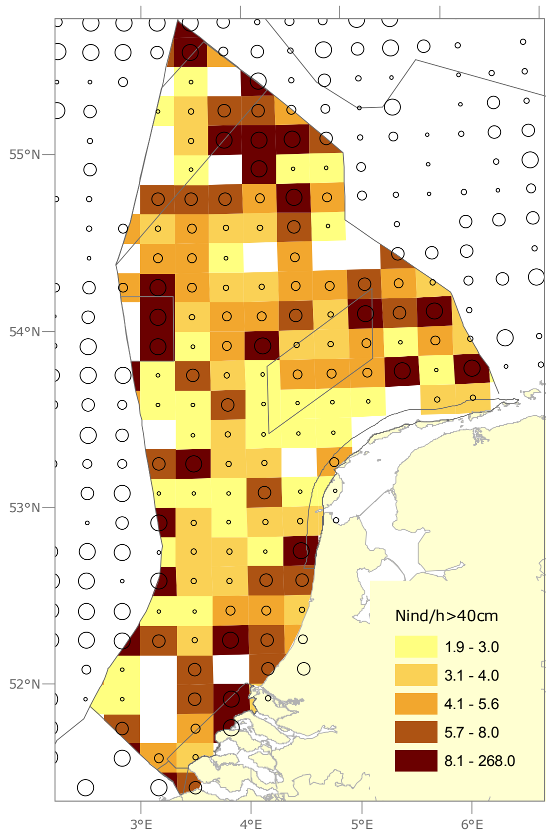
Fish IBTS mean Nind/h >40 cm



Fish DFS mean Nind/h >40 cm



Fish MAX all surveys mean Nind/h >40 cm



4.3 Seabirds

4.3.1 Data and sampling methods

Data on seabird densities and distribution is available from two sources: aerial surveys from the Rijkswaterstaat Waterdienst (RWS, Ministry of Transport, Public Works and Water Management) monitoring scheme and ship-based surveys stored in the ESAS (European Seabirds at Sea) database. From both datasets, only data from 1991 till 2008 was analysed.

Aerial surveys

Starting in late 1984, the distribution of seabirds has been surveyed bimonthly by means of aerial surveys. The bimonthly sampling design ensures that the dataset covers all periods relevant for the selected species. The extent of the survey spans the entire DCS.

Ship-based surveys

The ESAS database is composed of ship-based surveys which are added on a project basis. Therefore, effort is unevenly spread over both years and months. Overall, this dataset covers all periods relevant for the selected species, but due to many missing years is unable to trace interannual variation within small plots. There is also considerable spatial variation.

Selectivity issues

Aerial surveys differ from ship-based surveys in several aspects, most notably for the reduced ability to identify certain sets of species to species level. Most important in this respect are divers and auks. Most common species, however, can be reliably recorded and identified from both platforms.

Identification of species

Both aerial and ship-based surveys have been carried out by experienced observers, familiar with all species regularly occurring in the study area.

Species selection

Considered seabird species include those that occur annually on the DCS in sufficient numbers to warrant reasonable density estimates. This excludes therefore all species of shearwater and storm-petrel, the rare skuas (Pomarine *Stercorarius pomarinus* and Long-tailed Skua *Stercorarius longicaudus*), Sabines Gull *Xema sabini* and also some species that are never observed during aerial surveys and almost never during ship-based surveys, such as Horned Grebe *Podiceps auritus*, European Shag *Phalacrocorax aristotelis* and Black Guillemot *Cepphus grylle*. The resulting list is shown in Appendix D.

4.3.2 Maps

Specific bird values

Seabirds show large temporal variation in their use of the Dutch Continental Shelf. In contrast to the other groups (benthos, fish and mammals), we decided to focus on temporal variation of seabirds, and not on actual metric values. The so-called specific bird values are the sum of different scores (scale 1-5) for the 5 biodiversity metrics that are described below and are listed in Table 23. Maps are produced per 2 monthly period, which correspond to the aerial survey frequency (see above). To produce maps, specific bird values are calculated per 5x5 km grid cells.

Whenever data were not available at all, the 5x5 km gridcell was left empty (white). The final map (all seasons) was constructed by taking the highest value per gridcell from all 2 monthly periods.

Metric 4. Resilience

To scale the birds for this metric we considered average clutch size (X), whether or not the species can produce replacement clutches (Y) and mean age at first breeding (Z) (values taken from Nettleship & Brikhead (1985) for alcids and from Cramp & Simmons for the remaining species), and calculated using the formula:

$$(X+Y)/Z$$

where Y could be either 0 (no replacement clutches); 0.5 (replacement clutches only in part of the distribution range) or 1 (replacement clutches common when the first clutch is lost). This resulted in values ranging from 0.1 (Northern Fulmar) to 7.3 (Greater Scaup) as listed in Appendix D.

The metric values were re-scaled to a scale of 1- 5 (Figure 28).

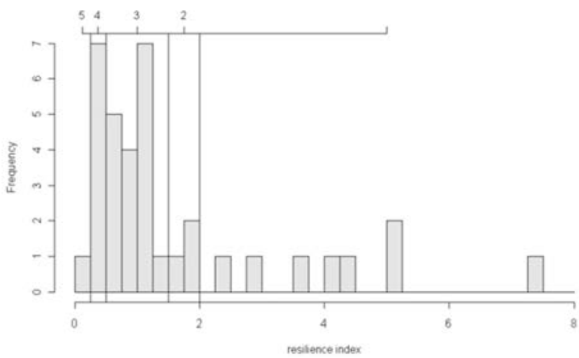


Figure 28. Histogram showing the resilience index values (lower x-axis) and how these are rescaled (upper x-axis) in birds.

Metric 5. Dependence on the marine environment

Species that spend most of their time on land or in freshwater habitats and use the North Sea only occasionally or in case of severe weather (freezing over of fresh water lakes) were given 1 (Mediterranean Gull) or 2 points (some grebes, ducks, gulls and terns); species that use the North Sea and estuaries or inland habitats about equally often were given 3 points; species that spend most of their time in the North Sea (while occurring in Dutch waters) were given 4 points and species that spend (nearly) all of their time in the North Sea were given 5 points (Leopold et al. in prep.).

Metric 6. Breeding in the Netherlands?

Species that breed in the Netherlands and provision their chicks with food from the Dutch part of the North Sea should be considered of higher conservation value than birds breeding elsewhere, as these are especially dependent on the Dutch EEZ. In this light, the Netherlands have a special responsibility for: Lesser Black-backed Gull (58,500-72.000 pairs in NL, compared to a total population of 525,000 birds); Sandwich Tern (14,500 pairs in NL, compared to a total population of 165,000 birds) and Herring Gull (62-67,000 pairs in NL, compared to a total population of 1,090,000 birds; SOVON 2002). These species were assigned 5, 4 and 4 points, respectively. All remaining species that breed in the Netherland s (but in far less significant relative numbers) got 1 point and non-breeding species got 0.

Metric 7. Importance of Dutch Continental Shelf

The importance of the Dutch Continental Shelf (DCS) for a certain species was expressed as the maximum percentage of the total biogeographical population that uses the DCS. Seasonal maxima within the Dutch DCS were taken from ship-based and aerial surveys (directly or from published reports on the Fulmar and the Kittiwake (Berrevoets & Arts 2001, Berrevoets & Arts 2003), on Scaup (Baptist & Wolf 1993). These percentages were then rescaled (Figure 29).

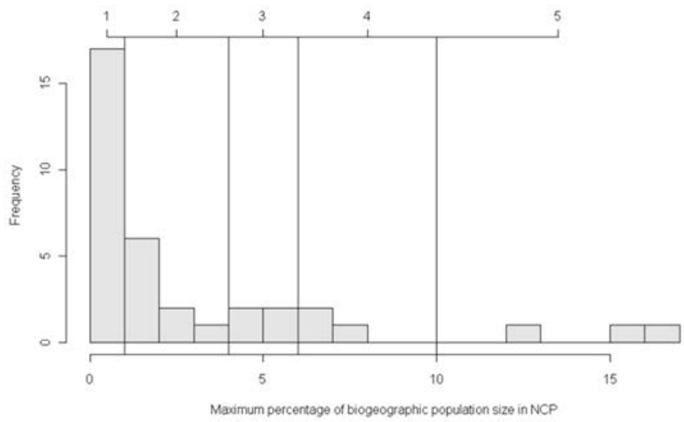


Figure 29. Histogram of the maximum percentage of the biogeographical population size that uses the Dutch EEZ (lower x-axis) and how these are rescaled (upper x-axis). See Appendix D for values per species.

Metric 9. Rarity

The rarity of a species is defined here as the size of the biogeographical population. Geographical population size is taken from Wetlands International (2002) and listed in Appendix D. How biogeographical population sizes are rescaled is depicted in Figure 30.

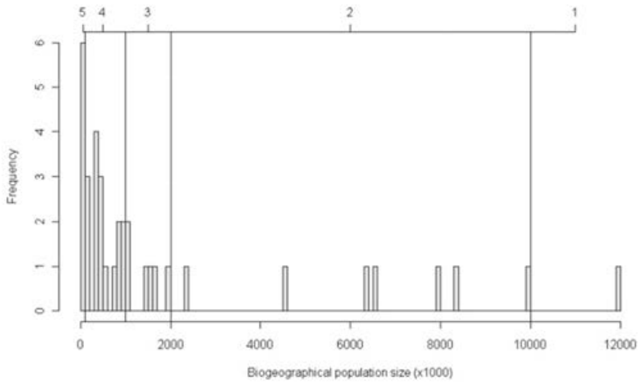


Figure 30 Histogram of biogeographical population size (lower x-axis) and how these are rescaled (upper x-axis). See Appendix D for values per species.

Total bird values: metrics 4, 5, 6, 7, 9 combined

For birds, the metrics were already combined into 1 map and are called bird values. We focus here on the temporal variability and less on the values of the metrics themselves, since the total number of species is far smaller than in benthos or fish.

Total bird values are plotted for the entire DCS per two-month period in Figure 31 and averaged to get a year-round map of seabird values. Several areas stand out in terms of total bird values. Most obviously, the entire coastal zone scores consistently high values throughout the year. In summer, this area is used by breeding seabirds, in particular Great Cormorants, Herring and Lesser Black-backed Gulls, Sandwich Terns, Common and Arctic Terns. Outside the breeding season, the area is used by a large number of migrating and wintering species. Species with high indactor values include Black-throated and Red-throated Divers, Great Crested Grebes, Common Eider, Common Scoter and Great Black-backed Gulls. Also many skuas and terns pass through the coastal areas during migration.

Slightly more offshore are the Borkum Reef area and the Zeeuwse Banken, both of which may hold reasonable numbers of migrating Red-throated Divers in spring (April).

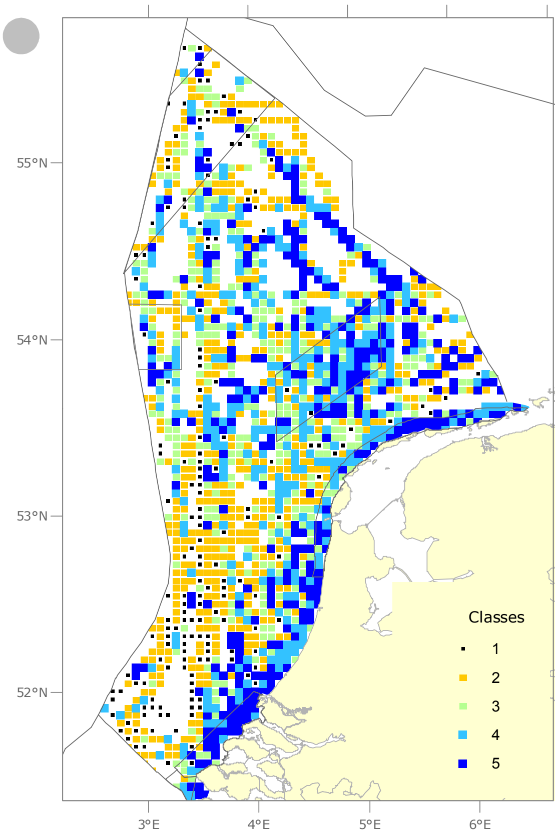
From the offshore areas, especially the Frisian Front stands out due to its high bird values. These peak in summer and autumn, when large numbers of Common Guillemots visit the area after the breeding season. In summer, this area may function as a foraging area for Lesser Black-backed Gulls breeding at the Wadden Sea islands. During late summer/early autumn, Great Skuas migrate through the southern North Sea, and the Frisian Front is one of the areas in which high concentrations can be found.

Also the Cleaver Bank holds high bird values year-round. This area does not qualify as an MPA because not a single species exceed the RAMSAR-criteria. However, this area holds high densities of Northern Fulmars, Northern Gannets, Black-legged Kittiwakes, Great Black-backed Gulls and Common Guillemots. jointly making the Cleaver Bank an area with high bird densities and values.

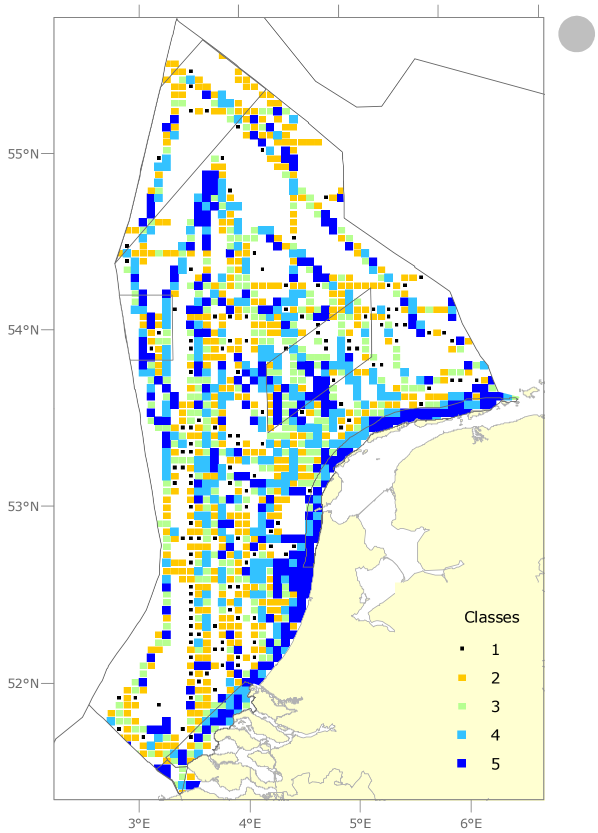
In late winter, the entire Southern Bight sustains high bird values. The avifauna is dominated by Common Guillemots and Razorbills, which use the area during winter and migration. There is probably a high turnover, meaning the area is used by many more birds than present at any single moment.

All in all, the Coastal Sea and the Cleaver Bank score high values throughout the year, whereas the Frisian Front has high bird values in summer and autumn, and the other areas score high values only in specific times of year.

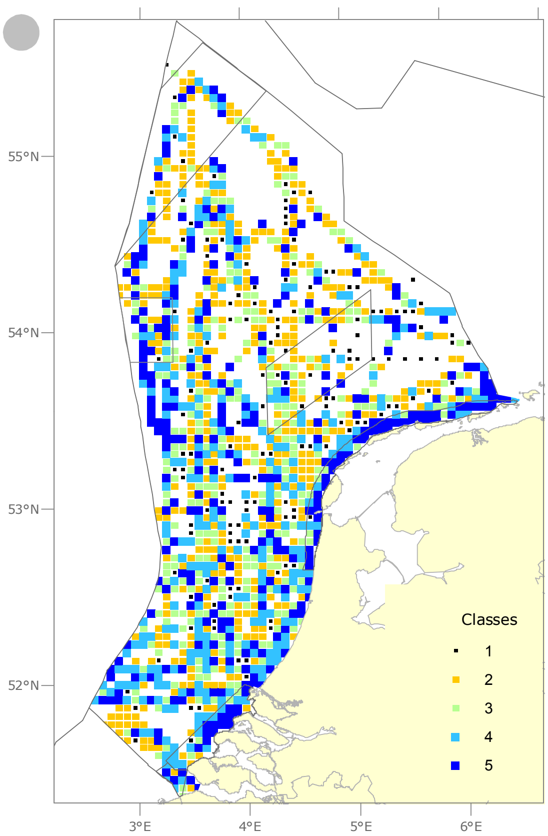
Birdvalues August-September



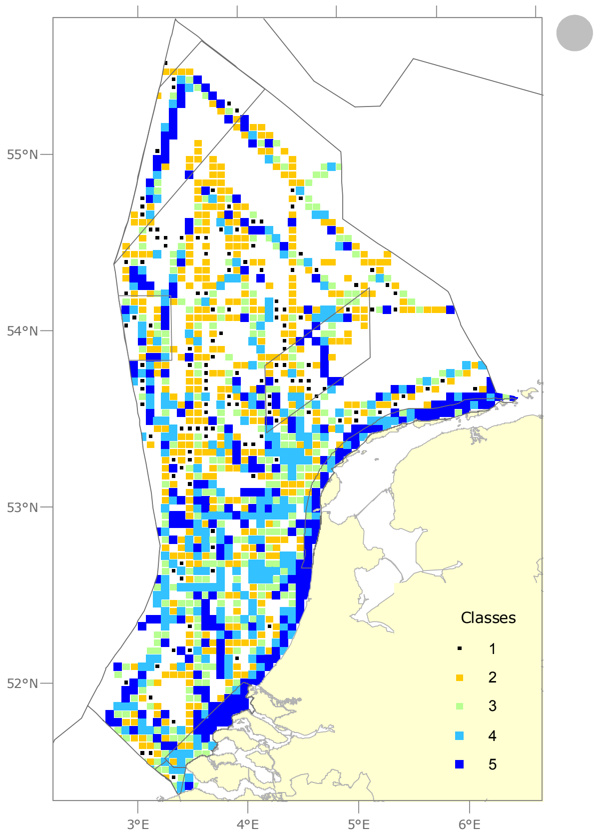
Birdvalues October-November



Birdvalues December-January



Birdvalues February-March



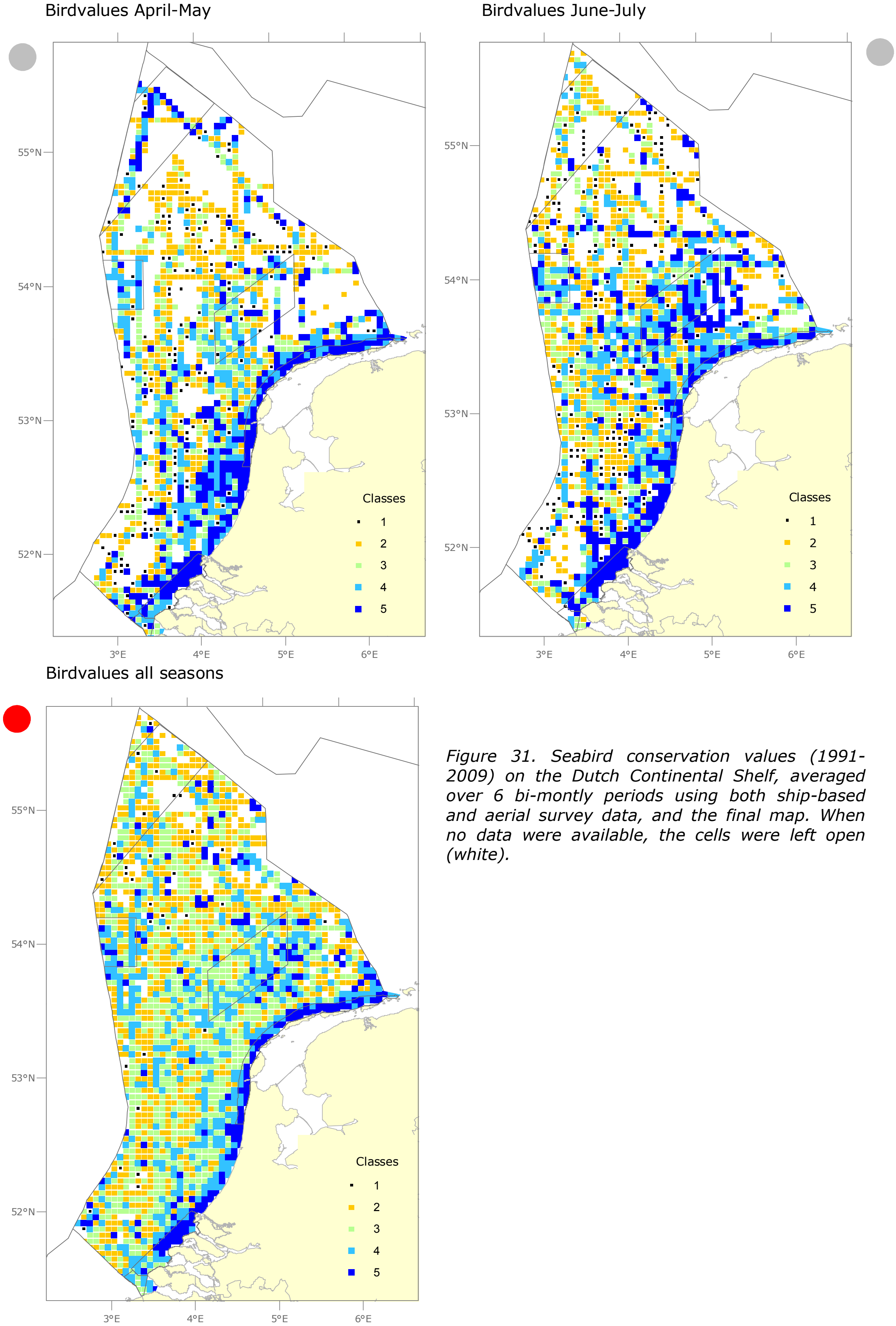


Figure 31. Seabird conservation values (1991-2009) on the Dutch Continental Shelf, averaged over 6 bi-montly periods using both ship-based and aerial survey data, and the final map. When no data were available, the cells were left open (white).

4.4 Marine mammals

4.4.1 Data and sampling methods

We estimated the distribution patterns of marine mammals on the basis of the data described below. We did not use the actual data to calculate density maps, since the spatial resolution and coverage was not sufficient (see below). Data on marine mammal sightings on the Dutch Continental Shelf are available from a diverse set of sources; ship-based counts, aerial counts, telemetry studies, and non-systematic observations.

Ship based surveys

The European Seabirds at Sea Database (ESAS) was established in 1991 as a collaboration between individuals and institutes who had collected data on the distribution of seabirds and marine mammals in north-west European offshore areas, including the Dutch Continental Shelf. The most recent version of this database contains over two million records which were collected over 25 years. The data consists of ship-based observation with a standardized strip-transect method.

Aerial surveys

Starting in late 1984, the distribution of marine mammals has been surveyed bimonthly by means of aerial surveys (e.g., Arts 2011). The bimonthly sampling design ensures that the dataset covers all periods relevant for the selected species. The extent of the survey spans the entire DCS. Since spring 2009 IMARES conducts twice a year aerial surveys of harbour porpoises in Dutch waters using an international standardized survey method (Scheidat & Verdaat 2009). For this survey a small aircraft equipped with bubble windows is used to improve sighting conditions.

Telemetry studies

VHF-radio transmitters using manual or a permanent receiving stations, have successfully been used to describe the seals' presence and location, determined by triangulation. This method has been used widely in the North Sea to track harbour seals (Tougaard et al. 2003, Brasseur et al. 2006). However marine mammals easily swim out of the receiving range of handheld and shore based receivers and, as smaller satellite tags were developed in the early 1990s, more animals have been tracked using these tags. Satellites collect information, which is transmitted to a ground station making it available to the scientists. The so-called ARGOS is the most common system used (Argos 1989) and by now is used in Dutch waters for harbour- and grey seals. In contrary to the Danish waters no telemetry studies are conducted on harbour porpoises in Dutch waters. The latest insights regarding telemetry work on harbour seals could not be used, however, because the reports are still in review.

