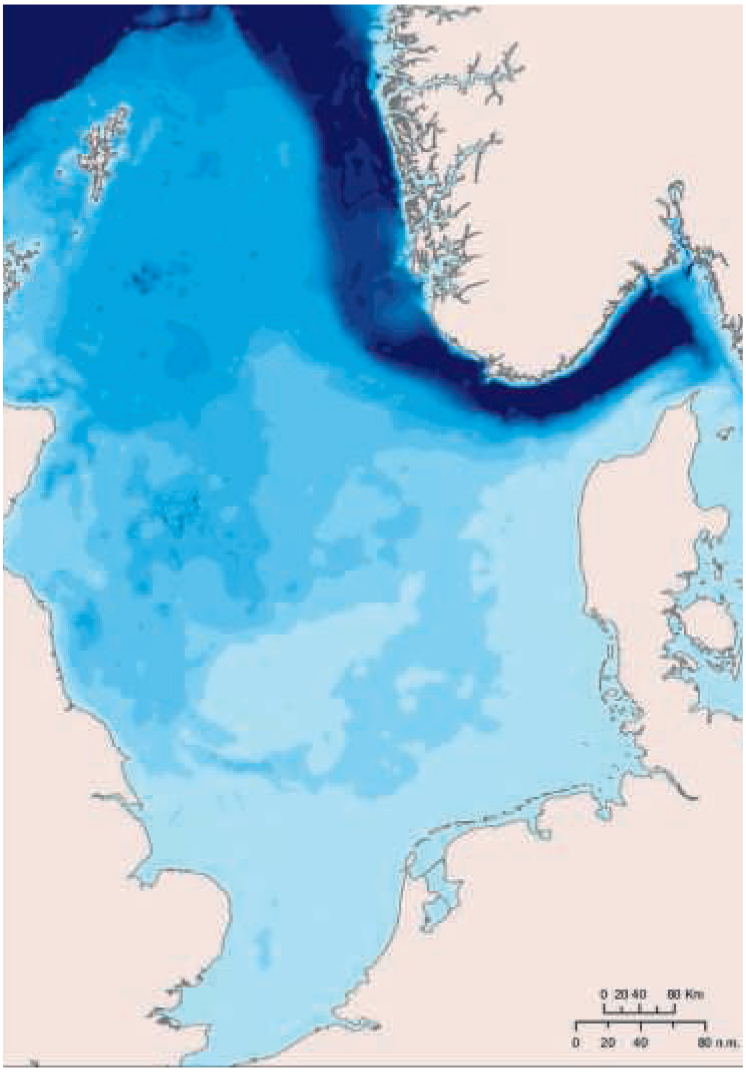
MEFEPO

Making the European Fisheries Ecosystem Plan Operational

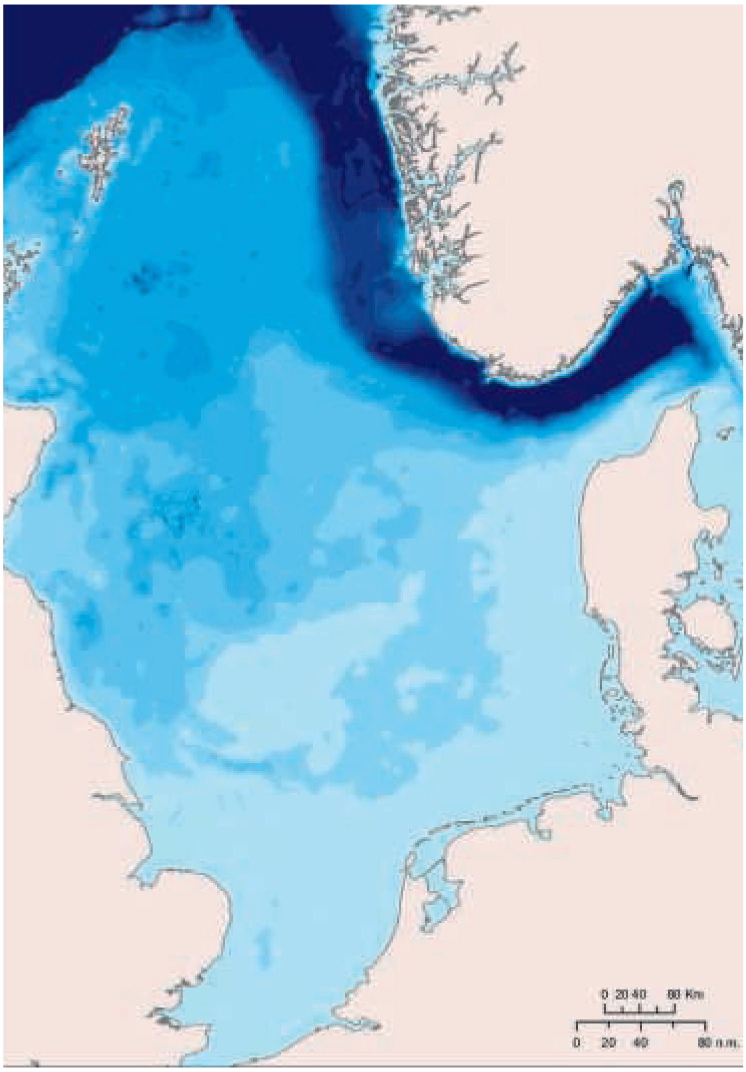
North Sea Atlas



2nd Edition August 2011

MEFEPO

North Sea **Atlas**



2nd Edition - August 2011

"To rebuild a vibrant fishing economy in Europe, the marine environment must be protected more effectively. From now on, EU fisheries will be managed by multi-annual plans and governed by the ecosystem approach and the precautionary principle to ensure that the impacts of fishing activities on the marine ecosystem are limited. The fishing industry will have a better and more stable basis for long-term planning and investment. This will safeguard resources and maximise long-term yields."

European Commission
MEMO/11/503 on the Reform of the Common Fisheries Policy 2011

"The oceans and the seas sustain the livelihoods of hundreds of millions of people, as a source of food and energy, as an avenue for trade and communications and as a recreational and scenic asset for tourism in coastal regions. So their contribution to the economic prosperity of present and future generations cannot be underestimated."

José Manuel Barroso
President EU Commission
EU Green Paper on Maritime Policy 2006

MEFEPO PROJECT

Welcome to the second edition of the MEFEPO North Sea (NS) Atlas. The MEFEPO (Making the European Fisheries Ecosystem Plan Operational) project is made up of a group of ecologists, economists, management experts and fisheries scientists who are trying to make ecosystem based fisheries management (EBFM) a reality in Europe. EBFM seeks to support the 'three pillars of sustainability' (ecological, social and economic).

The MEFEPO project is now in its final phase and we are currently working to develop draft operational Fisheries Ecosystem Plans (FEPs) for our case study regions (North Sea, NS; North Western Waters, NWW; and South Western Waters, SWW) which will be published later this year.

This Atlas is intended for policy makers, managers and interested stakeholders. Its purpose is to provide a broad overview of the ecosystem of the North Sea (NS) Regional Advisory Council (RAC) area. We have tried to make the science as clear and concise as possible, and keep technical language to a minimum. The information has been presented through a blend of text, tables, figures and images. There is a glossary of terms (p. 103-104) and a list of more detailed scientific references (p. 105-109) for those interested in following up certain issues.

The first edition of the Atlas, published in 2009, was extremely well received and this new edition has been modified in response to stakeholder feedback to provide updated information on the physical and chemical features, habitat types, biological features, birds, mammals, fishing activity and other human activities taking place within the NS region. Background material on five NS fisheries (flatfish, sandeels, herring, mixed white fish and *Nephrops*), which have been used throughout the MEFEPO project, is presented.