Individual observations

Sightings of cetaceans are recorded in *Marine Mammal Database*. Apart from the ship-based survey data this database also contains all systematically collected data on marine mammals during so-called seawatches by land-based observers from the working group CvZ/NZG (Dutch Seabirdgroup). These birdwatchers use a standardized method to record the coastal migration of seabirds, and the presence of marine mammals. The *stranding database* of NCB Naturalis contains all data of stranded cetaceans in the Netherlands. However this data is not additional for insight in offshore distribution. All cetacean sightings within the Dutch National Database Flora and Fauna (NDFF) can also be found in the Marine Mammal Database. However the NDFF also contains individual (mainly coastal) seal observations.

Identification of species

Most aerial- and ship-based surveys and land-based seawatches are conducted by observers. Rarities are described and documented (preferably with photo). All sightings are checked and only validated sightings are added to the databases.

Species selection

Only resident or annual present species are used to identify areas with a higher biodiversity. Therefore for the Dutch Continental Shelf (DCS) Harbour Seal, Grey Seal, Harbour Porpoise, White-beaked Dolphin and Minke Whale were selected.

For none of the cetacean species there is sufficient data to calculate density maps of the entire DCS for all seasons. Therefore, abundances were roughly estimated, using five scales (**0-4**): **0** means the species occurs here only as a vagrant; **1** occasional; **2** scarce; **3** regular and **4** common. Below, the considerations underlying the distribution maps used are presented below. The distribution maps are shown in Table 15.

Minke Whale

Minke Whales are rare in Dutch waters. The number of sightings in available databases is too low to calculate densities and abundances, but it is clear that sightings are generally confined to two areas: the Cleaver Bank and Dogger Bank. On the international Dogger Bank, numbers peak in May with densities of 0.029 Minke Whales km^{-2} (De Boer 2010). Minke Whales have also been recorded at the Cleaver Bank, with sightings in august 1998 (1), July 2005 (2), July 2006 (16), June 2010 (1) indicating that this area is regularly visited by this species. Outside these areas, Minke Whales only occur irregularly. Therefore, abundance score 1 was assigned to the Dogger Bank and Cleaver Bank areas and the remainder was scored as 0.

White-beaked Dolphin

White-beaked Dolphins are scarce on the Dutch Continental Shelf. Their occurrence appears to be erratic, with periods with many sightings interspersed with periods with almost no sightings (Camphuysen 2005, Camphuysen & Peet 2006). Sightings from the ESAS database and RIKZ aerial survey database, (partly) published in Reid et al (2003), Camphuysen (2005), Camphuysen & Peet (2006), Van der Meij & Camphuysen (2006) and Brasseur et al (2008), clearly show that highest densities are found along the western border of the DCS, in particular areas like the Brown Ridge, Clearer Bank and Dogger Bank. However, especially the data from the Marine Mammal Database (Camphuysen 2005) shows that White-beaked Dolphins also occur in the central part of the Southern Bight. However, this data is not corrected for effort. The absence of sightings from the north-eastern part of the DCS is remarkable and may be related to low observer effort in this area. Sightings within 10km from shore are rare (Camphuysen & Peet 2006). These coastal waters were therefore given abundance score 0; the western border of the DCS, where almost all effort-based sightings originate, was assigned abundance score 2. The remaining part of the DCS, where occasional sightings do occur, was assigned score 1.

Harbour Porpoise

Harbour Porpoise is the most common cetacean in Dutch waters. There have been several efforts to map the distribution and estimate the numbers present, but none have yet attained sufficient data to reveal clear temporal and spatial patterns, as is reviewed in the Harbour Porpoise Protection Plan (Camphuysen & Siemersma 2011, in prep.). Patchy distribution patterns with local high densities have been observed (e.g. Scheidat & Verdaat 2009). In the German EEZ, porpoises show aggregation zones in spring: the Sylter Outer Reef and to a lesser extend the Borkum Reef Ground, which were identified as key foraging areas (Gilles et al. 2009). It is not clear (yet) to what extent the timing and locations of these hotspots are predictable or persistent, and what they mean. Therefore, we choose a conservative approach, in which the entire DCS was assigned abundance score: 3. This is in line with the Harbour Porpoise protection plan (Camphuysen & Siemersma 2011, in prep.).

Grey Seal

Distribution of Grey Seals has been inferred from movements made by individually tracked seals from Dutch haul-out sites. The maps are based on modelling work presented in Brasseur et al. (2010) and predict the density of seals given preferences for environmental characteristics as inferred from satellite tracking data and the number of seals counted at haul-outs. Areas with the highest densities, close to shore and haul-outs, are assigned abundance score 4, whereas preferred habitat outside this region are assigned score 3. Seals can, and probably do, use the remaining part of the DCS as well, and therefore this part got score 2. The map does not include data from e.g. Scottish seals, since they were not available to us. Such data may however change the distribution pattern a lot.

Harbour Seal

Distribution of Harbour Seals has been interfered from movements made by individually tracked seals from Dutch haul-out sites. The maps are based on modelling work presented in Brasseur et al. (2008) and predict the density of seals given preferences for environmental characteristics as inferred from satellite tracking data and the number of seals counted at haul-outs. Areas with the highest densities, close to shore and haul-outs, are assigned abundance score 4, whereas preferred habitat outside this region are assigned score 3. Harbour Seals can, and probably do, use the remaining part of the DCS as well, and therefore this part got score 2.

4.4.2 Maps

Due to the small number of species, maps per metric are heavily influenced by species-specific distribution patterns. A consequence of using an even distribution for Harbour Porpoise is that this species does not influence any spatial differentiation. It should be noted, however, that this does not mean that this species does not account for local biodiversity and that temporal hotpots may occur.

Metric 4. Resilience

An index of resilience of marine mammals was calculated using a similar approach as used for seabirds. Here, the number of offspring per year was divided by the average age at first breeding. Another approach is to estimate the maximum lifetime reproductive output using the number of calves per year, the age at first breeding and the lifespan. Ordering the five species gives the same ranking for both indexes. That is, White-beaked Dolphin has the lowest resilience, scoring 5 points, followed by Minke Whale (4), Harbour Porpoise (3), Grey Seal (2) and Harbour Seal (1). See Table 13 for the underlying values.

White-beaked Dolphin (5 points) and Minke Whale (4 points) show the lowest resilience and therefore their distribution shows clearly in the map. White-beaked Dolphins occur mainly along the western border of the DCS, including the Brown Ridge, and Minke Whales occur at the Dogger Bank and Cleaver Bank. Seals have a higher resilience and therefore their distribution does hardly influence the spatial pattern for this metric.

Metric 7. Importance of Dutch Continental Shelf

This is the maximum proportion of the biogeographical population that occurs on the DCS. The biogeographical population size and the maximum number occurring on the DCS were taken from literature sources (see Table 14 for references). Species were ranked according to the the proportion of the population occurring on the DCS and assigned points. Harbour Porpoise scored 5 points, followed by Harbour Seal (4), Grey Seal (3), White-beaked Dolphin (2) and Minke Whale (1).

Harbour Porpoise scores the highest value in this metric, but due to the even distribution pattern used for this species, it does not influence the spatial pattern. It is followed by Harbour Seal (4 points) and Grey Seal (3 points), and this is clearly expressed in the map, highlighting the coastal zone of the Wadden Sea Islands and the Voordelta – areas where both species occur in high numbers (Figure 33)

Metric 9. Rarity

Species with a smaller biogeographical population size are considered to be rarer. Biogeographical population sizes were taken from literature (Table 14) and species were ranked accordingly. Harbour Seal has a restricted range and a small population and therefore scores 5 points, followed by White-beaked Dolphin, Grey Seal, Minke Whale and Harbour Porpoise.

In the metric rarity/biogeographical population size, Harbour Seal and White-beaked Dolphin received 5 and 4 points, respectively, and their distribution therefore determine the main patterns shown in the map. Here, the area of the Brown Ridge (White-beaked Dolphins) and the coastal zone of the Wadden Sea islands and the Voordelta (Harbour Seal) score highest values (Figure 33).

Summed points

Summing the maps of all metrics reveals a pattern in which several areas show elevated scores. The combined map is however, not very clear (see discussion in Chapter 5.). Highest values are reached at the Brown Ridge. This can be explained by the occurrence of White-beaked Dolphins, scoring many points in the rarity metric, and the occurrence of Grey and Harbour Seals. Also the coastal zone of the Wadden Sea Islands and the Voordelta are highlighted, due to the abundance of Grey Seals and Harbour Seals. The Cleaver Bank and Dogger Bank show up due to the occurrence of Minke Whales, having high scores for resilience and biogeographical population size (Figure 33).

Table 13. Resilience data (Christensen 1982, Gaskin et al. 1984, Read 1990, Read & Gaskin 1990, Best 1992, Caswell et al. 1998, Waring et al. 2002, Börjesson & Read 2003, Lockyer 2003, Taylor et al. 2007).

Species	Average number of calves	Calving interval (y)	Average age at first breeding (range)	Generation length (y)	N calves/ lifetime	Resilience index
Harbour seal (*Phoca vitulina*)	1	1	5 (3-7)	20	15	1
Grey seal (*Halichoerus grypus*)	1	1	5 (3-7)	15-30	10-25	2
Harbour porpoise (*Phocoena phocoena*)	1	1 (1-2)	5 (3-5)	8-14.1	3-9	3
White-beaked dolphin (*Lagenorhynchus albirostris*)	1	2.5 (2-3)	8 (8-10)	17	3	5
Minke whale (*Balaenoptera acutorostrata*)	1	1 (1-3)	7 (6-8)	13	6	4

Table 14. Maximum occurrence of marine mammals in the Dutch sector of the North Sea as a percentage of their total biogeographic population sizes (Reeves et al. 1999, Härkönen et al. 2007, Hammond et al. 2008, Thompson & Härkönen 2008, IWC 2010). Grey seals: numbers are counted individuals in colonies, real numbers may be higher since part of the population is not visible during counts. Harbour porpoise numbers: M. Scheidat, pers. com.

Species	Biogeographical population size	Maximum number on DCS	Max %	Points
Harbour seal (*Phoca vitulina*)*	70,000	6339	9 %	4
Grey seal (*Halichoerus grypus*)*	117,000	2108	1.8 %	3
Harbour porpoise (*Phocoena phocoena*)	386,000	Spring 2010: 66,000	10 %	5
White-beaked dolphin (*Lagenorhynchus albirostris*)	100,000	500	< 0,5 %	2
Minke whale (*Balaenoptera acutorostrata*)	174,000	26	< 0,02 %	1

**minimum estimate: only counted number in colonies.*

Table 15. Summary of Specific Marine mammal Values (column F) for all species included in the analyses per grid cell of 5x5 km in the Dutch EEZ. In the calculation of total points column D and E are averaged and summed with A-C. See text for explanation of columns A-F.

Species	Biogeographic population size	Resilience index	Dependence on DCS
Harbour seal (*Phoca vitulina*)	5	1	4
Grey seal (*Halichoerus grypus*)	3	2	3
Harbour porpoise (*Phocoena phocoena*)	1	3	5
White-beaked dolphin (*Lagenorhynchus albirostris*)	4	5	2
Minke whale (*Balaenoptera acutorostrata*)	2	4	1

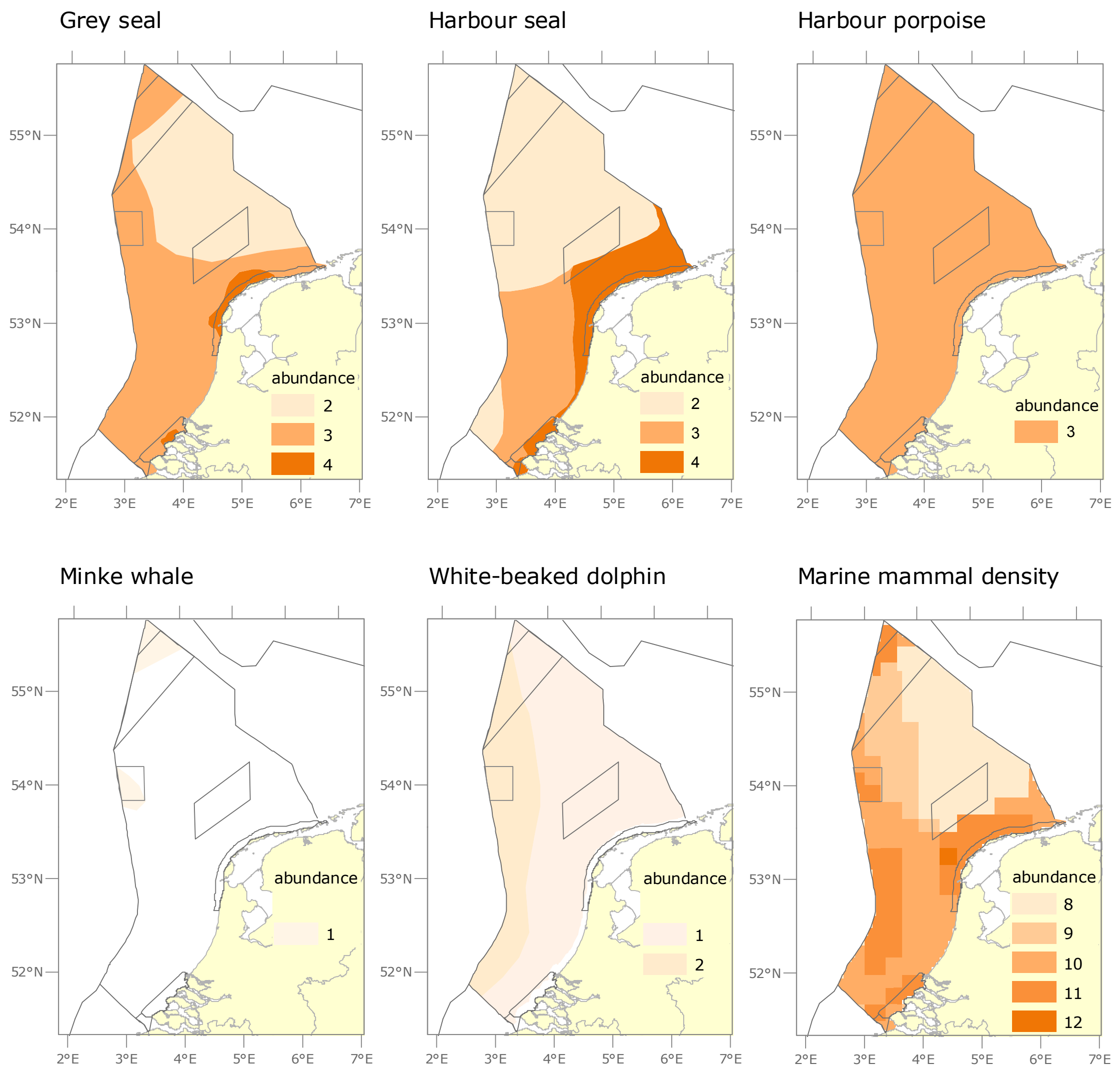
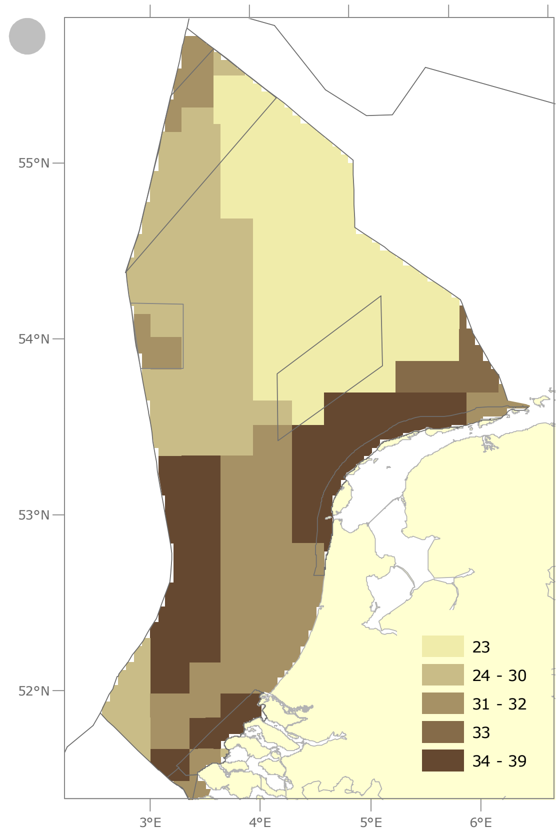


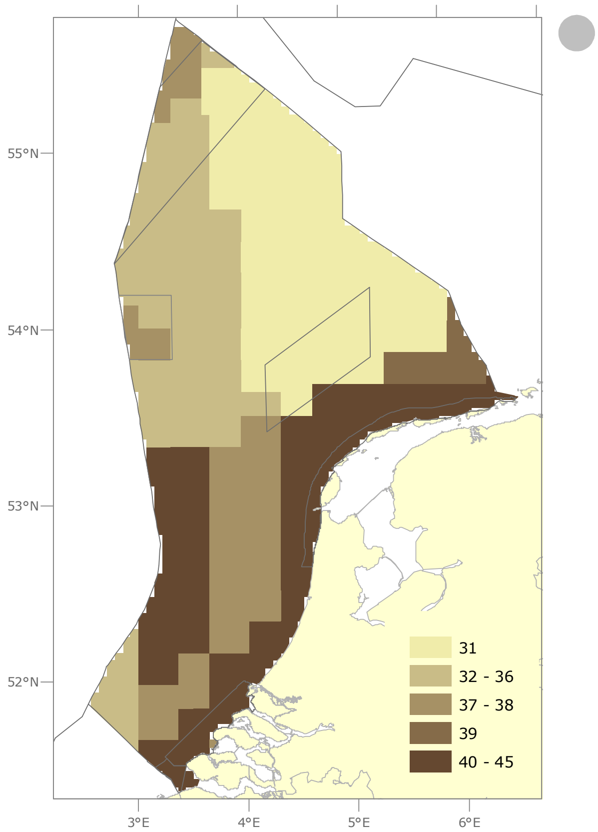
Figure 32. Distribution maps of four marine mammal species showing roughly estimated abundances on a scale of 0 (absent) to 4 (abundant) and total marine mammal abundance (1/9 ICES rectangles).

Figure 33.(next page) Maps showing species abundance scores multiplied by metric values and summed over all species per 1/9 ICES gridcell. In the lower right map, these values are summed.

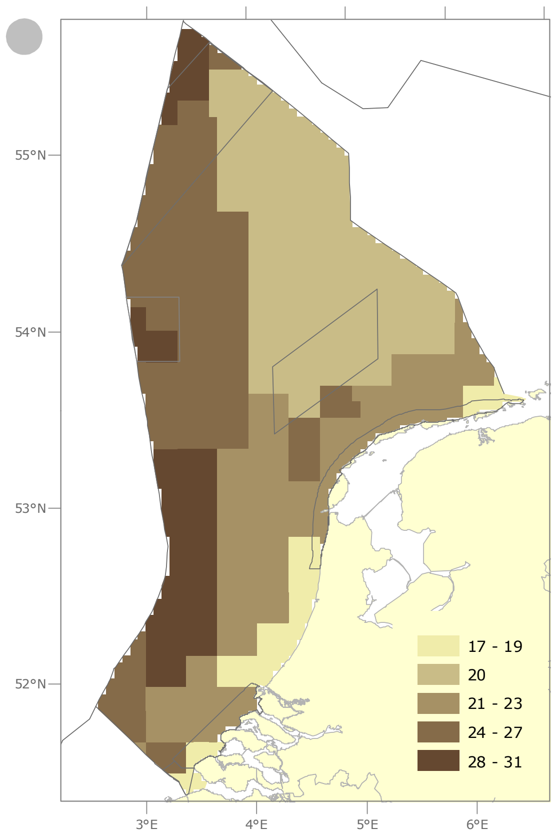
Biogeographical population size



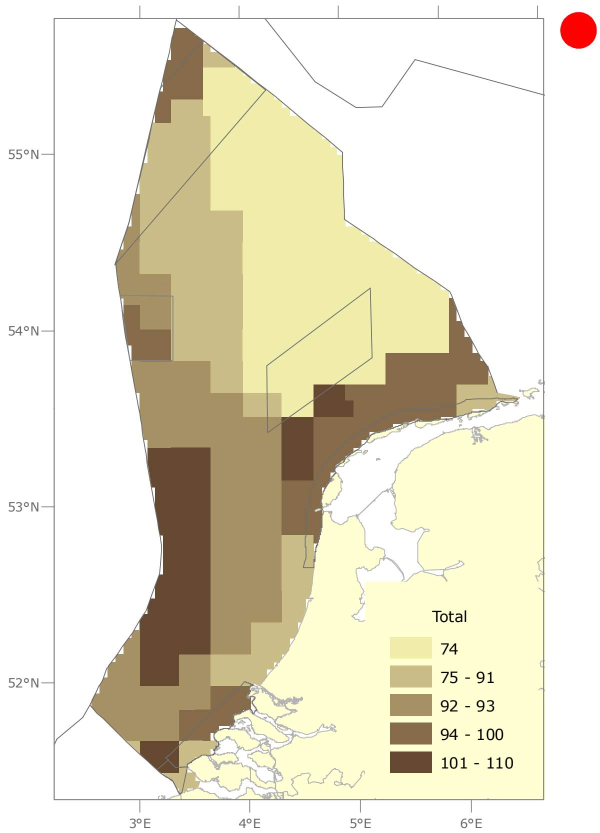
Importance of DCS



Resilience



Total ecopoints



4.5 Habitats

4.5.1 Data and sampling methods

To determine habitat distribution, we defined habitats as combinations of abiotic parameters: depth distribution (10-m depth classes), sediment size, salinity regime and the presence or absence of summer stratification. The habitats were plotted by combining 3 existing maps in GIS (Figure 34 and Figure 35). In Appendix E details are provided.

In the discussion section, we discuss the habitats by area. The names of the areas can be found in Figure 37.

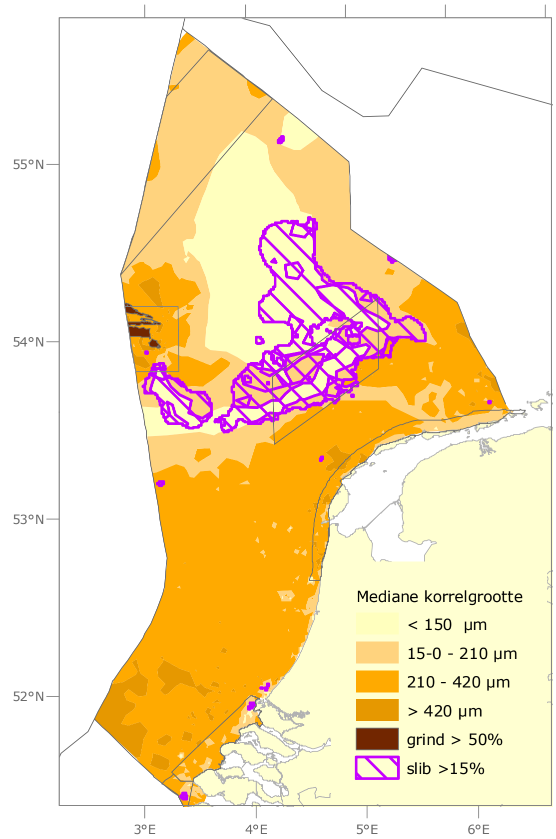
4.5.2 Maps

Metric 9. Rarity

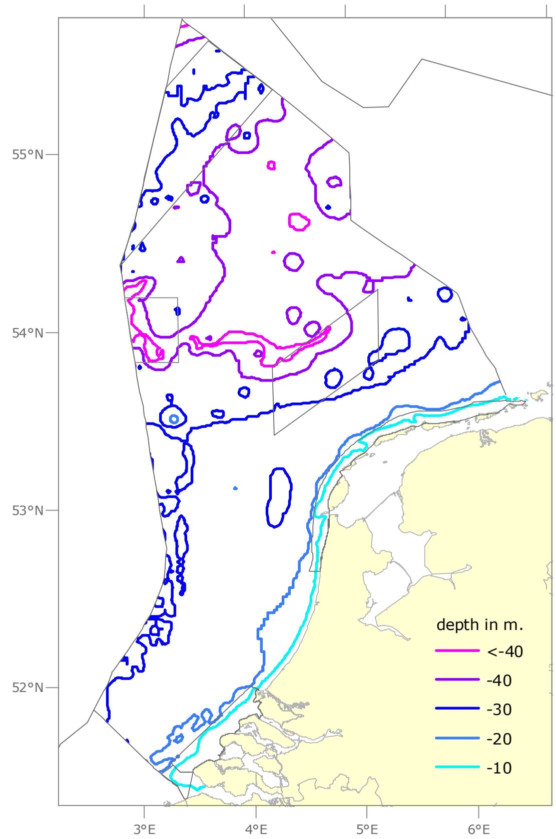
We calculated the rarity of a habitat type as the percentage of the total area. Rare habitats were given high points (5), while common habitats were given 1 point. The rarity values were plotted as percentiles on the map.

The most common habitat is the medium deep and deep sea with medium coarse sand. Rare habitats are found on only a few locations (Figure 36).

Sediment



Depth contours



Summer stratification possible

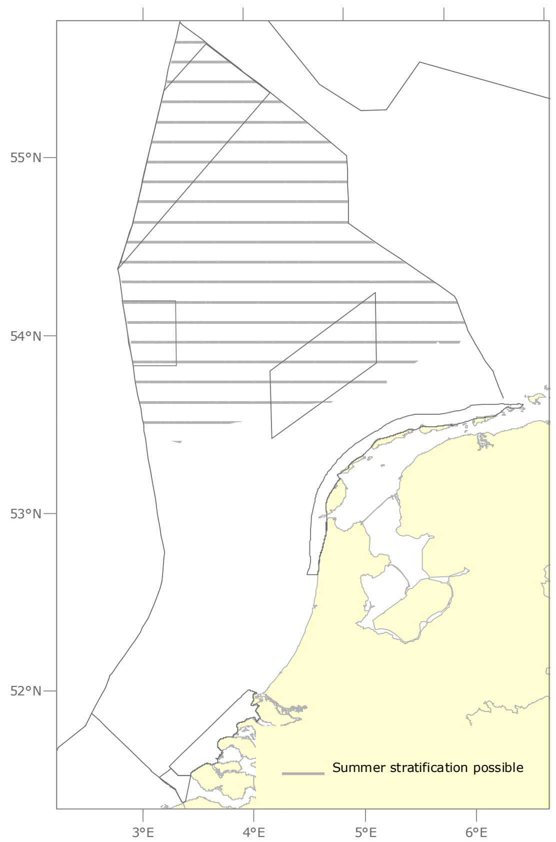


Figure 34. Sediment type, depth and possible summer stratification on the Dutch Continental Shelf. These 3 maps served as input to create the map in Figure 35.

Habitat types

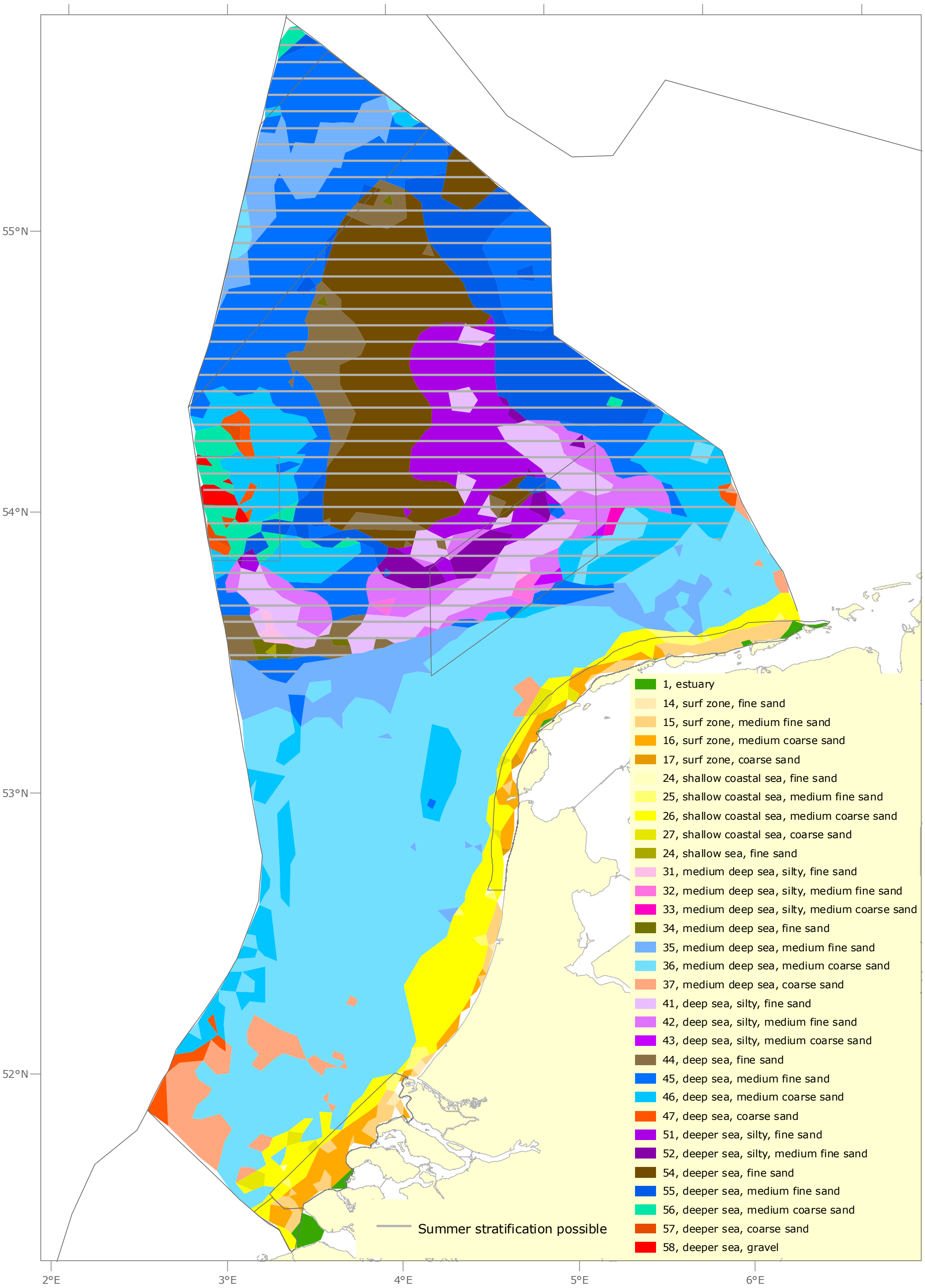


Figure 35. Habitat distribution (see Appendix E for details).

Habitat rarity %

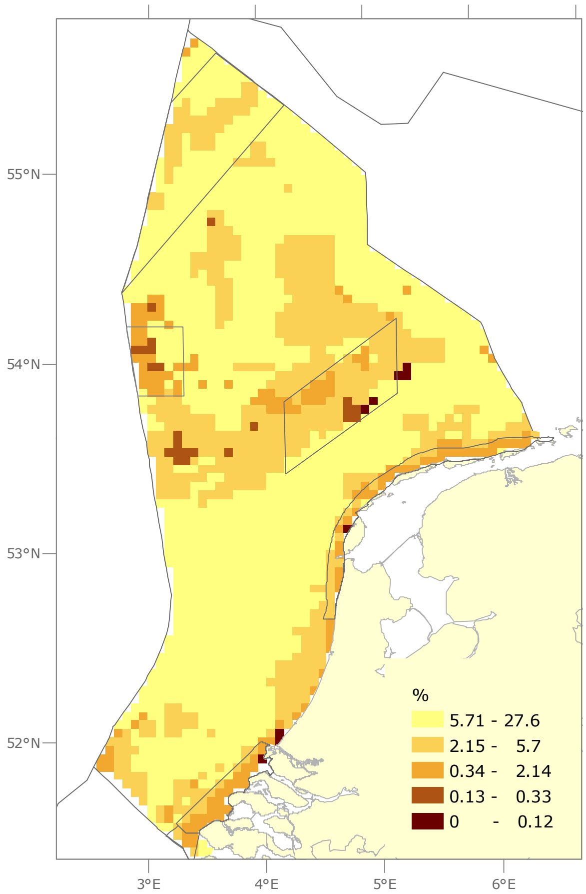


Figure 36. Occurrence of habitat types (% cover relative to total surface of the Dutch Continental Shelf).

5 Discussion

5.1 The relation between this report and the MSFD

At the moment of writing of this report (early 2011) EU Member States, including the Netherlands, are in the process of developing indicators for each of the 11 GES descriptors. The final versions of the indicators are to be submitted to the EU by mid-2012. In the Netherlands, the selection procedure for GES indicators takes place in spring 2011, while this project started late 2010. This report therefore feeds into the selection procedure of GES indicators, but does not deliver the final GES descriptor 1 indicators. The biodiversity metrics we used were based on the EU Commission Decision on criteria and methodological standards for GES descriptor 1 (EU 2010) and on the possibilities for spatial application of our data.

GES descriptor 1 furthermore specifically calls for species centric information. This means that a selection of species should act as surrogates for the whole species assemblage. This species centric approach makes sense, since changes in the status of a species are better detectable than integrated metrics such as species richness and evenness. For example, when a certain species goes extinct, and new species enter the area, the total number of species may remain stable. In a spatial application of biodiversity metrics, however, single species maps are less interesting and do not show where 'hotspots' of biodiversity can be found. To obtain a robust image of biodiversity, we needed to obtain an overview of biodiversity traits on a higher taxonomic level first, before we would be able to indicate important single species. We therefore focussed on a multi-species approach, which provides better insight in the characteristics of each area in the North Sea. In our approach, data on single species characteristics (species distribution, population structure, etc.) form the basis for maps on higher taxa levels. By doing so, the maps are also useful for GES descriptor 4 on foodwebs and GES descriptor 6 on seabed integrity, since they require aggregated information on biodiversity. For species specific distribution maps, we refer to the Ecological Atlas of the North Sea (Lindeboom et al. 2008) and other atlases (Knijn et al. 1993, Holtmann et al. 1996). For the megabenthos (Triple-D data), an atlas is currently developed by the NIOZ. For fish, a new atlas is being prepared by IMARES/CEFAS.

Some of the maps show biodiversity metrics on the level of higher taxa, such as species richness and evenness. Other maps show aggregated information for a selected number of species, for example the map of old growing (>10 y) benthos. Such species can be considered as indicator species that could be used in other MSFD studies and are listed in tables in this report. Methods to combine individual biodiversity indicators into a single biodiversity value for GES-descriptor 1, using different or equal weights per indicator, still need to be developed and will be part of the further MSFD process. All species characteristics (maximum age, maximum length and weight, etc.) are based on actual data, on literature values and to a lesser extent on expert judgement.

5.2 Biodiversity metrics

The biodiversity metrics in this report have been developed to provide the information on different aspects of biodiversity as proposed in the Commission Decision on criteria and methodological standards (EU 2010). Our approach was to take the suggestions for indicators provided by the Commission Decision as a starting point for the development of biodiversity metrics and develop metrics that could provide the required information. In this report, the ecological significance of each biodiversity metric is therefore less thoroughly treated than if one were to start to develop indicators from scratch. The development of the metrics was determined by data availability, spatial scale of the data (coverage at least DCS), and the time available for this study.

The choices for metrics in relation to data availability are discussed in Chapter 4. Below we shortly discuss some issues about the metrics themselves. In general, we preferred to use existing methods of calculation of metrics, which led to slightly different methods of calculation for different species groups for the same metric (e.g. rarity, see below). Hence, not every metric is calculated in a similar way. Another issue is that it was not meaningful and not possible to calculate the same metrics for all species assemblages and habitats (see Chapter 4).

Metric (1), distribution, serves as the underlying set of data for the other metrics and is not really an informative metric itself when information of many species is aggregated. Metrics (2) , density, and (3), biomass, show total numerical density and biomass, respectively, and provide simple and commonly used information. The metric (4) resilience (or vulnerability) aims to indicate which species are most vulnerable to human impact, or for which species attaining a normal population structure in terms of age and size distribution is probably most difficult under human pressures. For benthos, we wanted to calculate this metric by following the approach in the Marine macrofauna genus trait handbook (www.genustraithandbook.org.uk/) of Marine Ecological Surveys Ltd (2008). However, since finding all the parameters (including size, life-span, age at maturity, etc.) for all benthic species is a very time consuming exercise, we concentrated on potential maximum age only (see discussion in section 4.1). For birds and marine mammals, an existing method (Leopold in prep.) was used, with which the resilience is expressed in terms of lifetime reproductive output.

The metric (5), dependence on marine environment, and (6), breeding in the Netherlands, obviously apply to birds only and are used to calculate the 'bird values'(Leopold in prep.), as explained in section 4.3. Metric (7) Importance of the DCS for the species, applies to both seabirds and marine mammals and expresses which part of the biogeographic population uses the DCS. For fish and benthos, such an analysis is not possible due to the large number of species and the lack of information. Metric (8), trends, was calculated only for fish, thanks to the good data availability for this group. Although we were also interested in trends of other species groups, such as benthos, time series for especially larger benthic species (megabenthos) were not available. For seabirds and marine mammals time series are of less importance. Marine mammals have generally increased in numbers, so there is no need to look for areas where populations with a long-term negative trend have retreated. For seabirds it may have been interesting to perform trend analyses, but this was not part of the Bird Value method (Leopold in prep.) and was therefore not done. For habitats, in terms of sediment characteristics, no information on trends was available.

In this study, the term 'rarity' (metric 9) indicates how common a species is, although the method of calculation differs between species groups, since we wanted to use existing calculation methods. For benthic species, we used the frequency of occurrence of species within the dataset, following Lavaleye (2000), while for fish both numeric density and frequency of occurrence were taken into account to calculate the metric, following Daan (2000). The frequency of occurrence and also the numeric density depend on the choices made to include or exclude species in the dataset, on the catchability in the case of fish, on the number of samples taken, etc.. These topics are discussed in Chapter 4. For benthos, there are so many species that it is not possible to make a distinction between vagrant species, extra-limital species and/or rare species (see discussion in ICES 2011). For fish, a large number of species were excluded from the analyses (see section 4.2.1.5), following the approach of Daan (2000). For birds and marine mammals only those species were taken into account that regularly occur on the DCS (see section 4.3).

Metric (10), large specimens within populations, only applies to fish and indicates where individuals of species occur with a length of at least 75% of the maximum length, thus showing information on the population structure. When the level is set too high (90%), there is not sufficient data to produce a map, while if the level is too low, 50%, the map is not distinctive. The interpretation of the map is somewhat difficult, due to the inclusion of both small and large growing species (species with a small or large maximum size).

Metric (11), potential large species, shows where relatively large growing species (species with a large maximum size) occur, the idea being that larger growing species form a component of the ecosystem that is under pressure. This metric is only applicable to fish and benthos, and not to seabirds and mammals. However, since the interpretation of the map is difficult, since it is about potential lengths and not real lengths, we decided to produce a separate map showing fish > 40 cm.

Metric (12), species richness, and (13), species evenness, are metrics that are used to inform on the number of species present and the numerical distribution, respectively. In biodiversity studies these metrics are commonly used, although the Commission Decision (EU 2010) with its species more centric approach does not mention them.

5.3 Biodiversity patterns

General remarks
In general, one has to keep in mind that the biodiversity patterns presented in this study are there without any spatial protection measures in place. Human activities will have shaped the biodiversity patterns to what they now look like.

Usefulness of combined biodiversity metrics
The approach that we wanted to take in this study was to compose maps for a number of different biodiversity metrics on the level of taxonomic groups (e.g. macrobenthos, megabenthos, etc.), aggregate them to the level of higher taxa (benthos, fish, etc.) and then combine them into a single biodiversity map, that would show the hotspots where biodiversity for all components would be highest. In this approach, the different maps were given the same weight.

In general, the maps per biodiversity metric and sometimes per species group provide the most information, while in the higher level maps information tends to get lost. Combining maps by equal weight means that larger clusters of areas will get ‘diluted’ by maps with a ‘checkerboard’ pattern, resulting in a final map with less clear patterns. If we would have given different weights to the different metrics, the patterns would probably even harder to interpret. Also the combination of different scales (1/9 ICES rectangles, 5x5 km areas) may result in patterns that are not clear. However, if all species groups would have high biodiversity values in the same area, a combined map would have shown that, but this is not the case. We conclude therefore that compiling a final map should be seen as an methodological exercise and we did not include such a map because of the arguments stated above. Instead, we summarised the highlights in a table in combination with a map.

Benthos
For benthos, clear spatial patterns are visible on the Dutch Continental Shelf. The macrobenthic community in the Northern part of the DCS, north of the Frisian front is characterised by a high species richness with a relative high number of rare species (low frequency of occurrence), a relative high number of old growing (>10 y) and larger growing species (>1 g AFDW). The megabenthos shows the highest biodiversity values in the Frisian Front area and the Oyster Grounds. The density of datapoints is also highest here, which may partly affect the kriging procedure, but if we look at the datapoints themselves, they all show high values in these areas. The southern part, especially in the Southern Bight, contains relatively low species numbers, with a high evenness, low densities and biomass, hosts a relative low number of species, and few larger and older growing species. In the Southern Bight, the

megabenthos scores low on all biodiversity metrics. The coastal zone in general contains high biomass and high densities, but low number of species. Temporal and spatial trends of macrobenthos were not discussed in this study, but have been described in previous work (Craeymeersch et al. 2008).

Fish

The maps made for fish show less clear patterns than those of the benthos. The importance of temporal variation is clearly demonstrated in the species richness maps for Q1 and Q3, which are very different between seasons (Figure 24).

Since fish are very mobile species, and many of the species migrate and since the DCS is not so large on the scale of the larger North Sea, it is not surprising that patterns are less clear as compared to benthos. Some patterns emerge though: the species richness and frequency of occurrence of the larger growing species (>90 cm) appear to be higher in the deeper part of the DCS.

Seabirds

Clear spatial patterns are visible for birds, although they are partly related to the sampling effort. The flight transects, for example, are evident on each map. The Coastal Sea and the Cleaver Bank score high values throughout the year, whereas the Frisian Front has high bird values in summer and autumn, and the other areas (Dogger Bank, Brown Bank, and others) score high values only in specific times of year. For the birds it is important to plot seasonal maps, as is done in this report, as the majority of seabirds species occurring in the North Sea are migratory and their occurrences are therefore confined to specific seasons. Many species, for example, are completely absent during the breeding period and show high densities during the winter, or *vice versa*. Such seasonality must therefore be considered when identifying seabird abundances. Furthermore, one of the two databases used here shows a high amount of temporal variation in effort (ESAS). Basing a density calculation on year-round sums of counts and effort, therefore, can lead to serious errors in the case of missing effort in specific seasons. Another effect of migratory behaviour is that during migration, the turnover of individuals in a certain area may be much higher than the amount of birds at a given point in time. Although the area may therefore be important to a large amount of individuals, it may not be reflected in the survey results.

Marine mammals

The maps for marine mammals are not very useful as a starting point for spatial protection measures. Due to the low number of marine mammal species regularly occurring on the DCS, the separate metric maps and the final map is heavily influenced by the distribution pattern of each species. Generally, the pattern is governed by the distribution patterns of White-beaked Dolphin and the two species of seal, highlighting the Brown Ridge area, the Voordelta (Southern Coastal Sea) and the coastal zone of the Wadden Sea islands. The occurrence of Minke Whales elevates the amount of points at the Dogger and Cleaver Banks.

The use of an even distribution for Harbour Porpoise (densities equally spread across the DCS) results in the absence of differentiation between areas. There are some indications that in the German EEZ, the Borkum Reef Ground and the Sylter Outer Bight support higher densities (Gilles et al. 2009, Scheidat & Verdaat 2009). In general however, for the DCS, such aggregations have not been observed. This is in line with the Harbour Porpoise Conservation Plan (Camphuysen & Siemersma 2011, in prep.).

Given the scarcity of encounters during effort-based observations, large amounts of effort are needed to get reasonable density estimates. An area with particularly low effort is the north-eastern part of the DCS. This is also the area that scores the lowest amount of points.

5.4 Habitats

The DCS is not extremely diverse in habitat types, compared to the EEZs of other countries. We have ‘created’ a number of habitat types, based on the combination of abiotic characteristics. By increasing the number of categories per abiotic parameter, e.g. by creating more depth classes, the habitat map becomes more complicated. The general message is that there is a lot of generally occurring habitat types on the DCS and a few more rare habitat types (for locations, see Figure 36).

6 Conclusions

The aim of this report was to indicate areas that stand out in terms of biodiversity, and that may serve as a starting point for spatial protection measures within the framework of the MSFD, based on the criteria for GES descriptor 1 'Biological diversity is maintained'. This report shows that such spatial indications exist. Below we will first provide general conclusions and then conclusions per area.

6.1 General conclusions

- Mapping of biodiversity hotspots on the level of individual biodiversity metrics within taxonomic groups is useful. Separate maps of biodiversity metrics are therefore most informative.
- When different metrics are combined in a map, by adding and rescaling, maps tend to lose information.
- Spatial patterns of benthic biodiversity are more consistent than for other taxonomic groups, which can probably be attributed to the sedentary lifestyle.
- For fish, spatial biodiversity patterns are less clear than for benthos, probably because fish are very mobile species.
- Although birds are mobile species as well, some areas have consistently higher bird values than others. In the coastal zone this is caused by the higher number of species present (coastal birds).
- For marine mammals, spatial patterns that resulted from the method applied in this study (aggregation of maps) were difficult to interpret. This is partly due to the data constraints and partly to the low number of species. For this group, it is best to consider the species separately.
- Based on the conclusions above, we suggest that biodiversity patterns have to be assessed at the relevant scale, which is larger for fish and marine mammals (greater North Sea) than for benthos. For birds, it is useful to determine temporal patterns.
- Assuming that spatial protection measures will focus on distinctive clusters of high biodiversity (potential) within the DCS, it will be easier to take spatial protection measures for benthos and birds than for the other taxonomic groups.

6.2 Conclusions per area

Below we describe biodiversity highlights for a number of different areas on the Dutch Continental Shelf (DCS). The naming of the areas is based on the naming of the areas of special ecologic values 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 values, we added some names (Figure 37). This way, we can roughly describe the whole of the DCS. The scale of the areas is tens of kilometres since is not useful to draw conclusions on the smallest scale used in this report, the 5x5 km unit areas, since these are only used for technical reasons, i.e. to enable the combination of different maps in GIS software. Moreover, most dataseries are designed to draw conclusions on much larger scales, and for a lot of species, especially mobile species, small scales have no biological meaning, so using small scales would not be appropriate. In Table 16 we provide an overview of biodiversity characteristics per area and their Natura 2000 status.

Dogger Bank
The Dogger Bank is a Special Natura 2000 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, old growing and relatively large growing species, a high species richness and a high evenness. The fish species evenness is high. As far as the other parts of the ecosystem is 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 are occasionally seen: minke whales.

Gas seeps
Although some seeping gas has been reported for this area, structures formed by gas have not yet been found (Natura 2000 habitat type H1180) (Van Bemmelen & Bos 2010) therefore this area does not qualify under the Habitat Directive. The habitat type H1180 has been removed from the reference list of habitats for the Netherlands by the European Commission. 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 old growing species, and high values for species richness. For the other species groups and metrics, no real exceptional values are found.

Cleaver Bank
The Cleaver Bank, including a deeper trench named the Botney Cut, is a SAC (Natura 2000 habitattype H1170, reefs) under the Habitat directive, characterised by a macrobenthic community that scores high for biomass, species that potentially grow large (>1000 mg), frequency of occurrence (or rarity) and evenness and a relatively high density of megabenthos. Other metrics for megabenthos (e.g. species richness) could not 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.

Central Oyster Grounds
The Central Oyster Grounds contain a relatively large number of old growing, large growing macrobenthic species and a high macrobenthic species richness. Also for megabenthos this area is higly 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 therefore is not 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 growing 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 Reef
In the Borkum Reef area Natura 2000 habitat type H1170 (abiotic reef) is present (Bos 2011 (in prep)). Macrobenthos (of the soft substrate) shows a relatively high number of long lived species (>10 y) and a relatively high density.