The Atlas compliments a *Technical Review Document on the Ecological, Social and Economic Features of the North Sea region* (van Hal *et al.* 2009) which provides more detailed information and is available to download from the project website: www.liv.ac.uk/mefepo

Knowledge of the NS area is advanced compared to the other MEFEPO project regions (NWW and SWW) and the information used in this Atlas was widely dispersed in the grey literature, various national reports, national research programmes and published papers. The recently published OSPAR Quality Status Report 2010 for the North-East Atlantic was a major source of new information for this second edition.

This Atlas has also been produced in French, and Atlases for the NWW and SWW regions are available to download at: www.liv.ac.uk/mefepo. As the MEFEPO project ends we hope the Atlases will form a useful part of the legacy and we hope that, if they continue to be useful, further editions will follow.

MEFEPO PROJECT TEAM

This Atlas was produced by the EU FP-7 funded MEFEPO project; production was led by the University of Liverpool, UK (North Sea WP1 leaders).

The MEFEPO project partners are:

(1) University of Liverpool, (ULIV), UK, (Project Coordinator)
(2) Instituto de Investigação das Pescas e do Mar, (IPIMAR), Portugal
(3) Wageningen IMARES (IMARES), Netherlands
(4) Université de Bretange Occidentale, (UMR-CNRS), France
(5) Marine Institute, (MI) Ireland
(6) University of Tromsø, (UIT), Norway
(7) Centre for Environmental, Fisheries and Aquaculture Sciences, (CEFAS), UK
(8) Institute for Fisheries Management, (IFM), Denmark
(9) Universidad dos Acores, (IMAR/DOP), Portugal
(10) Instituto Español de Oceanografía, (IEO), Spain

Every effort has been made to ensure the accuracy of the information contained in this atlas. However the size of the document means that much of the detail has had to be omitted and some simplifications have been made for the sake of clarity.

MEFEPO has also produced a companion technical report that contains more detail and full references to the original sources, see www.liv.ac.uk/mefepo

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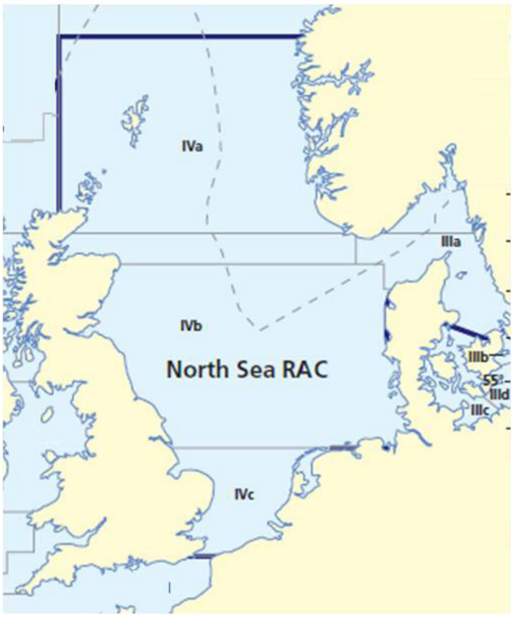
SUMMARY



The North Sea is a marginal, shallow sea on the European continental shelf. It is more than 970 kilometres from north to south and 580 kilometres from east to west, with an area of around 750,000 square kilometres. The North Sea RAC area is larger, because it includes the Skagerrak and Kattegat which connect the North Sea Proper to the Baltic. The North Sea is bordered by England, Scotland, Norway, Denmark, Germany, the Netherlands, Belgium and France. In the southwest, beyond the Straits of Dover, the North Sea becomes the English Channel which connects to the Atlantic Ocean. The North Sea is a fairly shallow, coastal sea and depths in the southern basin do not exceed 50m. The northern areas are deeper but are still generally less than 200m except in the Norwegian Trough, in the north-east, which is the only region of very deep water.