Between Cleaver Bank, Brown Bank and Frisian Front
The area in the western part of the North Sea, above the Brown Bank, 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 habitattype in part of the area is rare according to this study.

Brown Bank
The Brown Bank shows a moderately high evenness of macrobenthos, but low values for other benthos biodiversity metrics. Also fish shows a relatively high evenness. In the Brown Bank area and south of it, birds surveys are currently executed by IMARES (2009-2012) to determine whether this area qualifies as a SPA within the project described in section 1.5. These data have not been analysed in this study.

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

Coastal Sea north
The northern part of the coastal Sea is a Natura 2000 SPA and SAC, starting from Bergen 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 of the Dutch Continental Shelf, the area is important for 2 species of seals and the habitat type is rare.

Coastal Sea middle
The middle part of the coastal Sea is not protected as SPA /SAC, rich in biomass and density of macrobenthos and megabenthos, 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 habitattype 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 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.

Table 16. 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 the definition of habitats in this study (i.e. combination of abiotic characteristics).

Area	**Natura 2000 (+Natura 2000 habitat types)**	**Macrobenthos**	**Megabenthos**	**Fish**	**Birds**	**Mammals**	**Habitat**
Dogger Bank	SAC (H1110_C)	High density Many rare species Many old growing species Many big growing species High species richness High evenness		High evenness		Minke whale present (occasional sighting)	
Gas seeps		High density Many old growing 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 old growing species Many big growing species High species richness	High density Many rare species High species richness		High bird values (Aug-Sept)		Rare habitat
Frisian Front	SPA	Many big growing 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	Old growing species High density					
Brown Bank		High evenness		High evenness	Under investigation	White beaked dolphin (occasional sighting)	
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

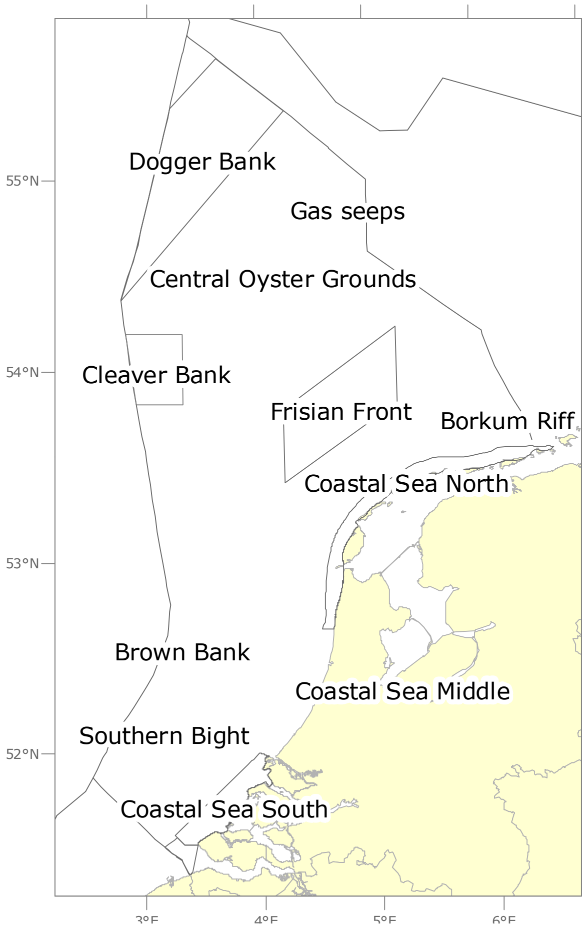


Figure 37. Different areas and their names on the DCS. Not all names are official names. The Natura 2000 areas are indicated with lines.

7 Quality Assurance

Decimal characters: Data is in derogation Dutch SI reported a decimal point (.) instead of a comma (,).

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 57846-2009-AQ-NLD-RvA). This certificate is valid until 15 December 2012. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Environmental Division has NEN-AND-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 27 March 2013 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

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Appendix A. Biodiversity metrics

Based on the criteria for GES-descriptor 1: “Biodiversity” we have defined 13 metrics (or metrics) of biodiversity that are described in this chapter.

Metric 1. Distribution

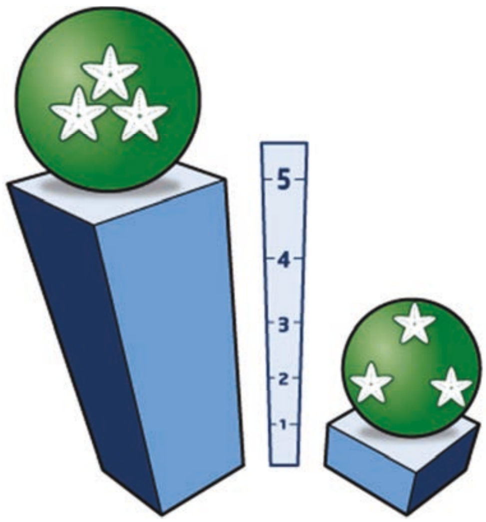
1. Description	The distribution of a species indicates where it is found based on the survey data. In this report, the species distribution maps (presence/absence) serve as underlying maps for other metrics.	X	benthos
		X	fish
		X	birds
		X	mammals
		X	habitats
2. Calculation of metric values per species	For each species the presence/absence per (sampling) location is determined		
3. Standardising values	Not applicable		
4. Mapping	Not applicable		
5. Interpretation of map	Not applicable		

Metric 2. Density

<table>
<tr><td>1. Description</td><td>Density is the total number of individuals at a location.</td><td>X

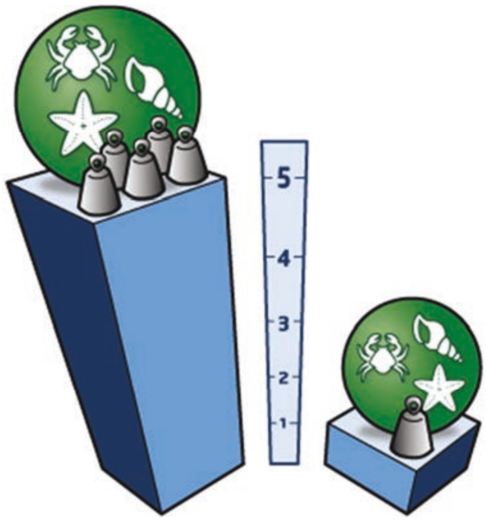
X
X
</td><td>benthos
fish
birds
mammals
habitats</td></tr>
<tr><td>2. Calculation of metric values per species</td><td colspan="3">Density is expressed as the number of individuals per unit surface, summed over all species (this is different per survey and species group).

• Benthos: density is expressed as number of individuals per m^2 (n/m^2)
• Birds: first, the average density (n/km^2) per two-month period is calculated per 5x5km block for each species. Then, the maximum of these six values is taken for each block and species.
• Marine mammals: density was expressed as a chance from 0 (no chance) to 4(high chance), based on literature and expert judgement.</td></tr>
<tr><td>3. Standardising values</td><td colspan="3">• Benthos: density data are divided into 5 equally sized classes and then given 1 to 5 points, where 1 is a low density and 5 a high density.
• Birds: density values are not rescaled, but integrated in the final map directly (see bird sections).
• Mammals: encounter chances per unit area are divided into 5 equally sized classes and then given 1 to 5 points, where 1 is a low density and 5 a high density.



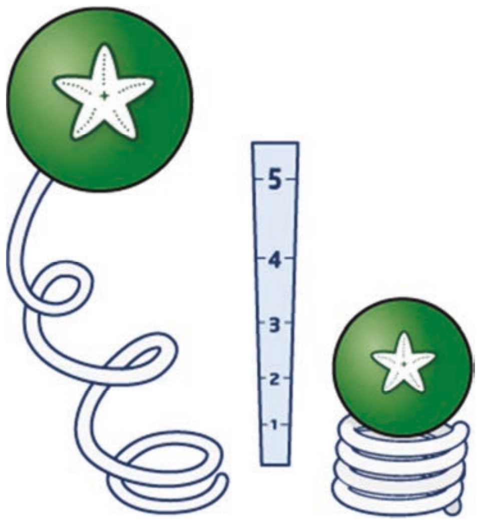
High density (5 points) *low density (1 point)*</td></tr>
<tr><td>4. Mapping</td><td colspan="3">• Benthos: two maps are made: one with scaled densities at sampling stations, and one with interpolated densities for the whole DCS (scaled data are cokriged with a sediment distribution, since benthos communities are correlated to sediment characteristics).
• Birds: maps are only made for total bird values (per season and total), not for densities alone.
• Mammals: scaled values (scale 1-5) are plotted at the relatively large scale of 1/9 ICES rectangles, to express the uncertainties of these maps.</td></tr>
<tr><td>5. Interpretation of map</td><td colspan="3">5 points: high density of individuals (all species together)
1 point: low density of individuals (all species together)</td></tr>
</table>

Metric 3. Biomass

<table>
<tr><td>1. Description</td><td>Biomass is the total biomass of all species at a location.</td><td><table><tr><td>X</td><td>benthos</td></tr><tr><td></td><td>fish</td></tr><tr><td></td><td>birds</td></tr><tr><td></td><td>mammals</td></tr><tr><td></td><td>habitats</td></tr></table></td></tr>
<tr><td>2. Calculation of metric values per species</td><td colspan="2">Biomass is expressed as the total biomass of all species together
Benthos: biomass is expressed as total grams ash free dry weight (g AFDW). AFDW is usually used instead of fresh weight, since water content of species (for example inside a sponge or worm) may vary considerably among indivuals of the same size.</td></tr>
<tr><td>3. Standardising values</td><td colspan="2">The biomass data are divided into 5 equally sized classes and then given 1 to 5 points, where 1 is a low biomass and 5 a high biomass.


High biomass (5 points) low biomass (1 point)</td></tr>
<tr><td>4. Mapping</td><td colspan="2">Benthos: two maps are made: one with scaled biomass at sampling stations, and one with interpolated biomass for the whole DCS (scaled data are cokriged with a sediment distribution, since benthos communities are correlated to sediment characteristics).</td></tr>
<tr><td>5. Interpretation of map</td><td colspan="2">5 points: high biomass (all species together)
1 point: low biomass (all species together)</td></tr>
</table>

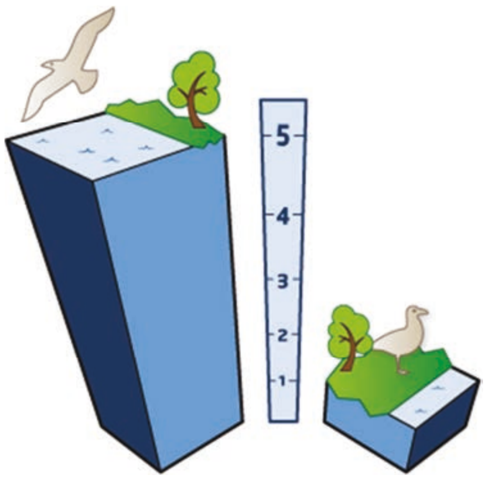
Metric 4. Resilience

<table>
<tr><td>1. Description</td><td>The resilience of a species indicates how fast a species can recover after an impact. The resilience metric is based on reproductive capacity of a species or proxies thereof, such as a large maximum age or a large weight.
<table><tr><td>X</td><td>benthos</td></tr><tr><td></td><td>fish</td></tr><tr><td>X</td><td>birds</td></tr><tr><td>X</td><td>mammals</td></tr><tr><td></td><td>habitats</td></tr></table></td></tr>
<tr><td>2. Calculation of metric values per species</td><td>Benthos. We used a large maximum age (>10y) as a proxy for resilience of benthos species. We determined maximum ages per species through literature research. Maximum ages that could not be determined from the literature, were estimated using expert judgment (R. Witbaard, M. Lavaleye). Maximum ages were only determined for macrobenthos (BIOMON) species.
Birds. For birds we calculated the rate of reproduction using the formula (X+Y)/Z, where X = average clutch size (X), Y = whether or not the species can produce replacement clutches (Y) and Z = average age at first breeding, where Y could be either 0 (no replacement clutches); 0.5 (replacement clutches only in part of the distribution range) or 1 (replacement clutches common when the first clutch is lost). This resulted in values ranging from 0.1 (Northern Fulmar) to 7.3 (Greater Scaup), as listed in Appendix D.
Mammals: we estimated the maximum lifetime reproductive output using the number of calves per year, the age at first breeding and the lifespan.</td></tr>
<tr><td>3. Standardising values</td><td>Benthos: Per sampling station, we counted the number of species with a potential age > 10y. Next, the number of species per station were rescaled from 1-5 to get metric values per location.
Birds: resilience values per species were combined with other values of other metrics and not depicted separately.
Mammals: resilience values per species were multiplied with species density per 1/9 ICES square to obtain total resilience values per unit surface. The total values per ‘station’ were then rescaled from 1-5.

Low resilience (or high vulnerability) (5 points) high resilience (or low vulnerability) (1 point)</td></tr>
<tr><td>4. Mapping</td><td>Benthos: two maps are made: one with scaled values (1-5) per sampling station and one with interpolated values for the whole DCS (scaled data are cokriged with a sediment distribution, since benthos communities are correlated to sediment characteristics).
Birds: we did not make a separate map for bird resilience. Instead, all metrics were summed per species and mapped in a final map. Resolution: 5x5 km
Mammals: resilience values (1-5) were plotted at a 1/9 ICES scale.</td></tr>
<tr><td>5. Interpretation of map</td><td>High values: fragile species that may disappear quickly
Low values: resilient species that can withstand pressures well</td></tr>
</table>

Metric 5. Dependence on the marine environment

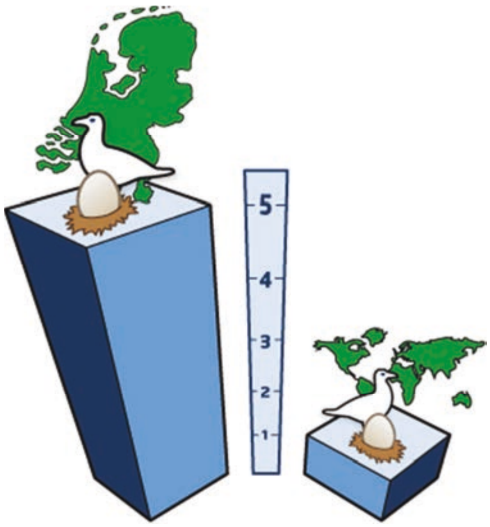
<table>
<tr><td>1. Description</td><td>The marine species metric indicates to what extend a bird species depends on the marine environment.

<table>
<tr><td></td><td>benthos</td></tr>
<tr><td></td><td>fish</td></tr>
<tr><td>X</td><td>birds</td></tr>
<tr><td></td><td>mammals</td></tr>
<tr><td></td><td>habitats</td></tr>
</table></td></tr>
<tr><td>2. Calculation of metric values per species</td><td>• Birds: For each bird species, literature data on their dependence on the marine environment was looked up.</td></tr>
<tr><td>3. Standardising values</td><td>• Birds: Species that spend the majority of their time on land or in freshwater habitats and use the sea off the Netherlands only by exception or in case of severe weather (freezing over of fresh water lakes) were given 1 (Mediterranean Gull) or 2 points (some grebes, ducks, gulls and terns); species that use the North Sea about equally often as they use estuaries or inland habitats were given 3 points; species that spend the majority of their time in the North Sea (while occurring in Dutch waters) were given 4 points and those species that spend (nearly) all of their time in the North Sea were given 5 points

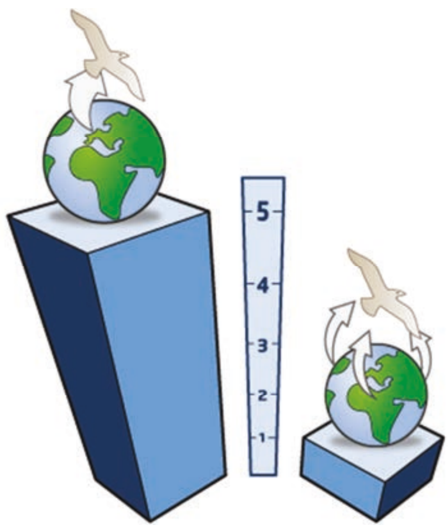


True marine species (5 points) mainly land/freshwater species (1 point)</td></tr>
<tr><td>4. Mapping</td><td>• Birds: we did not make a separate map for bird dependence on the marine environment. Instead, all metrics were summed per species and mapped in a final map. Resolution: 5x5 km.</td></tr>
<tr><td>5. Interpretation of map</td><td>High values: species is truly marine.
Low values: species spend majority of their time on land/fresh water.</td></tr>
</table>

Metric 6. Breeding in the Netherlands

1. Description	The breeding in NL metric indicates whether a bird species breeds in the Netherlands and if so, if a significant part of the biogeographical breeding population depends on the Dutch EEZ for provisioning of the chicks.	 X 	benthos fish birds mammals habitats
2. Calculation of metric values per species	• Birds: For each bird species, literature data on their breeding location was looked up. Birds that breed locally and provision their chicks with food from the Dutch part of the North Sea were considered of higher conservation value than birds breeding elsewhere, as these are especially dependent on the Dutch EEZ (Leopold et al. in prep.)		
3. Standardising values	• Birds: 1 point: the species breeds elsewhere and the Dutch EEZ is not important for provisioning of chicks. 5 or 4 points: the species breeds in the Netherlands and a significant part of the biogeographical population depends on the Dutch EEZ for provisioning of the chicks.  *Breeds in the Netherlands (5 points)* *breeds abroad (1 point)*		
4. Mapping	• Birds: we did not make a separate map for bird dependence on the marine environment. Instead, all metrics were summed per species and mapped in a final map. Resolution: 5x5 km.		
5. Interpretation of map	High values (dark color): species breeds in NL. Low values (light color): species does not breed in NL.		

Metric 7. Importance of the Dutch Continental Shelf for the species

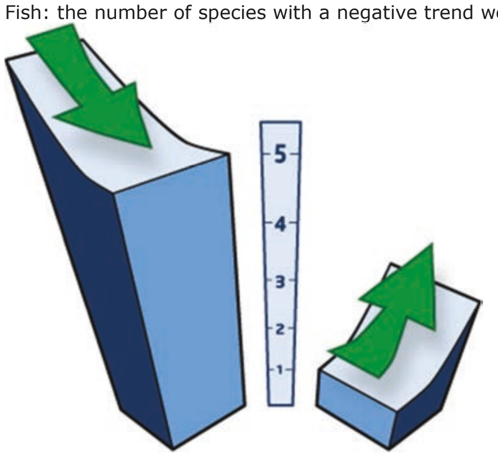
1. Description	This metric indicates how important the Dutch Continental Shelf is for the biogeographical population.	benthos fish X birds X mammals habitats
2. Calculation of metric values per species	• Birds: Per species, the maximum number present on the Dutch EEZ was divided by the size of the total North Sea population as determined from literature values. • Mammals: see birds.	
3. Standardising values	• Birds: Relative maximum proportions of occurrence, as compared to the total relevant biogeographical populations were re-scaled from 1-5 (Leopold et al. in prep.) • Mammals: see birds  *Dutch EEZ is of high importance to population (5 points)* *Dutch EEZ is of low importance to population (1 point)*	
4. Mapping	• Birds: we did not make a separate map for this metric. Instead, all metrics were summed per species and mapped in a final map. Resolution: 5x5 km. • Mammals: density (i.e. chances, see metric 1) was multiplied by the number of points. These were summed over all species per 1/9 ICES rectangle.	
5. Interpretation of map	High values: DCS is of high importance to the biogeographical population of a bird/marine mammal species. Low values: DCS is of low importance to the biogeographical population of a bird/marine mammal species.	

Metric 8. Trends

<table>
<tr><td>1. Description</td><td>This metric describes the whether populations show a negative, neutral or positive trend over the last 25 years.</td><td>
X

</td><td>benthos
fish
birds
mammals
habitats</td></tr>
<tr><td>2. Calculation of metric values per species</td><td colspan="3"><u>Fish:</u>
Trend analyses are based on fishery survey data for 1985-2009 Per survey and per species, graphs of trends were plotted, and trends were estimated using different methods (a linear model and visual judgement). Trends were estimated as negative, neutral or positive (see section 4.2.2 for more information).</td></tr>
<tr><td>3. Standardising values</td><td colspan="3">

- Fish: the number of species with a negative trend were counted.



High number of species with a long-term negative trend (5 points)

Low number of species with a long term negative trend (1 point)

NB: this picture depicts both negative and positive trends, while for the production of maps we used the number of species with a negative trend only.
</td></tr>
<tr><td>4. Mapping</td><td colspan="3">

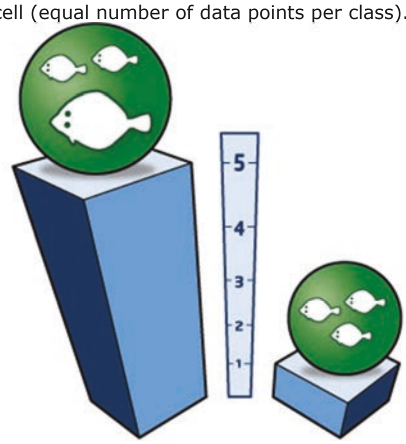
- Fish: Per 1/9 ICES rectangle the total number of species with a negative trend in the Southern North Sea is shown and rescaled from 1 to 5.
</td></tr>
<tr><td>5. Interpretation of map</td><td colspan="3">Low: low number of species with a negative trend.
High: high number of species with a negative trend.</td></tr>
</table>

Metric 9. Rarity

1. Description	The metric Rarity indicates how rare a species is compared to other species.	X benthos X fish X birds X mammals X habitats
2. Calculation of metric values per species	• Benthos: macrobenthos (BIOMON + Cleaver Bank): For each species it was determined how many times it occurred in all samples. Species that occurred in less than 5% of the samples were considered rare. Triple-D data: species that occurred in less than 15% of the samples were considered rare. • Fish: For fish rarity, we use an existing method (Daan 2000) which takes into account both numeric density and frequency of occurrence. Both aspects are combined in an index of rarity. For these calculations the data of all fish surveys described are used. The calculations are done based on the list of selected species in Appendix C and we only used the data of the last ten years (2000-2009). • Birds: rarity is defined as the size of the biogeographical population as found in the literature. • Mammals: rarity is defined as the size of the biogeographical population as found in the literature. • Habitats: rarity is expressed as the relative surface (surface per habitat type divided by surface of DCS).	
3. Standardising values	• Benthos: macrobenthos (BIOMON + Cleaver Bank) and megabenthos (Triple-D + Cleaver Bank): per station, the number of rare species present in the dataset were counted. Data were rescaled from 1-5 (equal number of data per class). • Fish: the rarity-values per 1/9 of an ICES-rectangle were calculated and rescaled from 1-5 (equal number of data per class). • Birds: biogeographical population sizes were rescaled (1-5) as depicted in Figure 30. We did not make a separate graph for rarity, instead all metric values were summed per species, multiplied by density, and then used for mapping. • Mammals: rarity data are rescaled from 1-5 (equal number of data per class). • Habitats: rarity data are rescaled from 1-5.  *High number of rare species (5 points) low number of rare species (1 point)* NB: this picture depicts both rare and common species, while for the production of maps we used the number of rare species only.	
4. Mapping	• Benthos: two maps are made: one with scaled data per sampling station and one with interpolated scaled data for the whole DCS (scaled data are cokriged with a sediment distribution, since benthos communities are correlated to sediment characteristics). • Fish: rescaled rarity values are plotted per 1/9 ICES rectangle. • Birds: we did not make a separate map for this metric. Instead, all metrics were summed per species and mapped in a final map. Resolution: 5x5 km.	

	• Mammals: points (scale 1-5) are plotted at the relatively large scale of 1/9 ICES rectangles, to express the uncertainties of these maps. • Habitats: points (scale 1-5) are plotted per habitat type.
5. Interpretation of map	High score: area with species/habitats that are rare Low score: area with species/habitats that are common

Metric 10. Large specimens within populations

1. Description	This metric selects for large specimens within populations.	benthos X fish birds mammals habitats
2. Calculation of metric values per species	• Fish: based on all available fish surveys we calculated the number of species with specimens present with a length of at least 75% of the known maximum length per 1/9 ICES rectangle (95 species, period 2000-2009).	
3. Standardising values	• Fish: Per grid cell (1/9 ICES rectangle) we gave 1-5 points on the basis of the total number of species of which large individuals (>75% of max length) occured in the grid cell (equal number of data points per class).  *High number of fish species with individuals of 75% Lmax present (5 points)* *Low number of fish species with individuals of 75% Lmax (1 point)*	
4. Mapping	Fish: rescaled numbers of species with large specimens are plotted per 1/9 ICES rectangle. Note: large individuals of a species can mean that they are only about 5 cm in length (*Amphia minuta*), while other individuals have to be larger than 225 cm (*Dipturus batis*) to be included in this map.	
5. Interpretation of map	High score: area with a relatively high number of species of which individuals have been caught larger than 75% of the maximum length for that species. Low score: area with a relatively low number of species of which individuals have been caught larger than 75% of the maximum length for that species.	

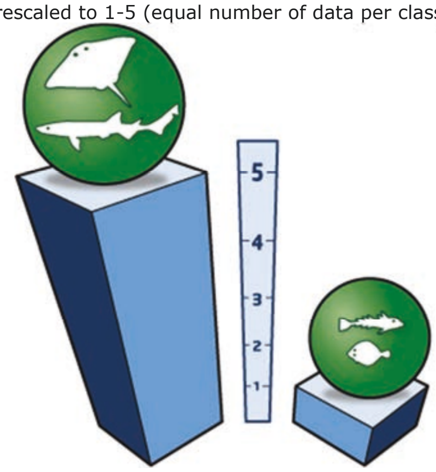
Metric 11. (Potentially) large species

<table>
<tr><td>1. Description</td><td>The Large species metric indicates where species occur that can potentially grow relatively large.</td><td>X benthos
X fish
birds
mammals
habitats</td></tr>
<tr><td>2. Calculation of metric values per species</td><td colspan="2">

- Benthos: Maximum weights of macrobenthic species were obtained from the macrobenthos dataset itself.
- Fish: Maximum lengths (LMax) values of North Sea fish species were obtained from literature. We calculated how many large growing species occurred per unit area. The data used is the presence/absence of species per 1/9 of an ICES-rectangle, of the data set of all surveys combined. Only the occurrence in the last 10 years is used (2000-2009). For mapping, we used only species with an Lmax of >90 cm.

</td></tr>
<tr><td>3. Standardising values</td><td colspan="2">

- Benthos: macrobenthos: species with a potential maximum weight > 1000 mg were selected. The number of species per location were rescaled from 1-5 (equal number of data per class).
- Fish: the number of present species with Lmax > 90 cm per 1/9 ICES rectangle were rescaled to 1-5 (equal number of data per class).



High number of potentially large growing species present (5 points)

Low number of potentially large growing species present (1 point)

NB: this picture depicts both large and small growing species, while for the production of maps we used the number of potentially large growing species only.

</td></tr>
<tr><td>4. Mapping</td><td colspan="2">

- Benthos: macrobenthos: two maps were made: the rescaled numbers of species with a relatively high potential weight were plotted per sampling point and interpolated (cokriged with sediment size).
- Fish: rescaled numbers of species with Lmax >90 cm were plotted per 1/9 ICES rectangle.

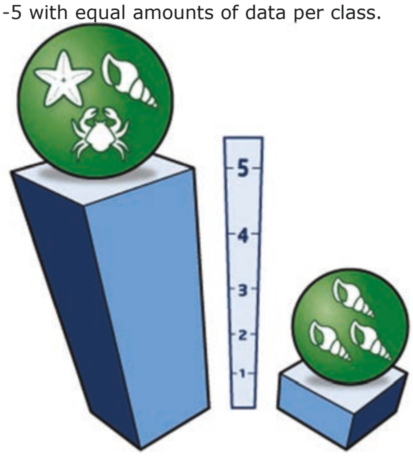
</td></tr>
<tr><td>5. Interpretation of map</td><td colspan="2">

High score: presence of a relatively high number of species with a large maximum length or weight
Low score: presence of a relatively low number of species with a large maximum length or weight

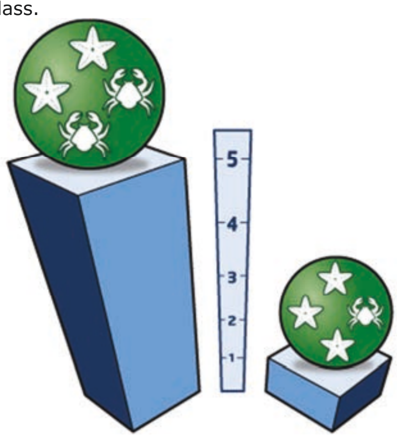
NB. This map does not depict the occurrence of large individuals of these species, only the occurrence of species that can **potentially** grow large.

</td></tr>
</table>

Metric 12. Species Richness

1. Description	Species richness is the total number of species per unit area or sampling station, calculated separately per group (fish, benthos, birds, marine mammals).	X benthos X fish birds X mammals habitats
2. Calculation of metric values per species	• Benthos: the number of species found depends strongly on the sampling effort. Therefore, we used samples or hauls as units and expressed species richness as the number of species per unit, averaged over years or areas. • Fish: just as in benthos, species richness depends on sampling effort. For fish we considered 20 hauls enough to have sampled most species. We therefore took at least 20 hauls in a 1/9 ICES rectangle. If the hauls were not present, they were randomly chosen from adjacent 1/9 ICES rectangles. • Mammals: species richness is expressed as the sum of chances of occurrences.	
3. Standardising values	• Benthos: numbers of species per unit area were rescaled to a scale of 1-5 with equal amount of data per class. • Fish: numbers of species per unit area were rescaled to a scale of 1-5 with equal amounts of data per class. • Mammals: numbers of species (total chances) per unit area were rescaled to a scale of 1-5 with equal amounts of data per class.  *High species richness (5 points)* *low species richness (1 point)*	
4. Mapping	• Benthos: rescaled species numbers were plotted in two maps: one showing the data per sampling point, the other showing kriged data (cokriged with sediment size) • Fish: rescaled species numbers are plotted per 1/9 ICES rectangle • Mammals: rescaled chances are plotted per 1/9 ICES rectangle	
5. Interpretation of map	Low score: a low number of species is present in the area High score: a high number of species is present in the area	

Metric 13. Species Evenness

1. Description	Evenness indicates how even species are numerically distributed	X benthos X fish birds mammals habitats
2. Calculation of metric values per species	• Benthos: evenness is calculated as the Shannon-Wiener index • Fish: evenness is calculated as the Shannon-Wiener index: Shannon-Wiener diversity index where P_i = the proportion of each species in the sample	
3. Standardising values	• Benthos: species evenness is rescaled to a scale of 1-5 with equal amounts of data per class • Fish: species evenness is rescaled to a scale of 1-5 with equal amounts of data per class.  *High evenness (5 points)* *low evenness (1 point)*	
4. Mapping	• Benthos: rescaled species numbers were plotted in two maps: one showing the data per sampling point, the other showing kriged data (cokriged with sediment size) • Fish: rescaled species numbers are plotted per 1/9 ICES rectangle	
5. Interpretation of map	Low score: a few species are dominant High score: species are evenly distributed	

Appendix B. Benthos

Table 17. Macrobenthos (BIOMON + Cleaver Bank). Stations with positions and the obtained rank numbers (scale 1-5) per biodiversity metric on basis of the species composition.

stations-posities	X gr_honderste	Y gr_honderste	agerank_nfinds class=5	weightrank_nfinds class=5	rarityrank_nfinds class=5	densityrank ogv all classes	weightrank ogv all classes	species richness all classes	shannonwienerrank all	Nspeciesold class=5	nspeciesrare class=5	nspecheavy class=5
COA01	5.998056	53.54278	1	3	2	5	3	2	2	1	2	4
COA02	5.63	53.50528	1	4	1	5	5	1	1	1	1	3
COA03	4.530556	52.54722	1	5	1	4	5	2	3	1	1	4
COA04	4.666667	52.83333	1	4	2	3	5	1	3	1	2	5
COA05	4.688889	53.05639	1	2	3	5	5	2	1	1	3	3
COA06	6.184167	53.53583	1	4	2	5	5	1	1	1	2	4
COA07	6.546111	53.5825	1	1	3	2	1	2	3	1	3	3
COA08	5.150556	53.415	1	3	1	3	5	2	2	1	1	4
COA09	4.5	52.75	2	2	4	5	5	3	1	2	3	3
COA10	4.405556	52.26	2	4	1	2	5	2	4	2	1	4
COA11	4.300278	52.29472	1	4	1	2	5	2	2	1	1	3
COA12	3.3875	51.61778	2	3	2	1	5	1	1	2	2	5
COA13	3.600556	51.70639	1	1	3	1	1	1	4	1	3	0
COA14	3.813333	51.79056	2	4	2	3	5	3	2	2	2	6
COA15	3.919167	51.92222	1	4	1	5	5	2	1	1	1	4
DOG01	4.05	55.47167	4	1	4	3	1	4	5	4	4	3
DOG02	3.641667	55.16667	3	2	2	3	3	4	5	4	2	3
DOG03	3.5	55.25	4	3	3	3	2	4	5	5	3	5
DOG04	3.157222	55.17056	3	2	4	4	2	4	5	5	4	5
DOG05	3.233333	54.91167	3	4	2	3	3	4	5	4	2	5
DOG06	3.083333	54.95167	3	2	3	3	1	4	4	4	3	3
DOG07	3	55	4	2	1	4	1	5	5	4	1	5
OFF01	5.983333	53.85833	3	2	1	4	2	3	3	5	1	5
OFF02	6.106944	53.62472	2	2	1	5	4	2	1	2	1	3
OFF03	5.826944	53.61111	2	3	1	4	5	2	3	2	1	4
OFF04	4.958333	53.66667	3	4	1	3	3	3	5	3	1	3
OFF05	4.375	53.48333	2	4	1	3	4	3	4	3	1	4
OFF06	4.442222	53.18778	2	1	1	2	1	2	4	2	1	4
OFF07	4.306111	53.09972	2	3	1	2	5	1	2	2	1	3
OFF08	4.008333	53.025	1	2	2	3	2	1	2	1	2	2
OFF09	4.230556	52.82222	1	1	1	2	2	1	2	1	1	2
OFF10	3.841667	52.76111	1	1	1	2	3	1	3	1	1	2
OFF11	3.521667	53.28333	2	1	2	2	1	2	4	2	2	2
OFF12	3.391667	53.06528	2	1	1	1	1	1	4	2	1	2
OFF13	3.193333	53.04944	2	1	1	1	1	1	4	2	1	3

stations-posities	X gr_honderste	Y gr_honderste	agerank_nfinds class=5	weightrank_nfinds class=5	rarityrank_nfinds class=5	densityrank ogv all classes	weightrank ogv all classes	species richness all classes	shannonwienerrank all	Nspeciesold class=5	nspeciesrare class=5	nspecheavy class=5
OFF14	3.288889	52.89806	2	2	1	2	1	1	3	2	1	2
OFF15	3.288333	52.83667	1	1	1	2	2	1	2	1	1	3
OFF16	3.5	52.75	1	1	2	1	1	1	3	1	2	2
OFF17	3.203333	52.46194	1	1	1	1	1	1	4	1	1	1
OFF18	3.190278	52.34028	1	1	1	1	1	1	4	1	1	3
OFF19	3.411667	52.25278	1	2	1	1	3	1	4	1	1	4
OFF20	3.5	52.25	1	2	1	1	2	1	4	1	1	2
OFF21	3	52	1	1	2	1	1	1	4	1	2	1
OFF22	3.9875	52.275	1	2	1	1	1	1	2	1	1	3
OFF23	4.163889	52.38556	1	3	4	3	5	2	2	1	4	4
OFF24	3.716111	52	1	1	1	1	1	1	4	1	1	3
OFF25	3.407222	52.10333	2	2	2	1	2	1	4	2	2	4
OFF26	3.192778	51.93528	1	1	1	1	1	1	5	1	1	1
OFF27	3.241111	51.69444	1	2	2	2	4	1	2	1	2	4
OFF28	2.88	51.87778	1	1	2	1	1	1	3	1	2	2
OFF29	6.31	53.95389	3	2	1	3	3	5	4	4	1	3
OFF30	4.938056	53.61556	2	2	1	3	4	5	3	2	1	4
OFF31	3.916944	52.99806	1	1	2	2	1	2	2	1	2	2
OFF32	4.048056	52.3875	1	1	2	2	1	2	2	1	2	1
OFF33	3.785278	52.475	2	3	5	5	4	5	4	3	4	5
OFF34	3.531389	52.56944	1	1	1	2	1	2	3	1	1	2
OFF35	3.113611	51.71833	1	1	2	2	1	2	3	1	2	2
OFF36	2.679167	51.95694	2	1	3	1	1	4	5	2	3	0
OYS01	3.425	54.38333	4	3	3	4	4	4	1	5	3	5
OYS02	5.541667	54.19167	4	4	2	3	2	3	3	3	2	5
OYS03	4	55	5	5	5	5	4	5	1	5	5	7
OYS04	2.933333	54.55	5	2	3	4	2	5	5	5	3	5
OYS05	4.916667	54.01944	4	5	2	3	4	5	3	4	2	9
OYS06	4.38	55.30667	5	2	1	5	4	5	1	5	1	8
OYS07	4.3	54.88333	4	4	5	3	2	5	2	4	5	8
OYS08	4.9	53.74444	3	3	1	4	4	4	2	2	1	5
OYS09	3.630556	53.75556	4	1	1	2	1	3	5	4	1	3
OYS10	3.708333	54.65	5	2	2	5	4	4	1	5	2	4
OYS11	5.166667	53.925	3	4	2	4	4	4	3	2	2	5
OYS12	4.433333	54.16667	4	5	1	2	4	4	5	4	1	6
OYS13	3.5	54.75	4	4	2	4	4	3	1	3	2	5
OYS14	4.741667	54.33333	4	3	3	3	3	4	3	4	3	7
OYS15	4.355556	54.475	4	5	4	2	4	5	5	5	4	6
OYS16	5.05	54.64167	3	3	1	3	2	3	1	2	1	4
OYS17	3.418889	54.00583	4	2	1	3	2	4	5	4	1	4

stations-posities	X gr_honderste	Y gr_honderste	agerank_nfinds class=5	weightrank_nfinds class=5	rarityrank_nfinds class=5	densityrank ogv all classes	weightrank ogv all classes	species richness all classes	shannonwienerrank all	Nspeciesold class=5	nspeciesrare class=5	nspecheavy class=5
OYS18	5.9	54.18889	5	3	1	5	2	4	2	5	1	6
OYS19	3.316667	54.33333	4	4	3	3	4	4	1	4	3	6
OYS20	2.864167	54.08333	5	3	3	3	3	4	5	5	3	7
OYS21	4.7675	53.76778	3	4	3	4	4	4	3	3	3	5
OYS22	3.641667	54.30833	5	2	2	3	2	5	4	5	2	7
OYS23	3.366667	54.82333	5	2	2	5	2	5	2	5	2	4
OYS24	3.496111	53.5	2	3	2	2	5	3	4	2	2	6
OYS25	4.533333	54.65	3	3	2	2	2	4	3	4	2	4
OYS26	4.791667	53.92222	3	4	1	3	3	4	3	3	1	6
OYS27	5	54.5	5	4	2	3	3	3	4	5	2	5
OYS28	3.5	53.75	5	1	1	2	3	3	4	5	1	2
OYS29	3	54.5	5	2	4	3	3	4	4	4	4	4
OYS30	3.305833	53.525	3	3	1	2	4	3	4	4	1	3
OYS31	4.151667	53.845	4	3	1	3	3	4	3	4	1	5
OYS32	5.083333	54.25833	3	5	2	3	4	4	2	2	2	6
OYS33	4.05	54.26667	4	5	1	3	3	5	1	4	1	6
OYS34	4.276944	53.62778	3	3	1	3	4	3	3	3	1	5
OYS35	3.873333	53.85861	5	2	1	3	2	3	4	5	1	5
OYS36	4.5	53.70139	3	3	2	2	3	5	3	2	2	5
OYS37	4.340833	54.15111	3	5	3	2	4	5	5	3	3	6
OYS38	3	53.5	3	2	1	2	2	4	5	3	1	2
OYS39	4	54.5	5	2	1	4	2	5	1	5	1	5
OYS40	5	55	5	2	1	5	2	5	3	4	1	5
OYS41	3.293333	54.86167	5	2	2	3	2	5	4	5	2	4
OYS42	6.214167	54.1175	4	3	1	3	2	5	4	5	1	5
KLA1	3.21415	54.11492	2	2	2	1	5	3	5	3	2	4
KLA2	3.22018	54.155	2	5	5	2	5	4	4	3	5	8
KLA2.1	3.22321	54.15554	2	1	2	1	1	1	4	3	2	5
KLA2.2	3.22595	54.14809	2	4	2	2	1	2	1	3	2	8
KLA2.3	3.22698	54.14915	2	1	4	1	1	2	5	2	4	3
KLA2.4	3.22595	54.14809	2	1	2	1	1	4	5	2	2	3
KLA3	3.20179	54.14498	2	1	2	2	5	2	5	2	2	2
KLA4	3.18182	54.0106	2	3	5	1	5	3	5	3	5	7
KLA5	3.18205	54.15685	2	1	2	2	5	2	5	2	2	4
KLA7	2.88368	53.95236	2	4	4	2	5	3	5	3	4	6
KLA8	2.88732	54.06286	3	4	4	1	5	2	4	2	4	6
KLA10	2.84136	54.17483	2	3	5	2	5	2	3	3	5	5

Table 18. Macrobenthos. Species ranks on base of rarity, potential maximum age and potential maximum weight. The meaning of the classes are explained in Table 7, Table 8 and Table 10. Maximum ages estimates and their references are listed as well. When no references are given, this means that the estimated maximum ages are based on related species within this table.

Taxon	Rarity class	Age class	Max Age (y)	Weight class	Total rank	Reference for maximum age
Abludomelita obtusata	3	1	1	1	5	Estimated, no literature found
Abra alba	1	3	3	2	6	(Marine Ecological Surveys Ltd 2008)
Abra nitida	2	4	7	2	8	(Robertson 1979, Josefson 1987)
Abra prismatica	2	2	2	3	7	Extrapolated based on genus
Abra tenuis	4	1	1	1	6	www.marlin.ac.uk/biotic/browse.php?sp=6210
Acanthocardia echinata	3	3	3	3	9	(Robertson 1979)
Acidostoma obesum	3	2	2	1	6	(Sainte-Marie et al. 1990)
Acrocnida brachiata	1	3	4	3	7	(Davoult et al. 2009)
Acteon tornatilis	4	3	3	2	9	Based on *Euspira pulchella*
Aglaophamus rubella	3	3	3	3	9	Based on other species in the order and family
Alvania lactea	4	1	1	2	7	No literature found
Ampelisca brevicornis	1	2	2	2	5	(Dauvin 1989)
Ampelisca diadema	5	2	2	2	9	(Marine Ecological Surveys Ltd 2008)
Ampelisca macrocephala	5	2	2	2	9	(Marine Ecological Surveys Ltd 2008) , www.marlin.ac.uk/biotic/browse.php?sp=6210
Ampelisca spinipes	3	2	2	2	7	Estimated, no literature found
Ampelisca tenuicornis	1	2	2	2	5	(Marine Ecological Surveys Ltd 2008)
Ampelisca typica	3	2	2	2	7	(Marine Ecological Surveys Ltd 2008)
Ampharete acutifrons	4	4	10	2	10	(Robertson 1979)
Ampharete finmarchica	2	3	5	2	7	(McHugh & Fong 2002)
Amphicteis gunneri	5	3	4	2	10	Based on higher taxonomy, (McHugh & Fong 2002)
Amphipholis squamata	3	3	3	2	8	(Marine Ecological Surveys Ltd 2008)
Amphiura chiajei	2	4	10	2	8	(Munday & Keegan 1992)
Amphiura filiformis	1	5	20	3	9	(Mortensen 1927, Buchanan 1964, O'Connor et al. 1983, Josefson 1987, Gage 1990)
Antinoe finmarchica	0	3	5	2	5	(McHugh & Fong 2002)
Aonides oxycephala	3	1	1	2	6	(Marine Ecological Surveys Ltd 2008)
Aonides paucibranchiata	1	1	1	2	4	(Marine Ecological Surveys Ltd 2008)
Aora typica	5	1	1	1	7	Estimated, no literature found
Aphelochaeta marioni	2	3	5	2	7	www.marlin.ac.uk/biotic/browse.php?sp=4317
Apherusa bispinosa	4	1	1	1	6	Estimated, no literature found
Apherusa clevei	5	1	1	1	7	Estimated, no literature found
Apherusa jurinei	4	1	1	1	6	Estimated, no literature found
Apherusa ovalipes	3	1	1	1	5	Estimated, no literature found
Aphrodita aculeata	2	4	10	4	10	www.marlin.ac.uk/biotic/browse.php?sp=4405
Apistobranchus tullbergi	5	1	1	1	7	Estimated, no literature found
Aplacophora	2	1	1	2	5	Estimated, no literature found
Aporrhais pespelecani	4	3	3	3	10	Estimated, no literature found
Arcopagia crassa	4	4	8	3	11	Witbaard expert judgement
Arctica islandica	2	5	200	5	12	(Witbaard et al. 1997, Witbaard & Bergman 2003, Witbaard 2007)
Argissa hamatipes	2	1	1	1	4	Estimated, no literature found
Aricidea jeffreysii	4	1	1	1	6	Estimated, no literature found
Aricidea minuta	1	1	1	2	4	Estimated, no literature found

Taxon	Rarity class	Age class	Max Age (y)	Weight class	Total rank	Reference for maximum age
Aricidea suecica	4	1	1	1	6	Estimated, no literature found
Ascidiacea	5	0	-	1	6	-
Aspidosiphon muelleri	5	1	1	3	9	As *Golfingia* (Marine Ecological Surveys Ltd 2008)
Astarte montagui	5	2	2	2	9	(Schaefer et al. 1985)
Asterias rubens	2	4	10	4	10	(Robertson 1979), http://www.marlin.ac.uk/reproduction.php?speciesID=2657
Astropecten irregularis	2	3	4	3	8	http://www.marlin.ac.uk/
Atylus falcatus	1	1	1	1	3	Estimated on genus-family or order
Atylus swammerdami	1	1	1	2	4	Estimated on genus-family or order
Atylus vedlomensis	3	1	1	2	6	Estimated on genus-family or order
Autolytus	4	2	2	1	7	(McHugh & Fong 2002)
Bathyporeia elegans	1	1	1	2	4	www.marlin.ac.uk/biotic/browse.php?sp=5999
Bathyporeia gracilis	4	1	1	1	6	Estimated on genus-family or order
Bathyporeia guilliamsoniana	1	1	1	2	4	Estimated on genus-family or order
Bathyporeia pelagica	4	1	1	1	6	www.marlin.ac.uk/biotic/browse.php?sp=4329
Bathyporeia pilosa	4	1	1	2	7	Estimated on genus-family or order
Bathyporeia tenuipes	2	1	1	1	4	Estimated on genus-family or order
Bodotria arenosa	4	1	1	1	6	Estimated on genus-family or order
Bodotria pulchella	5	1	1	1	7	Estimated on genus-family or order
Bodotria scorpioides	4	1	1	1	6	Estimated on genus-family or order
Bopyrus squillarum	5	1	1	2	8	Estimated on genus-family or order
Brada villosa	5	1	1	2	8	Estimated on genus-family or order
Branchiostoma lanceolatum	1	3	5	3	7	(Gosselck & Splitter 2007)
Brissopsis lyrifera	2	3	5	3	8	(Robertson 1979)
Buccinum undatum	5	5	20	5	15	www.marlin.ac.uk/biotic/browse.php?sp=6184
Callianassa subterranea	1	2	2	3	6	(Witbaard & Duineveld 1989)
Callianassa tyrrhena	2	2	2	3	7	Estimated on genus-family or order
Campylaspis glabra	5	1	1	1	7	Estimated on genus-family or order
Capitella capitata	1	2	2	2	5	(Méndez et al. 1997)
Caprellidae	1	1	0.5	1	3	(Takeuchi & Hirano 1991)
Carcinus maenas	4	4	6	4	12	(Van Moorsel 2005); www.marlin.ac.uk/biotic/browse.php?sp=4286
Caulleriella alata	3	4	7	1	8	(McHugh & Fong 2002)
Caulleriella killariensis	4	4	7	1	9	(McHugh & Fong 2002)
Cerianthus lloydii	2	4	6	4	10	Based on *Actinia equina*, (Westholt et al. 1999)
Chaetoderma nitidulum	5	1	1	2	8	No literature found
Chaetopterus variopedatus	1	3	3	4	8	(Thompson & Schaffner 2000, 2001)
Chaetozone christiei	3	4	7	2	9	(McHugh & Fong 2002)
Chaetozone setosa	1	3	5	2	6	(Robertson 1979, Josefson 1987); www.marlin.ac.uk/biotic/brows.php?=sp=6003
Chamelea striatula	1	5	20	3	9	(Witbaard et al. 2005)
Cheirocratus sundevallii	4	1	1	1	6	Estimated on genus-family or order
Chlamys varia	4	4	10	1	9	(Conan & Shafee 1978)
Chone duneri	2	1	1	2	5	Based on age of reproduction (McHugh & Fong 2002)
Chone infundibuliformis	4	1	1	2	7	Based on age of reproduction (McHugh & Fong 2002)
Cirolana borealis	4	4	6	3	11	(Johansen 2000)
Cirolana cranchii	4	4	6	3	11	(Johansen 2000)
Cirratulus cirratus	5	4	10	1	10	www.marlin.ac.uk/biotic/browse.php?sp=4461
Clymenura lankesteri	4	1	1	3	8	(Marine Ecological Surveys Ltd 2008)
Cochlodesma praetenue	4	3	5	2	9	(Allen 1958)

Taxon	Rarity class	Age class	Max Age (y)	Weight class	Total rank	Reference for maximum age
Corbula gibba	1	2	2	2	5	(Jensen 1990)
Corophium affine	4	1	0.5	1	6	**(**Marine Ecological Surveys Ltd 2008**)**
Corophium insidiosum	3	1	0.5	1	5	(Marine Ecological Surveys Ltd 2008) (Prato & Biandolino 2006)
Corophium volutator	5	1	0.5	1	7	Based on *Corophium crassicorne*, www.marlin.ac.uk/biotic/browse.php?sp=6260
Corymorpha nutans	4	1	1	1	6	Estimated on genus-family or order
Corystes cassivelaunus	1	3	5	4	8	(Van Moorsel 2005) ; www.marlin.as.uk/biotic/brows.php?sp=6175
Cossura longocirrata	0	1	1	1	2	Estimated, no literature found
Crangon crangon	3	3	5	3	9	(Van Moorsel 2005); www.marlin.ac.uk/biotic/browse.php?sp=4599
Cucumaria frondosa	4	4	10	3	11	(Purcell 2010)
Cylichna cylindracea	1	2	2	2	5	(Josefson 1987)
Decipula tenella	3	4	6	2	9	Based on *Montacuta ferruginosa*
Devonia perrieri	4	1	1	2	7	No literature found
Diastylis bradyi	1	1	1	2	4	Based on *Diasylis lucifera*; www.marlin.ac.uk/biotic/browse.php?sp=6268
Diastylis laevis	4	1	1	2	7	Estimated on genus-family or order
Diastylis rathkei	5	1	1	1	7	www.marlin/ac.uk/biotic/browse.php?sp=6269
Diastylis rugosa	5	1	1	1	7	Estimated on genus-family or order
Diogenes pugilator	4	2	2.25	2	8	(Manjon & Garcia-Raso 1998, Dolbeth et al. 2006)
Diplocirrus glaucus	1	2	2	2	5	(Josefson 1987)
Diplodonta rotundata	5	2	2	3	10	No literature found
Dodecaceria concharum	5	4	7	2	11	Estimated on genus-family or order (McHugh & Fong 2002)
Donax vittatus	1	3	3	3	7	(Ansell & Lagardère 1980)
Dosinia exoleta	2	5	20	3	10	(Marine Ecological Surveys Ltd 2008)
Dosinia lupinus	1	5	20	3	9	Witbaard unpublished
Dosinia lupinus lincta	5	5	20	2	12	Wibaard, unpublished
Drilonereis filum	5	4	10	3	12	(Marine Ecological Surveys Ltd 2008)
Dyopedos monacanthus	4	1	1	1	6	Witbaard, unpublished
Ebalia cranchii	2	1	1	3	6	(Marine Ecological Surveys Ltd 2008)
Ebalia granulosa	5	1	1	1	7	(Marine Ecological Surveys Ltd 2008)
Ebalia tuberosa	5	1	1	1	7	(Marine Ecological Surveys Ltd 2008)
Ebalia tumefacta	4	1	1	3	8	(Marine Ecological Surveys Ltd 2008)
Echinocardium cordatum	1	4	10	4	9	(Duineveld & Jenness 1984)
Echinocardium flavescens	3	4	10	3	10	Based on *Echinocardium cordatum* (Duineveld & Jenness 1984)
Echinocyamus pusillus	1	4	10	2	7	(Burton & Burton 2002)
Echiuridae	0	3	5	3	6	http://www.circac.org/documents/pdf/emc/recon_rpt_sec_4_5_6.pdf
Echiurus echiurus	5	3	5	2	10	http://www.circac.org/documents/pdf/emc/recon_rpt_sec_4_5_6.pdf
Eclysippe vanelli	5	3	4	2	10	Based on higher taxonomy, (McHugh & Fong 2002)
Edwardsia	1	4		3	8	Based on *Actinia equine*, (Westholt et al. 1999)
Edwardsia claparedii	1	4	6	3	8	Based on *Actinia equine*, (Westholt et al. 1999)
Endeis spinosa	5	1	1	1	7	Estimated on genus-family or order
Enipo kinbergi	2	3	5	3	8	(McHugh & Fong 2002)
Ensis arcuatus	3	4	7	4	11	Estimated on genus-family or order
Ensis directus	1	4	7	4	9	(Armonies & Reise 1999)
Ensis ensis	2	4	7	3	9	Estimated on genus-family or order
Ensis minor	5	4	7	4	13	Estimated on genus-family or order
Ensis phaxoides	4	4	7	3	11	Estimated on genus-family or order
Ensis siliqua	4	5	25	4	13	(Fahy & Gaffney 2001)
Enteropneusta	3	1	0.5	3	7	Rough estimate

Taxon	Rarity class	Age class	Max Age (y)	Weight class	Total rank	Reference for maximum age
Entoprocta	5	1	0.5	1	7	Rough estimate
Eteone barbata	4	1	1	2	7	Estimated on genus-family or order
Eteone flava	5	2	2	1	8	www.marlin.ac.uk/biotic/browse.php?sp=6288
Eteone foliosa	5	2	2	2	9	www.marlin.ac.uk/biotic/browse.php?sp=6288
Eteone longa	1	2	2	2	5	www.marlin.ac.uk/biotic/browse.php?sp=6288
Euchone rubrocincta	5	1	1	2	8	Based on genus (Chone)
Euclymene droebachiensis	4	3	5	2	9	www.marlin.ac.uk/biotic/browse.php?sp=6069
Eudorella emarginata	4	1	1	1	6	estimated, no literature found
Eudorella truncatula	1	1	1	1	3	estimated, no literature found
Eudorellopsis deformis	1	1	1	1	3	estimated, no literature found
Eulalia bilineata	5	4	10	1	10	Based on *Eulalia* spp; www.marlin.ac.uk/biotic/browse.php?sp=6045
Eulalia mustela	2	4	10	1	7	Based on *Eulalia* spp; www.marlin.ac.uk/biotic/browse.php?sp=6045
Eulima	2	2	2	2	6	Estimated on genus-family or order
Eumida sanguinea	1	2	2	2	5	(Marine Ecological Surveys Ltd 2008)
Eunereis longissima	1	2	2	3	6	(McHugh & Fong 2002)
Eunicida	0	0	-	1	6	-
Eupolymnia nebulosa	5	3	5	1	9	(Bhaud & Gremare 1991, McHugh & Fong 2002)
Eurydice pulchra	4	2	2	3	9	www.marlin.ac.uk/biotic/browse.php?sp=4385
Eurydice spinigera	4	2	2	1	7	Estimated on genus-family or order
Euspira pulchella	1	3	3	3	7	(Richardson et al. 2005)
Eusyllinae	0	0	-	1	6	-
Euzonus flabelligerus	3	4	6	2	9	(McHugh & Fong 2002)
Exogone dispar	5	2	2	1	8	(Marine Ecological Surveys Ltd 2008)
Exogone hebes	1	2	2	2	5	(McHugh & Fong 2002)
Exogone naidina	3	2	2	1	6	(McHugh & Fong 2002)
Galathea intermedia	4	1	1	2	7	(Marine Ecological Surveys Ltd 2008)
Gammaridae	0	1	1	1	2	Estimated, no literature found
Gammaropsis	4	1	1	1	7	(Marine Ecological Surveys Ltd 2008)
Gammaropsis maculata	4	1	1	1	6	Estimated on genus-family or order
Gammarus crinicornis	5	1	1	2	8	www.marlin.ac.uk/biotic/brows.php?sp=4407
Gammarus locusta	5	1	0.5	1	7	Based on *Gammarus chevreuxi*, www.marlin.ac.uk/biotic/brows.php?sp=6519, (Subida et al. 2005)
Gari fervensis	2	3	3	4	9	Based on photo (Marine Ecological Surveys Ltd 2008)
Gastrosaccus spinifer	3	1	1	2	6	(Marine Ecological Surveys Ltd 2008)
Gattyana cirrhosa	1	3	5	3	7	(Van Moorsel 2005)
Gibbula tumida	4	2	2	3	9	(Schöne et al. 2007)
Glycera alba	2	4	6	3	9	(Josefson 1987)
Glycera lapidum	1	3	5	2	6	Estimated on genus-family or order
Glycera rouxi	2	3	5	3	8	(Robertson 1979)
Glycinde nordmanni	2	2	2	2	6	(McHugh & Fong 2002)
Golfingia elongata	2	1	1	3	6	(Marine Ecological Surveys Ltd 2008)
Golfingia vulgaris	1	1	1	3	5	(Marine Ecological Surveys Ltd 2008)
Goniada maculata	1	2	2.5	3	6	(Josefson 1987, Marine Ecological Surveys Ltd 2008)
Goniadella bobrezkii	3	2	2	2	7	(McHugh & Fong 2002)
Goodallia triangularis	2	2	2	1	5	Estimated on genus-family or order
Gyptis capensis	1	1	1.5	2	4	(McHugh & Fong 2002) based on age at first reproduction
Halcampa chrysanthellum	5	4	6	3	12	Based on *Actinia equina* (Westholt et al. 1999)
Harmothoe antilopes	5	3	5	2	10	Based on *Harmotoe* spp. , www.marlin.ac.uk/biotic/browse.php?sp=6039

Taxon	Rarity class	Age class	Max Age (y)	Weight class	Total rank	Reference for maximum age
Harmothoe extenuata	4	3	5	2	9	(McHugh & Fong 2002)
Harmothoe glabra	3	3	5	2	8	(McHugh & Fong 2002)
Harmothoe imbricata	4	2	2	3	9	(Olive 1980)
Harmothoe impar	3	3	5	2	8	(McHugh & Fong 2002)
Harmothoe nodosa	3	3	5	2	8	(McHugh & Fong 2002)
Harmothoe sarsi sarsi	5	3	5	1	9	(McHugh & Fong 2002)
Harpinia antennaria	1	1	1	1	3	Estimated on genus-family or order
Harpinia crenulata	3	1	1	1	5	Estimated on genus-family or order
Harpinia laevis	5	1	1	1	7	Estimated on genus-family or order
Harpinia pectinata	3	1	1	1	5	Estimated on genus-family or order
Haustorius arenarius	5	1	1.5	1	7	Estimated on genus-family or order
Hesionura elongata	2	1	1	1	4	(McHugh & Fong 2002) based on age at first reproduction
Heteromastus filiformis	2	3	3	2	7	(Robertson 1979)
Heteromysis microps	5	1	1	1	7	Estimated on genus-family or order
Hiatella arctica	5	5	126	2	12	(Rysgaard & Glud 2007)
Hinia reticulata	5	5	15	3	13	(Marine Ecological Surveys Ltd 2008)
Hippomedon denticulatus	1	2	2	2	5	(Sainte-Marie et al. 1990)
Hyala vitrea	1	3	3	2	6	Based on *Onoba aculeus*. (Gorbushin & Levakin 1999)
Hydrobia ulvae	5	2	2	1	8	http://www.marlin.ac.uk/biotic/browse.php?sp=4186
Hydrozoa	2	4	6	2	8	Based on *Actinia equina* (Westholt et al. 1999)
Hypereteone foliosa	2	1	1	3	6	(McHugh & Fong 2002) based on age at first reproduction
Hyperia	0	1	1	1	7	Estimated on genus-family or order
Idotea neglecta	5	1	1	1	7	Estimated on genus-family or order
Ione thoracica	1	1	1	2	4	Estimated on genus-family or order
Iphimedia obesa	5	1	1	1	7	Estimated on genus-family or order
Iphinoe trispinosa	1	1	1	2	4	Estimated on genus-family or order
Labidoplax buskii	3	2	2	3	8	(Sewell 1994)
Laevicardium crassum	5	5	11	3	13	Witbaard, unpublished
Lamprops fasciata	4	1	1	1	6	www.marlin.ac.uk/biotic/browse.php?sp=6031
Lanice conchilega	1	1	1	3	5	(Marine Ecological Surveys Ltd 2008)
Laomedea flexuosa	3	1	0.5	1	5	Estimated on genus-family or order
Laonice bahusiensis	2	1	1	2	5	(Marine Ecological Surveys Ltd 2008)
Laonice cirrata	4	2	2.5	2	8	(McHugh & Fong 2002)
Lembos longipes	4	1	1	1	6	Estimated on genus-family or order
Lepidepecreum longicorne	3	1	1	1	5	Estimated on genus-family or order
Lepidonotus squamatus	5	3	5	2	10	Estimated on other species within family (McHugh & Fong 2002)
Leptocheirus hirsutimanus	3	1	1	2	6	Estimated on other species within family
Leptognathia	4	1	1	1	6	Estimated on genus-family or order
Lepton nitidum	3	2	2	1	6	Based on age of host *Upogebia*
Lepton squamosum	2	2	2	2	6	Based on age of host *Upogebia*
Leptosynapta inhaerens	2	2	2	3	7	(Sewell 1994)
Leucothoe incisa	1	1	1	2	4	Estimated on genus-family or order
Leucothoe lilljeborgi	3	1	1	1	5	Estimated on genus-family or order
Leucothoe richiardii	3	1	1	1	5	Estimated on genus-family or order
Levinsenia gracilis	2	1	1	2	5	Estimated on genus-family or order
Liocarcinus pusillus	3	3	3	2	8	Based on other species within family
Lophogaster typicus	5	1	1	1	7	Estimated on genus-family or order
Lovenella clausa	5	1	1	1	7	Rough estimate

Taxon	Rarity class	Age class	Max Age (y)	Weight class	Total rank	Reference for maximum age
Lucinoma borealis	2	3	5	3	8	Estimated on genus-family or order
Lumbrineris latreilli	1	3	3	3	7	(Josefson 1987, Marine Ecological Surveys Ltd 2008)
Lumbrineris pseudofragilis	3	2	2	2	7	(Robertson 1979)
Lutraria lutraria	4	3	5	5	12	Witbaard, unpublished (cross section)
Lyonsia norwegica	5	4	9	3	12	(Kidwell & Rothfus 2010)
Lysilla loveni	2	3	5	3	8	(McHugh & Fong 2002)
Macoma balthica	1	4	10	3	8	(Robertson 1979)
Mactra corallina	1	4	6	3	8	(Sakurai et al. 1998)
Maera othonis	4	1	1	2	7	Estimated, no literature found
Magelona alleni	1	3	3	2	6	(Marine Ecological Surveys Ltd 2008)
Magelona filiformis	2	3	5	1	6	Extrapolated from Marlin database (www.marlin.ac.uk)
Magelona johnstoni	1	3	5	2	6	Extrapolated from Marlin database (www.marlin.ac.uk)
Magelona mirabilis	1	3	5	2	6	www.marlin.ac.uk/biotic/browse.php?sp=4355
Magelona papillicornis	1	3	5	2	6	Extrapolated from Marlin database (www.marlin.ac.uk)
Malacoceros vulgaris	5	2	2	3	10	www.marlin.ac.uk/biotic/browse.php?sp=6529
Maldanidae	0	0	-	3	6	-
Malmgrenia glabra	2	3	5	2	7	(McHugh & Fong 2002)
Malmgrenia ljungmani	5	3	5	2	10	(McHugh & Fong 2002)
Malmgrenia marphysae	3	3	5	2	8	(McHugh & Fong 2002)
Malmgreniella lunulata	1	3	5	3	7	(McHugh & Fong 2002)
Mangelia nebula	4	2	2	2	8	Estimated on genus-family or order
Marphysa belli	4	1	1	3	8	Estimated on genus-family or order
Mediomastus fragilis	1	1	1	2	4	(Marine Ecological Surveys Ltd 2008)
Megaluropus agilis	1	1	1	1	3	Estimated on genus-family or order
Megamphopus cornutus	3	1	1	2	6	Estimated on genus-family or order
Melphidippella macra	5	1	1	2	8	Estimated on genus-family or order
Menigrates obtusifrons	5	1	1	1	7	Estimated on genus-family or order
Mesopodopsis slabberi	5	1	1	2	8	Estimated on genus-family or order
Metopa alderi	5	2	2	3	10	(Sainte-Marie et al. 1990)
Metopa borealis	5	1	1	1	7	Estimated on genus-family or order
Metopa bruzelii	5	1	1	1	7	Estimated on genus-family or order
Microphthalmus sczelkowii	4	2	2	1	7	(McHugh & Fong 2002) based on age at first reproduction
Microphthalmus similis	5	2	2	1	8	(McHugh & Fong 2002) based on age at first reproduction
Microprotopus maculatus	3	1	1	1	5	Estimated, no literature found
Modiolus modiolus	5	5	80	5	15	(Anwar et al. 1990)
Molgula oculata	0	2	2	2	4	(Frame & McCann 1971)
Monoculodes carinatus	4	1	1	2	7	Estimated on genus-family or order
Montacuta ferruginosa	1	4	6	2	7	(Gage 1966)
Musculus discors	5	3	3	2	10	www.marlin.ac.uk/biotic/browse.php?sp=4370
Mya arenaria	4	5	11	5	14	www.marlin.ac.uk/biotic/browse.php?sp=4240
Mya truncata	3	5	25	5	13	(Witbaard et al. 2005)
Myriochele heeri	2	3	4	2	7	(McHugh & Fong 2002)
Myriochele oculata	2	3	4	2	7	(McHugh & Fong 2002)
Myrtea spinifera	5	2	2	1	8	Based on *Keletistis rhizoecus*, (Zabbey et al. 2010)
Mysella bidentata	1	4	7	2	7	(Wolff& al, 1973; (Ockelmann & Muus 1978, Josefson 1987, Petersen & Lützen 2008)
Mysella dawsoni	3	4	7	1	8	Based on *Mysella bidentata*
Mysia undata	2	4	6	3	9	Based on growth lines of a photo on www.conchology.be

Taxon	Rarity class	Age class	Max Age (y)	Weight class	Total rank	Reference for maximum age
Mysis	0	1	1	2	7	(Robertson 1979)
Mytilus edulis	5	5	21	4	14	www.marlin.ac.uk/biotic/browse.php?sp=4250
Natatolana borealis	5	4	6	3	12	(Johansen 2000)
Natica	0	3	5	1	4	www.marlin.ac.uk/biotic/browse.php?sp=6183
Nebalia bipes	3	1	1	2	6	Estimated on genus-family or order
Nematoda	1	1	0.5	2	4	Rough estimate
Nemertina	1	1	1	3	5	Rough estimate
Nephrops norvegicus	5	4	10	4	13	www.marlin.ac.uk/biotic/browse.php?sp=4390
Nephtys assimilis	2	4	9	3	9	(McHugh & Fong 2002)
Nephtys caeca	1	4	9	4	9	(Olive 1980)
Nephtys cirrosa	1	3	3	3	7	www.marlin.ac.uk/biotic/browse.php?sp=4414
Nephtys hombergii	1	4	7	3	8	(Olive 1980, Rainer 1991)
Nephtys incisa	2	3	3	3	8	(Robertson 1979, Josefson 1987)
Nephtys longosetosa	2	4	6	3	9	(McHugh & Fong 2002)
Nereis diversicolor	4	3	3	3	10	www.novelguide.com/a/discover/grze
Nicomache	0	1	1	3	4	Estimated on genus-family or order
Nicomache lumbricalis	5	1	1	3	9	Estimated on genus-family or order
Notomastus latericeus	1	1	1	3	5	(Van Moorsel 2005); www.marlin.ac.uk/biotic/browse.php?sp=6397
Nucula nitidosa	1	4	6	2	7	www.marlin.ac.uk/biotic/brows.php?=4408
Nucula nucleus	3	4	6	2	9	Based on *Nucula nitidosa*
Nuculoma tenuis	2	4	6	2	8	Estimated on genus-family or order
Obelia bidentata	5	3	3	1	9	(Marine Ecological Surveys Ltd 2008)
Odostomia	0	1	1	1	7	Estimated on genus-family or order
Oenopota turricula	5	1	1	1	7	Estimated on genus-family or order
Oligochaeta	2	1	1	2	5	Estimated on genus-family or order
Ondina divisa	5	1	1	2	8	Estimated on genus-family or order
Ophelia limacina	1	4	10	3	8	Based on Ophelia spp. , www.marlin.ac.uk/biotic/brows.php?sp=6070
Ophelia rathkei	5	4	6	1	10	(McHugh & Fong 2002)
Opheliida	0	4	6	1	5	(McHugh & Fong 2002)
Opheliidae	0	4	6	1	5	(McHugh & Fong 2002)
Ophelina acuminata	2	4	6	3	9	(McHugh & Fong 2002)
Ophiodromus flexuosus	1	2	2	2	5	(McHugh & Fong 2002)
Ophiothrix fragilis	5	2	2	3	10	(Marine Ecological Surveys Ltd 2008)
Ophiura	0	0	-	1	6	-
Ophiura affinis	4	3	3	2	9	www.marinespecies.org
Ophiura albida	1	3	3	3	7	www.marinespecies.org
Ophiura ophiura	2	3	5	3	8	(Gage 1990)
Ophiuroidea	0	3	5	1	4	Estimated based on species within genus
Opisthodonta pterochaeta	4	2	2	1	7	(McHugh & Fong 2002)
Orbinia armandi	5	3	5	3	11	www.marlin.ac.uk/biotic/browse.php?sp=4410
Orbinia sertulata	2	3	5	3	8	www.marlin.ac.uk/biotic/browse.php?sp=4410
Orchomene humilis	3	2	2	1	6	(Sainte-Marie et al. 1990)
Orchomene nanus	1	2	2	1	4	(Sainte-Marie et al. 1990)
Owenia fusiformis	1	3	5	3	7	www.marlin.ac.uk/biotic/browse.php?sp=4410;
Pagurus bernhardus	4	4	10	3	11	www.marlin.ac.uk/biotic/browse.php?sp=6173
Pagurus cuanensis	5	4	10	3	12	www.marlin.ac.uk/biotic/browse.php?sp=6173
Pandalina brevirostris	5	2	2	3	10	(Marine Ecological Surveys Ltd 2008)
Paramphilochoides	5	1	1	1	7	Based on (Sainte-Marie 1991)

Taxon	Rarity class	Age class	Max Age (y)	Weight class	Total rank	Reference for maximum age
odontonyx						
Paraonis fulgens	1	2	2	2	5	(Josefson 1987)
Pariambus typicus	5	1	1	1	7	Estimated on genus-family or order
Parvicardium ovale	5	1	1	3	9	(Lastra et al. 1992)
Peachia cylindrica	4	4	10	3	11	Based on *Obelia longissima* (www.marlin.ac.uk)
Pectinaria auricoma	1	2	2	3	6	(Olive 1980)
Pectinaria koreni	1	1	0.5	3	5	www.marlin.ac.uk/biotic/browse.php?sp=6428; (Irlinger et al. 1991)
Pelonaia corrugata	5	2	2	4	11	Based on *Molgula*
Perioculodes longimanus	1	1	1	2	4	Estimated on genus-family or order
Petalosarsia declivis	5	1	1	1	7	Estimated on genus-family or order
Petricola pholadiformis	5	5	20	4	14	(Duval 1963, Pinn et al. 2005)
Phascolion strombi	4	1	1	2	7	Based on *Golfingia*
Phaxas pellucidus	1	2	2	3	6	Estimated on genus-family or order
Pherusa plumosa	5	1	1	2	8	Estimated on genus-family or order
Philine	0	3	5	1	4	www.marlin.ac.uk/biotic/browse.php?sp=4245
Philine scabra	5	3	5	1	9	www.marlin.ac.uk/biotic/browse.php?sp=4245
Philocheras bispinosus	4	1	1	2	7	Estimated on genus-family or order
Philocheras trispinosus	4	1	1	3	8	Estimated on genus-family or order
Pholoe baltica	2	3	3	1	6	Based on *Pholoe minuta* (Josefson 1987, Heferman & Keegan 1988)
Pholoe inornata	1	3	3	3	7	Based on *Pholoe minuta*, (Josefson 1987, Heferman & Keegan 1988)
Phoronida	1	1	1	2	4	www.marlin.ac.uk/biotic/browse.php?sp=6436 (Josefson 1987)
Photis longicaudata	4	1	1	1	6	Estimated on genus-family or order
Phoxichilidium femoratum	5	1	1	1	7	Based on Pycnogonida (Marine Ecological Surveys Ltd 2008)
Phoxocephalus holbolli	4	1	1	2	7	Estimated on genus-family or order
Phtisica marina	4	1	1	1	6	Estimated on genus-family or order
Phyllodoce groenlandica	2	1	1	3	6	(McHugh & Fong 2002) based on first reproduction
Phyllodoce laminosa	5	1	1	2	8	(McHugh & Fong 2002) based on first reproduction
Phyllodoce lineata	4	1	1	2	7	(McHugh & Fong 2002) based on first reproduction
Phyllodoce maculata	2	1	1	3	6	(McHugh & Fong 2002) based on first reproduction
Phyllodoce mucosa	2	1	1	2	5	(McHugh & Fong 2002) based on first reproduction
Phyllodoce rosea	1	1	1	2	4	(McHugh & Fong 2002) based on first reproduction
Phyllodocidae	0	1	1	1	2	(McHugh & Fong 2002) based on first reproduction
Pisidia longicornis	4	2	2	2	8	(Marine Ecological Surveys Ltd 2008)
Pisione remota	2	3	3	1	6	www.marlin.ac.uk/biotic/browse.php?sp=6048
Pistella lornensis	2	3	3	2	7	Estimated on genus-family or order
Platyhelminthes	2	1	1	3	6	Rough estimate
Podarkeopsis capensis	2	2	2	2	6	(McHugh & Fong 2002)
Poecilochaetus serpens	1	1	1	2	4	Estimated on genus-family or order
Polinices catena	4	3	5	4	11	www.marlin.ac.uk/biotic/browse.php?sp=6183
Polybius holsatus	4	4	10	4	12	www.marlin.ac.uk/biotic/browse.php?
Polybius marmoreus	4	3	3	3	10	Based on *Necora puber* (Mill et al. 2009)
Polycirrus medusa	3	3	3	2	8	(Marine Ecological Surveys Ltd 2008)
Polydora caeca	5	2	2	1	8	(Lambeck & Valentijn 1987)
Polydora ciliata	2	1	1	2	5	www.marlin.co.uk/biotic/browse.php?sp=4244
Polynoe kinbergi	5	3	5	2	10	Based on other species in order and family (McHugh & Fong 2002)
Polyphysia crassa	5	1	1	3	9	Estimated on genus-family or order
Polyplacophora	4	1	0.5	1	6	Rough estimated
Pontocrates altamarinus	1	1	1	2	4	Estimated on genus-family or order

Taxon	Rarity class	Age class	Max Age (y)	Weight class	Total rank	Reference for maximum age
Pontocrates arenarius	3	1	1	1	5	Estimated on genus-family or order
Priapulida	4	1	0.5	3	8	Estimated on genus-family or order
Prionospio cirrifera	2	1	1	2	5	www.marlin.co.uk/biotic/browse.php?sp=6456
Prionospio multibranchiata	5	2	2.5	1	8	(McHugh & Fong 2002)
Processa edulis crassipes	5	1	1	2	8	Estimated on genus-family or order
Processa modica modica	3	1	1	2	6	Estimated on genus-family or order
Processa nouveli holthuisi	3	1	1	3	7	Estimated on genus-family or order
Protodorvillea kefersteini	2	1	1	2	5	(Marine Ecological Surveys Ltd 2008)
Psammechinus miliaris	2	4	7	3	9	(Jensen 1969)
Psammodrilida	5	1	1	1	7	Estimated on genus-family or order
Pseudione borealis	4	1	1	1	6	Estimated on genus-family or order
Pseudocuma gilsoni	5	1	1	1	7	(Marine Ecological Surveys Ltd 2008)
Pseudocuma longicornis	1	1	1	1	3	www.marlin.ac.uk/biotic/browse.php?sp=6030
Pseudocuma similis	2	1	1	2	5	www.marlin.ac.uk/biotic/browse.php?sp=6030
Pseudomystides limbata	4	1	1	3	8	Estimated on genus-family or order
Pseudopolydora antennata	4	2	2.5	1	7	(McHugh & Fong 2002)
Pseudopolydora pulchra	4	2	2.5	2	8	(McHugh & Fong 2002)
Pycnogonida	0	1	1	1	2	(Marine Ecological Surveys Ltd 2008)
Pygospio elegans	4	2	2.5	2	8	Based on other species in genus and family (McHugh & Fong 2002)
Retusa umbilicata	5	1	1	2	8	Estimated on genus-family or order
Rhodine loveni	4	3	3.5	2	9	(Josefson 1987, McHugh & Fong 2002)
Roxania utriculus	5	0	-	1	6	-
Sabella pavonina	5	3	5	2	10	www.novelguide.com/a/discover/grze
Sabella penicillus	5	3	5	2	10	Based on *Sabella pavonica*
Sagartia troglodytes	5	4	6	3	12	Based on Actinia equine (Westholt et al. 1999)
Saxicavella jeffreysi	4	2	2	2	8	Estimated on genus-family or order
Scalibregma inflatum	1	2	2	3	6	www.marlin.co.uk/biotic/browse.php?sp=6077; (Josefson 1987, Mackie 1991).
Scaphander lignarius	5	3	5	2	10	Estimated on genus-family or order
Schistomysis kervillei	5	1	0.5	2	8	(Marine Ecological Surveys Ltd 2008)
Scolelepis bonnieri	1	2	2.5	3	6	(McHugh & Fong 2002)
Scolelepis foliosa	4	2	2.5	2	8	(McHugh & Fong 2002)
Scolelepis squamata	2	2	2.5	3	7	(McHugh & Fong 2002)
Scolelepis tridentata	5	2	2.5	2	9	(McHugh & Fong 2002)
Scoletoma fragilis	3	4	10	2	9	(McHugh & Fong 2002)
Scoloplos armiger	1	3	4	3	7	(Van Moorsel 2005); www.marlin.ac.uk/biotic/browse.php?sp=6020
Scopelocheirus hopei	4	2	2	1	7	(Sainte-Marie et al. 1990)
Sigalion mathildae	1	3	4	3	7	(McHugh & Fong 2002)
Siphonoecetes kroyeranus	2	1	1	1	4	Estimated on genus-family or order
Sipuncula	0	0		3	3	-
Siriella	5	1	0.5	2	8	Based on other species within the family
Sosane gracilis	5	3	4	2	10	(McHugh & Fong 2002)
Spatangus purpureus	3	4	9	2	9	(Gage 1987)
Sphaerodorum flavum	4	1	1	1	6	Estimated on genus-family or order
Sphaerosyllis hystrix	3	1	1	1	5	(Marine Ecological Surveys Ltd 2008)
Spio filicornis	1	1	1	2	4	(Van Moorsel 2005); www.marlin.ac.uk/biotic/browse.php?=4406
Spio goniocephala	3	2	2.5	1	6	(McHugh & Fong 2002)
Spio martinensis	4	1	1	1	6	(Van Moorsel 2005)
Spionida	0	1	1	1	2	Estimated on genus-family or order

Taxon	Rarity class	Age class	Max Age (y)	Weight class	Total rank	Reference for maximum age
Spiophanes bombyx	1	2	2	2	5	(Robertson 1979)
Spiophanes kroeyeri	2	2	2.5	2	6	(McHugh & Fong 2002)
Spisula elliptica	2	3	5	3	8	Estimated on genus-family or order
Spisula solida	4	4	10	3	11	www.marlin.ac.uk/biotic/browse.php?sp=4598;
Spisula subtruncata	1	3	3	3	7	Witbaard, unpublished data
Stenula rubrovittata	4	1	1	1	6	Estimated on genus-family or order
Sthenelais boa	3	3	3	3	9	(Olive 1980)
Sthenelais limicola	1	3	4	3	7	(McHugh & Fong 2002)
Streptosyllis websteri	2	2	2	1	5	(McHugh & Fong 2002)
Striarca lactea	5	3	3	2	10	Rough estimate
Subadyte pellucida	5	3	5	2	10	Based on other species in order and family (McHugh & Fong 2002)
Syllis gracilis	5	2	2	1	8	(McHugh & Fong 2002)
Synchelidium haplocheles	3	1	1	1	5	estimated on genus-family or order
Synchelidium maculatum	1	1	1	1	3	estimated on genus-family or order
Synelmis klatti	1	1	1	2	4	estimated on genus-family or order
Tanaidacea	4	1	0.5	1	6	estimated on genus-family or order
Tapes rhomboides	3	2	2	4	9	(Marine Ecological Surveys Ltd 2008)
Tellina fabula	1	3	3	3	7	www.marlin.ac.uk/biotic/browse.php?sp=4354
Tellina pygmaeus	2	3	3	2	7	estimated on genus-family or order
Tellina tenuis	2	3	3	3	8	estimated on genus-family or order
Terebellides stroemi	2	3	3	3	8	(Duchêne 1977, Robertson 1979)
Thecata	0	4	6	1	10	Based on Actinia equine (Westholt et al. 1999)
Thelepus cincinnatus	5	3	5	1	9	(Duchêne 1991, McHugh & Fong 2002)
Thia scutellata	2	1	1	3	6	estimated on genus-family or order
Thracia convexa	3	5	12	3	11	estimated on genus-family or order
Thracia papyracea	1	5	12	3	9	estimated on genus-family or order
Thracia phaseolina	3	5	12	3	11	estimated on genus-family or order
Thyasira flexuosa	1	2	2.5	2	5	Based on *Thyasira equalis*: (Josefson 1987)
Thyone fusus	3	4	10	3	10	Based on *Trachythyone*
Thysanocardia procera	3	1	1	3	7	Based on sipunculid
Timoclea ovata	3	2	2	2	7	(Marine Ecological Surveys Ltd 2008)
Tmetonyx similis	5	2	2	1	8	(Sainte-Marie et al. 1990)
Tornus subcarinatus	3	1	1	1	5	estimated on genus-family or order
Trachythyone elongata	3	4	10	3	10	(Fish 1967)
Travisia forbesii	2	1	1	3	6	(Marine Ecological Surveys Ltd 2008)
Trichobranchus roseus	5	3	3	3	11	Estimated on genus-family or order
Tryphosella sarsi	3	2	2	1	6	(Sainte-Marie et al. 1990)
Tryphosites longipes	4	2	2	2	8	(Sainte-Marie et al. 1990)
Tunicata	0	1	1	1	7	Estimated on genus-family or order
Turbellaria	1	1	0.5	2	4	Estimated on genus-family or order
Turbonilla lactea	5	1	1	1	7	Estimated on genus-family or order
Turbonilla pusilla	4	1	1	2	7	Estimated on genus-family or order
Turritella communis	2	4	6	3	9	www.marlin.ac.uk/biotic/browse.php?sp=6181
Typosyllis armillaris	5	1	1	1	7	(Marine Ecological Surveys Ltd 2008)
Typosyllis cornuta	2	1	1	1	4	(Marine Ecological Surveys Ltd 2008)
Unciola crenatipalma	5	1	1	1	7	Estimated on genus-family or order
Unciola planipes	3	1	1	1	5	Estimated on genus-family or order
Upogebia deltaura	1	3	3	4	8	(Marine Ecological Surveys Ltd 2008)

Taxon	Rarity class	Age class	Max Age (y)	Weight class	Total rank	Reference for maximum age
Upogebia stellata	2	3	3	3	8	Based on *Upogebia deltaura*
Urothoe brevicornis	1	1	1	2	4	(Marine Ecological Surveys Ltd 2008)
Urothoe elegans	2	1	1	1	4	Estimated on genus-family or order
Urothoe marina	2	1	1	2	5	Estimated on genus-family or order
Urothoe poseidonis	1	1	1	2	4	Estimated on genus-family or order
Venerupis senegalensis	4	4	6	5	13	www.marlin.ac.uk/biotic/browse.php?sp=4319
Vitreolina philippi	4	1	1	2	7	Estimated on genus-family or order
Westwoodilla caecula	3	1	1	1	5	Estimated on genus-family or order
Hydroida	1	1	0.5	0	2	Rough estimate

Appendix C. Fish

Table 19. The selection of fish species used in the analysis. The DCS column indicates if the species has been caught in the last ten years (2000-2009) on the DCS by at least one of the surveys. The Lmax is maximum length reported in cm (Engelhard et al. 2011). Rarity is the index value per species calculated for the whole North Sea and for the DCS area. A lower rarity value means more common.

Nr	species	Common name	Dutch name	DCS	Lmax (cm)	Rarity	Rarity DCS
1	*Agonus cataphractus*	Hooknose	Harnasmannetje	x	21	0.28	0.24
2	*Alosa alosa*	Allis shad	Elft	x	70	0.42	0.41
3	*Alosa fallax*	Twait shad	Fint	x	50	0.39	0.39
4	*Amblyraja radiata*	Starry skate	Sterrog	x	90	0.26	0.39
5	*Ammodytes sp.*	Sandeel	Kleine/Noorse zandspiering	x	25	0.26	0.24
6	*Anarhichas lupus*	Wolffish	Zeewolf		125	0.48	
7	*Aphia minuta **	Transparent goby	Glasgrondel	x	6	0.34	0.35
8	*Argentina silus*	Greater argentine	Zilversmelt		60	0.23	
9	*Argentina sphyraena*	Lesser argentine	Zilversmelt	x	32	0.19	0.22
10	*Arnoglossus laterna*	Scaldfish	Schurftvis	x	20	0.17	0.08
11	*Aspitrigla cuculus*	Red gurnard	Engelse poon	x	50	0.36	0.41
12	*Atherina presbyter*	Sand-smelt	Kornaarvis	x	20	0.39	0.34
13	*Belone belone*	Garfish	Geep	x	90	0.44	0.43
14	*Brosme brosme*	Tusk	Lom		100	0.43	
15	*Buglossidium luteum*	Solenette	Dwergtong	x	15	0.15	0.10
16	*Callionymus lyra*	Dragonet	Pitvis	x	32	0.20	0.14
17	*Callionymus maculatus*	Spotted dragonet	Gevlekte pitvis	x	16	0.32	0.38
18	*Callionymus reticulatus*	Reticulated dragonet	Rasterpitvis	x	11	0.33	0.31
19	*Chelon labrosus*	Thick-lipped grey mullet	Diklipharder		60	0.19	
20	*Ciliata mustela*	Five-bearded rockling	Vijfdradige meun	x	45	0.33	0.28
21	*Ciliata septentrionalis*	Northern rockling	Noorse meun	x	17	0.40	0.19
22	*Clupea harengus*	Herring	Haring	x	40	0.07	0.04
23	*Cyclopterus lumpus*	Lumpsucker	Snotolf	x	61	0.47	0.47
24	*Dasyatis pastinaca*	Stingray	Pijlstaartrog		60		
25	*Dicentrarchus labrax*	European seabass	Zeebaars	x	100	0.41	0.35
26	*Dipturus batis*	Common skate	vleet	x	250	0.50	0.29
27	*Echiichthys vipera*	Lesser weever	Kleine pieterman	x	15	0.18	0.13
28	*Echiodon drummondii*	Pearlfish	Parelvis		30	0.45	
29	*Enchelyopus cimbrius*	Four-bearded rockling	Vierdradige meun	x	41	0.26	0.22
30	*Engraulis encrasicolus*	Anchovy	Ansjovis	x	20	0.29	0.27
31	*Entelurus aequoraeus*	Snake pipefish	Adderzeenaald	x	60	0.33	0.42
32	*Eutrigla gurnardus*	Grey gurnard	Grauwe poon	x	50	0.10	0.11
33	*Gadus morhua*	Cod	Kabeljauw	x	190	0.20	0.25
34	*Gaidropsarus vulgaris*	Three-bearded rockling	Driedradige meun	x	43	0.36	0.29
35	*Galeorhinus galeus*	Tope	Ruwe haai	x	200	0.47	0.46

Nr	species	Common name	Dutch name	DCS	Lmax (cm)	Rarity	Rarity DCS
36	*Gasterosteus aculeatus*	Three-spined stickleback	Driedoornige stekelbaars	x	8	0.33	0.33
37	*Glyptocephalus cynoglossus*	Witch	Witje	x	60	0.33	0.43
38	*Gobius niger*	Black goby	Zwarte grondel	x	15	0.28	0.31
39	*Hippoglossoides platessoides*	Long rough dab	Lange schar	x	50	0.10	0.19
40	*Hippoglossus hippoglossus*	Halibut	Heilbot	x	200	0.50	0.38
41	*Hyperoplus lanceolatus*	Greater sandeel	Smelt	x	40	0.26	0.23
42	*Lampetra fluviatilis*	Lamprey	Rivierprik	x	45	0.38	0.35
43	*Lepidorhombus whiffiagonis*	Megrim	Scharretong	x	59	0.32	0.35
44	*Leucoraja naevus*	Cuckoo ray	Koekoeksrog	x	70	0.36	0.46
45	*Limanda limanda*	Dab	Schar	x	40	0.06	0.02
46	*Liparis liparis*	Sea-snail	Slakdolf	x	18	0.28	0.26
47	*Liparis montagui*	Montagu's seasnail	Kleine slakdolf	x	10	0.43	0.36
48	*Lophius piscatorius*	Anglerfish	Zeeduivel	x	200	0.37	0.49
49	*Lumpenus lampretaeformis*	Snake blenny	Ijslandse bandvis		49	0.32	
50	*Melanogrammus aeglefinus*	Haddock	Schelvis	x	112	0.09	0.27
51	*Merlangius merlangus*	Whiting	Wijting	x	70	0.06	0.06
52	*Microchirus variegatus*	Thickback sole	Dikrugtong	x	20	0.40	0.47
53	*Micromesistius poutassou*	Blue whiting	Blauwe wijting	x	47	0.24	0.38
54	*Microstomus kitt*	Lemon sole	Tongschar	x	45	0.19	0.26
55	*Molva molva*	Ling	Leng	x	200	0.41	0.44
56	*Mullus surmuletus*	Striped red mullet	Mul	x	40	0.34	0.31
57	*Mustelus asterias*	Smoothhound	Gladde haai	x	140	0.44	0.42
58	*Mustelus mustelus*	Starry smoothhound	Gevlekte haai	x	150	0.48	0.42
59	*Myoxocephalus scorpius*	Bull-rout	Zeedonderpad	x	60	0.28	0.33
60	*Myxine glutinosa*	Hagfish	Slijmprik		45	0.36	
61	*Osmerus eperlanus*	Smelt	Spiering	x	45	0.21	0.18
62	*Pegusa lascaris*	Sand sole	Franse tong	x	40	0.47	0.46
63	*Petromyzon marinus*	Sea lamprey	Zeeprik	x	120	0.45	0.43
64	*Pholis gunnellus*	Butterfish	Botervis	x	25	0.37	0.33
65	*Platichthys flesus*	Flounder	Bot	x	50	0.26	0.25
66	*Pleuronectes platessa*	Plaice	Schol	x	100	0.13	0.05
67	*Pollachius pollachius*	Pollack	Witte koolvis	x	130	0.42	0.34
68	*Pollachius virens*	Saithe	Zwarte koolvis	x	130	0.26	0.41
69	*Pomatoschistus sp.*	Gobies	Grondel	x	9.5	0.23	0.18
70	*Psetta maxima*	Turbot	Tarbot	x	100	0.39	0.36
71	*Raja clavata*	Thornback ray	Stekelrog	x	90	0.41	0.44
72	*Raja montagui*	Spotted ray	Gevlekte rog	x	80	0.38	0.43
73	*Raniceps raninus*	Tadpole-fish	Vorskwab	x	30	0.49	0.40
74	*Salmo sp.*	Salmon/trout	Zalm/forel	x	140	0.50	0.40
75	*Sardina pilchardus*	Pilchard	Pelser	x	25	0.33	0.28

Nr	species	Common name	Dutch name	DCS	Lmax (cm)	Rarity	Rarity DCS
76	*Scomber scombrus*	Mackerel	Makreel	x	55	0.18	0.20
77	*Scophthalmus rhombus*	Brill	Griet	x	75	0.38	0.39
78	*Scyliorhinus canicula*	Lesser spotted dogfish	Hondshaai	x	80	0.34	0.41
79	*Sebastes viviparus*	Small redfish	Kleine roodbaars	x	35	0.36	0.17
80	*Solea solea*	Sole	Tong	x	70	0.25	0.20
81	*Spinachia spinachia*	Sea stickleback	zeestekelbaars	x	22	0.45	0.39
82	*Sprattus sprattus*	Sprat	Sprot	x	15	0.09	0.04
83	*Squalus acanthias*	Spurdog	Doornhaai	x	105	0.44	0.49
84	*Syngnathus sp.*	Pipefish	Grote/Kleine zeenaald	x	46	0.34	0.30
85	*Taurulus bubalis*	Sea scorpion	Groene zeedonderpad	x	17.5	0.44	0.51
86	*Trachinus draco*	Greater weever	Grote pieterman	x	40	0.26	0.44
87	*Trachurus trachurus*	Horse mackerel	Horsmakreel	x	60	0.20	0.18
88	*Trigla lucerna*	Tub gurnard	Rode poon	x	75	0.30	0.27
89	*Triglops murrayi*	Sculpin	Murray's zeedonderpad		19	0.40	
90	*Trisopterus esmarkii*	Norway pout	Kever	x	26	0.08	0.34
91	*Trisopterus luscus*	Bib	Steenbolk	x	45	0.31	0.28
92	*Trisopterus minutus*	Poor cod	Dwergbolk	x	26	0.22	0.29
93	*Zeugopterus norvegicus*	Norwegian topknot	Dwergbot	x	12	0.46	0.48
94	*Zeus faber*	John Dory	Zonnevis	x	66	0.47	0.47
95	*Zoarces viviparus*	Viviparous blenny	Puitaal	x	52	0.30	0.31

* *Aphia minuta* is only selected in the MIK-survey due to its small size, although it is sometime caught in one of the other surveys. The species therefore becomes rarer in this study than it would have been if it was not excluded from the other surveys.

Table 20. Trends of fish species in the Southern North Sea for 1985-2009 'NA' means that the species was sampled in less than 5% of the hauls and therefore excluded from the analysis.

	IBTS_Q3	**IBTS_Q3**	**IBTS_Q1**	**IBTS_Q1**	**BTS**	**GAM**	**Overall**
species	**linear**	**GAM**	**linear**	**GAM**	**p-K2**	**K4_visual**	**trend**
Agonus cataphractus	pos	pos	pos	pos	pos	pos	pos
Alosa alosa	NA	NA	NA	NA	NA	NA	neut
Alosa fallax	NA	NA	NA	NA	NA	NA	neut
Amblyraja radiata	neut	neut	pos	pos	NA	NA	neut
Ammodytes sp.	neut	neut	pos	pos	neg	neut	neut
Anarhichas lupus	NA	NA	NA	NA	NA	NA	neut
Aphia minuta	NA	NA	NA	NA	NA	NA	neut
Argentina silus	NA	NA	NA	NA	NA	NA	neut
Argentina sphyraena	NA	NA	NA	NA	NA	NA	neut
Arnoglossus laterna	pos	pos	pos	pos	pos	pos	pos
Aspitrigla cuculus	NA	NA	NA	NA	NA	NA	neut
Atherina presbyter	NA	NA	NA	NA	NA	NA	neut
Belone belone	NA	NA	NA	NA	NA	NA	neut
Brosme brosme	NA	NA	NA	NA	NA	NA	neut
Buglossidium luteum	pos	pos	pos	pos	pos	pos	pos
Callionymus lyra	pos	pos	pos	pos	pos	pos	pos
Callionymus maculatus	NA	NA	NA	NA	NA	NA	neut
Callionymus reticulatus	NA	NA	NA	NA	pos	pos	pos
Chelon labrosus	NA	NA	NA	NA	NA	NA	neut
Ciliata mustela	NA	NA	NA	NA	NA	NA	neut
Ciliata septentrionalis	NA	NA	NA	NA	NA	NA	neut
Clupea harengus	neg	neg	neut	neut	pos	pos	neut
Cyclopterus lumpus	NA	NA	neg	neg	NA	NA	neg
Dasyatis pastinaca	NA	NA	NA	NA	NA	NA	neut
Dicentrarchus labrax	NA	NA	NA	NA	NA	NA	neut
Dipturus batis	NA	NA	NA	NA	NA	NA	neut
Echiichthys vipera	pos	pos	pos	pos	pos	pos	pos
Echiodon drummondi	NA	NA	NA	NA	NA	NA	neut
Enchelyopus cimbrius	pos	pos	ops	pos	pos	pos	pos
Engraulis encrasicolus	neut	pos	pos	pos	NA	NA	pos
Entelurus aequoraeus	pos	neut	NA	NA	NA	NA	neut
Eutrigla gurnardus	neg	neg	pos	pos	neg	neg	neut
Gadus morhua	neg	neg	neg	neg	neg	neg	neg
Gaidropsarus vulgaris	NA	NA	NA	NA	NA	NA	neut
Galeorhinus galeus	NA	NA	NA	NA	NA	NA	neut
Gasterosteus aculeatus	NA	NA	neg	neg	NA	NA	neg
Glyptocephalus cynoglossus	NA	NA	NA	NA	NA	NA	neut

	IBTS_Q3	IBTS_Q3	IBTS_Q1	IBTS_Q1	BTS	GAM	Overall
Gobius niger	NA	NA	NA	NA	NA	NA	neut
Hippoglossoides platessoides	neg	neut	pos	neut	neut	neut	neut
Hippoglossus hippoglossus	NA	NA	NA	NA	NA	NA	neut
Hyperoplus sp.	neut	neut	pos	pos	pos	pos	pos
Lampetra fluviatilis	NA	NA	NA	NA	NA	NA	neut
Lepidorhombus whiffiagonis	NA	NA	NA	NA	NA	NA	neut
Leucoraja naevus	NA	NA	NA	NA	NA	NA	neut
Limanda limanda	pos	pos	neut	neut	neg	neg	neut
Liparis liparis	NA	NA	pos	pos	NA	NA	pos
Liparis montagui	NA	NA	NA	NA	NA	NA	neut
Lophius piscatorius	NA	NA	NA	NA	NA	NA	neut
Lumpenus lampretaeformis	NA	NA	NA	NA	NA	NA	neut
Melanogrammus aeglefinus	neg	neut	neut	neut	NA	NA	neut
Merlangius merlangus	neg	neg	neg	neg	neut	neut	neg
Microchirus variegatus	NA	NA	NA	NA	NA	NA	neut
Micromesistius poutassou	NA	NA	NA	NA	NA	NA	neut
Microstomus kitt	pos	pos	pos	pos	pos	pos	pos
Molva molva	NA	NA	NA	NA	NA	NA	neut
Mullus surmuletus	pos	pos	pos	pos	pos	pos	pos
Mustelus asterias	NA	NA	NA	NA	NA	NA	neut
Mustelus mustelus	NA	NA	NA	NA	NA	NA	neut
Myoxocephalus scorpius	pos	pos	pos	pos	pos	pos	pos
Myxine glutinosa	NA	NA	NA	NA	NA	NA	neut
Osmerus eperlanus	NA	NA	NA	NA	NA	NA	neut
Pegusa lascaris	NA	NA	NA	NA	NA	NA	neut
Petromyzon marinus	NA	NA	NA	NA	NA	NA	neut
Pholis gunnellus	NA	NA	NA	NA	NA	NA	neut
Platichthys flesus	pos	pos	neg	neg	pos	pos	neut
Pleuronectes platessa	pos	neut	pos	neut	neut	neut	neut
Pollachius pollachius	NA	NA	NA	NA	NA	NA	neut
Pollachius virens	NA	NA	NA	NA	NA	NA	neut
Pomatoschistus sp.	pos	pos	pos	pos	pos	pos	pos
Psetta maxima	neut	neut	pos	pos	pos	neut	neut
Raja clavata	NA	NA	neut	neut	NA	NA	neut
Raja montagui	NA	NA	pos	pos	NA	NA	pos
Raniceps raninus	NA	NA	NA	NA	NA	NA	neut
Salmo sp.	NA	NA	NA	NA	NA	NA	neut
Sardina pilchardus	neg	neg	NA	NA	NA	NA	neg
Scomber scombrus	neg	neut	neut	neut	NA	NA	neut
Scophthalmus rhombus	neut	neut	NA	NA	pos	neut	neut
Scyliorhinus canicula	pos	pos	pos	pos	NA	NA	pos

	IBTS_Q3	IBTS_Q3	IBTS_Q1	IBTS_Q1	BTS	GAM	Overall
Sebastes viviparus	NA	NA	NA	NA	NA	NA	neut
Solea solea	neut	neut	pos	neut	neg	neut	neut
Spinachia spinachia	NA	NA	NA	NA	NA	NA	neut
Sprattus sprattus	pos	neut	neut	pos	neut	pos	pos
Squalus acanthias	neg	neg	neg	neg	NA	NA	neg
Syngnathus sp.	NA	NA	NA	NA	pos	pos	pos
Taurulus bubalis	NA	NA	NA	NA	NA	NA	neut
Trachinus draco	NA	NA	NA	NA	NA	NA	neut
Trachurus trachurus	neg	neg	pos	pos	pos	neut	neut
Trigla lucerna	pos	pos	NA	NA	pos	pos	pos
Triglops murrayi	NA	NA	NA	NA	NA	NA	neut
Trisopterus esmarkii	neut	neut	pos	pos	NA	NA	neut
Trisopterus luscus	neut	neut	pos	neut	pos	neut	neut
Trisopterus minutus	neg	neg	neg	neut	neg	neg	neg
Zeugopterus norvegicus	NA	NA	NA	NA	NA	NA	neut
Zeus faber	NA	NA	NA	NA	NA	NA	neut
Zoarces viviparus	NA	NA	NA	NA	NA	NA	neut

Appendix D. Birds

Values used for the assessment of bird metric values.

A: Biogeographical population

Table 21. Seabirds. Maximum occurrence of migratory seabirds that occur in the Dutch sector of the North Sea as a percentage of their total biogeographical population sizes (taken from Wetlands International 2002). Seasonal maxima within the Dutch EEZ were taken from ship-based and aerial surveys (directly or from published reports on the Fulmar and the Kittiwake (Berrevoets & Arts 2001, Berrevoets & Arts 2003), on Scaup (Baptist & Wolf 1993).

Species	Biogeographical population size (x1000)	Maximum number on DCS	max %	season
Red-throated Diver (*Gavia stellata*)	183-420	9800	5.4 (19.6)*	Win
Black-throated Diver (*Gavia arctica*)	360-690	400	0.1****	Win/Migr
'small diver' (*Gavia stellate/arctica*)	200-500		0.0	Win/Migr
'large diver' (*Gavia immer/adamsii*)	5	10	0.2	Win/Migr
Great Crested Grebe (*Podiceps cristatus*)	370-580	21,100	4.4	Win
Red-necked Grebe (*Podiceps grisegena*)	90-420	50	0.1	Win
Northern Fulmar (*Fulmarus glacialis*)	10,000	95,800	1.0	Aug-Sep
Northern Gannet (*Morus bassanus*)	892	25,600	2.9	Aut
Great Cormorant (*Phalacrocorax carbo*)	276-342	4000	1.3**	Sum
Greater Scaup (*Aythya marila*)	310	5000	1.6	Win
Common Eider (*Somateria mollissima*)	850-1200	70,000	6.8	Win
Long-tailed Duck (*Clangula hyemalis*)	4600	60	0.0	Win
Common Scoter (*Melanitta nigra*)	1600	110,000	6.9	Win
Velvet Scoter (*Melanitta fusca*)	1000	5000	0.5 (1.2)***	Win
Common Goldeneye (*Bucephala clangula*)	400	500	0.1	Win
Red-breasted Merganser (*Mergus serrator*)	170	250	0.1	Win
Arctic Skua (*Stercorarius parasiticus*)	55	300	0.5****	Aut
Great Skua (*Stercorarius skua*)	27	1500	5.5	Aug-Sep
Mediterranean Gull (*Larus melanocephalus*)	570-1110	100	0.0	Sum
Little Gull (*Larus minutus*)	66-102	14,200	16.9****	Migr
Black-headed Gull (*Larus ridibundus*)	5600-7300	24,900	0.4	Win
Common Gull (*Larus canus*)	1300-2100	61,500	3.6	Win
Lesser Black-backed Gull (*Larus fuscus*)	525	82,900	15.8	Spr/Sum
Herring Gull (*Larus argentatus*)	1090	139,200	12.8	Win
Great Black-backed Gull (*Larus marinus*)	420-510	36000	7.7	Win
Black-legged Kittiwake (*Rissa tridactyla*)	8400	155,700	1.9	Win
Sandwich Tern (*Sterna sandvicensis*)	159-171	7000	4.1	Spr/Sum
Common Tern (*Sterna hirundo*)	500-1000	10,600	1.4	Aug-Sep
Arctic Tern (*Sterna paradisaea*)	1320-2280	1000	0.1****	
'comic tern' (*S. hirundo / S. paradisaea*)	1000		0.0	
Little Tern (*Sterna albifrons*)	31-32	500	1.6****	Spr
Common Guillemot (*Uria aalge*)	8000	133,185	1.7	Aut
'large alcid' (*Alca torda / Uria aalge*)	6600	157,400	2.4	Aut/Win
Razorbill (*Alca torda*)	2400	24,215	1.0	Win
Little Auk (*Alle alle*)	1500	4300	0.3	Win
Atlantic Puffin (*Fratercula arctica*)	12,000	820	0.0	Win

* the population size for Red-throated Divers was upgraded from 75,000 (Rose & Scott 1994) to 183,000-420,000 (Wetlands International 2002), but downgraded again to 51,000 (BirdLife International 2004) for reasons that are not given in the latter publications. This last estimate would lead to a percentage of 19.6, as given in brackets.

** Continental Great Cormorants have only recently started breeding on coastal sites and using the coastal North Sea waters for obtaining their food. The current coastal population size in the Netherlands is around 5000 pairs and rapidly increasing.

*** Velvet Scoters usually occur in total numbers <5000 birds in the Dutch EEZ, but in 1993 a flock of 12,000 wintered off the island of Terschelling .

**** Black-throated Diver, Little Gull, Arctic Tern and Little Terns numbers peak in Dutch waters during the spring and/or autumn migration. Passage of these species may be massive and highly concentrated in time and place. At-sea surveys numbers generally render much lower numbers than inferred from seawatching. The three tern species mentioned here (but not included in Table 22) probably use the Dutch waters to a much lesser extent than Little Gull, Sandwich Tern and Common Tern, which are included; total numbers of individuals using the area exceed the numbers as inferred from at sea surveys at well on which the estimates in this table are based.

B: Resilience.

Table 22. Seabirds resilience. Data of alcids from Nettleship & Birkhead (1985) and other species from Cramp & Simmons (Cramp & Simmons 1977-1985).

Nr.	Species	Average clutch size (range)	Replacement clutches	Average age at first breeding (range)	Resilience index
1	Red-throated Diver (*Gavia stellata*)	2 (1-3)	1	2.5 (2-3)	1.2
2	Black-throated Diver (*Gavia arctica*)	2 (1-3)	1	2.5 (2-3)	1.2
3	'small diver' (*Gavia stellate/arctica*)	2 (1-3)	1	2.5 (2-3)	1.2
4	'large diver' (*Gavia immer/adamsii*)	2 (?)	1	2.5 (2-3)	1.2
5	Great Crested Grebe (*Podiceps cristatus*)	3.5 (2)	1	1.95 (1-2)	2.3
6	Red-necked Grebe (*Podiceps grisegena*)	4.5 (4-5)	1	2 (2)	2.8
7	Northern Fulmar (*Fulmarus glacialis*)	1 (1-2)	0	9.2 (6-12)	0.1
8	Northern Gannet (*Morus bassanus*)	1 (1)	1	5 (4-6)	0.4
9	Great Cormorant (*Phalacrocorax carbo*)	3.5 (3-6)	1	4.5 (3-5)	1.0
10	Greater Scaup (*Aythya marila*)	10 (6-15)	1	1.5 (1-2)	7.3
11	Common Eider (*Somateria mollissima*)	4.6 (4-6)	1	3 (2-3)	1.9
12	Long-tailed Duck (*Clangula hyemalis*)	7.9 (5-11)	1	2 (2)	4.5
13	Black Scoter (*Melanitta nigra*)	8 (5-11)	1	2.5 (2-3)	3.6
14	Velvet Scoter (*Melanitta fusca*)	8.4 (5-12)	1	2.25 (2-3)	4.2
15	Common Goldeneye (*Bucephala clangula*)	9.3 (5-13)	1	2 (2)	5.2
16	Red-breasted Merganser (*Mergus serrator*)	9.3 (6-14)	1	2 (2)	5.2
17	Arctic Skua (*Stercorarius parasiticus*)	2 (1-3)	1	4.39 (4-5)	0.7
18	Great Skua (*Stercorarius skua*)	2 (1-2)	1	7.5 (4-10)	0.4
19	Mediterranean Gull (*Larus melanocephalus*)	3 (2-3)	1	2.5 (2-3)	1.6
20	Little Gull (*Larus minutus*)	2.7 (2-3)	1	2.5 (2-3)	1.5
21	Black-headed Gull (*Larus ridibundus*)	2.8 (2-3)	1	2 (1-3)	1.9
22	Common Gull (*Larus canus*)	2.5 (2-5)	1	3 (2-4)	1.2
23	Lesser Black-backed Gull (*Larus fuscus*)	2.7 (1-4)	1	4 (3-6)	0.9
24	Herring Gull (*Larus argentatus*)	2.7 (2-4)	1	5 (3-7)	0.7
25	Great Black-backed Gull (*Larus marinus*)	2.9 (1-5)	1	4.5 (4-5)	0.9
26	Black-legged Kittiwake (*Rissa tridactyla*)	2 (1-3)	1	4.9 (3-8)	0.6
27	Sandwich Tern (*Sterna sandvicensis*)	1.6 (1-3)	1	3.5 (3-4)	0.7
28	Common Tern (*Sterna hirundo*)	2.7 (1-3)	1	3.5 (2-4)	1.1
29	Arctic Tern (*Sterna paradisaea*)	1.9 (1-3)	0.5	4 (2-4)	0.6
30	'comic tern' (*S. hirundo / S. paradisaea*)				0.9
31	Little Tern (*Sterna albifrons*)	2.2 (1-3)	1	3 (>=2)	1.1
32	Common Guillemot (*Uria aalge*)	1 (1)	1	4.9 (4-5)	0.4
33	'large alcid' (*Alca torda / Uria aalge*)				0.4
34	Razorbill (*Alca torda*)	1 (1)	1	4.5 (4-5)	0.4
35	Little Auk (*Alle alle*)	1 (1)	0.5	3 ()	0.5
36	Atlantic Puffin (*Fratercula arctica*)	1 (1)	0.5	5 (3-5)	0.3

Table 23. Summary of Specific Bird Values (SBV) (column F) for all bird species included in the analyses of total bird values per grid cell of 5x5 km in the Dutch EEZ. In the calculation of SBVs column D and E are averaged and summed with A-C. See text for explanation of columns A-F.

		A	B	C	D	E	F
Nr.	**Species**	**Biogeographic population size**	**Resilience**	**Dependence on marine environment**	**Dependence on Dutch EEZ**	**Dependence on NL for breeding**	**SBV**
1	Red-throated Diver (*Gavia stellata*)	4	3	5	3	0	**4**
2	Black-throated Diver (*Gavia arctica*)	4	3	4	1	0	**3**
3	'small diver' (*Gavia stellate/arctica*)	4	3	5	3	0	**4**
4	'large diver' (*Gavia immer/adamsii*)	5	3	5	1	0	**4**
5	Great Crested Grebe (*Podiceps cristatus*)	4	1	2	3	0	**2**
6	Red-necked Grebe (*Podiceps grisegena*)	4	1	2	1	0	**1**
7	Northern Fulmar (*Fulmarus glacialis*)	1	5	5	1	0	**3**
8	Northern Gannet (*Morus bassanus*)	4	4	5	2	0	**4**
9	Great Cormorant (*Phalacrocorax carbo*)	4	3	4	2	1	**3**
10	Greater Scaup (*Aythya marila*)	4	1	2	2	0	**1**
11	Common Eider (*Somateria mollissima*)	3	2	3	4	1	**2**
12	Long-tailed Duck (*Clangula hyemalis*)	2	1	3	1	0	**1**
13	Black Scoter (*Melanitta nigra*)	3	1	5	4	0	**3**
14	Velvet Scoter (*Melanitta fusca*)	3	1	4	1	0	**2**
15	Common Goldeneye (*Bucephala clangula*)	4	1	2	1	0	**1**
16	Red-breasted Merganser (*Mergus serrator*)	4	1	2	1	0	**1**
17	Arctic Skua (*Stercorarius parasiticus*)	5	3	5	1	0	**4**
18	Great Skua (*Stercorarius skua*)	5	4	5	3	0	**5**
19	Mediterranean Gull (*Larus melanocephalus*)	4	2	1	1	1	**2**
20	Little Gull (*Larus minutus*)	5	3	3	5	0	**4**
21	Black-headed Gull (*Larus ridibundus*)	2	2	2	1	1	**1**
22	Common Gull (*Larus canus*)	3	3	3	2	1	**3**
23	Lesser Black-backed Gull (*Larus fuscus*)	4	3	4	5	5	**5**
24	Herring Gull (*Larus argentatus*)	3	3	3	5	4	**4**
25	Great Black-backed Gull (*Larus marinus*)	4	3	4	4	0	**4**
26	Black-legged Kittiwake (*Rissa tridactyla*)	2	3	5	2	0	**3**
27	Sandwich Tern (*Sterna sandvicensis*)	4	3	4	3	4	**4**
28	Common Tern (*Sterna hirundo*)	4	3	4	2	1	**3**
29	Arctic Tern (*Sterna paradisaea*)	3	3	4	1	1	**3**
30	'comic tern' (*S. hirundo / S. paradisaea*)	3	3	4	2	1	**3**
31	Little Tern (*Sterna albifrons*)	5	3	2	2	1	**3**
32	Common Guillemot (*Uria aalge*)	2	4	5	2	0	**3**
33	'large alcid' (*Alca torda / Uria aalge*)	2	4	5	2	0	**3**
34	Razorbill (*Alca torda*)	2	4	5	1	0	**3**
35	Little Auk (*Alle alle*)	3	3	5	1	0	**3**
36	Atlantic Puffin (*Fratercula arctica*)	1	4	5	1	0	**3**

Appendix E. Habitats

Table 24. Habitat types in the Dutch North Sea, based on combinations of grain size, depth classes, summer stratification (absence/presence) and salinity classes. Silty: silt content >= 15%; Gravel: gravel content >=50%; Fine sand: median grain size <= 150 µm, medium fine sand: 150 - 210 µm, medium coarse sand: 210 - 420 µm; coase sand >420 µm.

Code	Sediment type	Depth class	Summer stratification	Salinity class	Suface (km^2)	Relative surface (%)	rarity
1	estuary	0	no	1	4028.07	6.85	1
14	surf zone, fine sand	0-10 m	no	2	37.88	0.06	5
15	surf zone, medium fine sand	0-10 m	no	2	700.09	1.19	3
16	surf zone, medium coarse sand	0-10 m	no	2	904.02	1.54	3
17	surf zone, coarse sand	0-10 m	no	2	22.71	0.04	5
24	shallow coastal sea, fine sand	10-20 m	no	2	10.93	0.02	5
25	shallow coastal sea, medium fine sand	10-20 m	no	2	215.51	0.37	3
26	shallow coastal sea, medium coarse sand	10-20 m	no	2	2780.73	4.73	2
27	shallow coastal sea, course sand	10-20 m	no	2	197.87	0.34	4
24	fine sand	10-20 m	no	3	13.24	0.02	5
31	silty, fine sand	20-30 m	yes	3	86.94	0.15	4
32	silty, medium fine sand	20-30 m	yes	3	113.55	0.19	4
33	silty, medium coarse sand	20-30 m	yes	3	49.89	0.08	5
34	fine sand	20-30 m	yes	3	133.55	0.23	4
35	medium fine sand	20-30 m	no	3	2015.90	3.43	2
36	medium coarse sand	20-30 m	no	3	16195.35	27.54	1
37	coarse sand	20-30 m	no	3	1262.11	2.15	3
41	silty, fine sand	30-40 m	yes	3	2376.41	4.04	2
42	silty, medium fine sand	30-40 m	yes	3	1892.75	3.22	2
43	silty, medium coarse sand	30-40 m	yes	3	53.03	0.09	5
44	fine sand	30-40 m	yes	3	1847.59	3.14	2
45	medium fine sand	30-40 m	yes	3	7541.53	12.82	1
46	medium coarse sand	30-40 m	yes	3	3514.86	5.98	1
47	coarse sand	30-40 m	yes	3	209.92	0.36	3
51	silty, fine sand	> 40 m	yes	3	2541.66	4.32	2
52	silty, medium fine sand	> 40 m	yes	3	633.77	1.08	3
54	fine sand	> 40 m	yes	3	5128.17	8.72	1
55	medium fine sand	> 40 m	yes	3	3355.23	5.71	1
56	medium coarse sand	> 40 m	yes	3	741.78	1.26	3
57	coarse sand	> 40 m	yes	3	74.50	0.13	4
58	gravel	> 40 m	yes	3	129.14	0.22	4

Silty: silt content >= 15%; Gravel: gravel content >=50%; Fine sand: median grain size <= 150 µm, medium fine sand: 150 - 210 µm, medium coarse sand: 210 - 420 µm; coase sand >420 µm.

Justification

Report C071/11
Project number: 4308201043

The scientific quality of this report has been peer reviewed by the a colleague scientist and the head of the department of IMARES.

Approved: Prof. Dr. Adriaan Rijnsdorp
Researcher

Signature:

Date: 29 June 2011

Approved: Jakob Asjes
Head of department of fish ecology

Signature:

Date: 29 June 2011