The main inflow of water into the North Sea is from the North Atlantic into the northern basin. Water also enters from the English Channel, although this is a smaller, warmer and more saline flow than the northern inflow. The volume of water entering the North Sea is highly variable between seasons and years, and is strongly correlated to climatic conditions. Water leaves the North Sea via the Norwegian coastal current.

Climate has a major impact on marine waters through its influence on wind speed, rainfall, evaporation and heat exchange between the air and sea. In the North Sea, surface temperatures follow a strong annual cycle caused by climatic conditions although the temperature of bottom waters tends to be more stable and is largely affected by the water bodies entering the North Sea. ICES recently stated that there "*is great confidence within the scientific community that climate change is a reality*". The increase in greenhouse gasses has caused global warming of the atmosphere and ocean, rising sea levels and changing wind patterns. Surface and bottom temperatures have increased in the North Sea in the last 25 years and climate change is affecting the distribution of fish as they move north to remain within their preferred temperature range.

The salinity of the North Sea is influenced by the large volume of freshwater entering from major European rivers and this is seen in the lower salinities of the south eastern North Sea. There is seasonal variation in the north east of the region due to the volume and salinity of water flowing out of the Baltic in the spring melt from freshwater ice. In coastal areas away from these influences the salinity is typically between 32 and 34.5 ppt.

The North Atlantic is the major source of nutrients for the North Sea; however the highest concentrations of nutrients enter via rivers and 30% of the nitrogen entering the North Sea comes from the atmosphere. The principle nutrients required for phytoplankton growth are nitrogen, usually in the form of nitrate, and phosphorous in the form of phosphate. Nutrient levels in the North Sea and Baltic have increased as a result of human activity; both nitrate and phosphate are elevated but nitrate has increased proportionally more. As nitrate is generally the limiting plant nutrient in marine waters this implies a potential change in the ecology of the system at the base of the food chain, with the power to propagate across the ecosystem.

Most of the North Sea seabed is made up of sediment of varying sizes. The marginal areas are eroding hard rock which often extends below the low tide level to form underwater rocky reefs and cliffs. This is most common in the northern North Sea where offshore islands and rocky foreshores are common. In contrast, sandy beaches are more common in the south-eastern North Sea. There is a strong association between the physical nature of the sea floor and the organisms that live there and seabed habitat mapping exercises are now being used to predict the distribution of ecological assemblages of species.

The Continuous Plankton Recorder (CPR) Survey's marine monitoring programme collects data from the North Sea on the ecology and biogeography of plankton, and has recorded changes in community structure over the last 5 decades. These changes have not been consistent across the North Sea which indicates the importance of smaller scale processes. Phytoplankton abundance has increased in the north-western and eastern North Sea. Diatoms and dinoflagellates have decreased in these regions but have increased in the north-eastern North Sea. The total abundance and mix of species in the zooplankton of the North Sea has also changed during this time; overall in the north-eastern Atlantic there has been a 10 degree of latitude shift northward in species distributions, with southern species extending further north and northerly species retreating.

The range of benthic habitats in the North Sea supports diverse and highly productive biological assemblages. The main organisms are various species of marine bristle worms (polychaetes), burrowing clams (bivalve molluscs), sand shrimps (amphipods), sea urchins and brittlestars. Various species of mobile scavengers, such as crabs, starfish and fish, range across the various habitats.

Over ten species of whales and dolphins are regularly sighted in the North Sea, although only the harbour porpoise, bottlenose dolphin, white-beaked dolphin and minke whale are considered to be truly resident species. In most regions these species have become the subject of a growing eco-tourism industry. Two seal species breed within the North Sea, the harbour seal and the grey seal; harbour seals occur throughout the North Sea, whereas grey seals almost exclusively occur around northern Britain.

The North Sea is important for seabirds, local breeding and non breeding seabirds along with passage migrants. Approximately 2.5 million pairs of sea birds, from 28 different species, breed on coasts in the region. The seas and varied coastlines are important for birds year round with many being of international or national importance as individual species or for their role in the ecological assemblages they support. Coastal and offshore waters provide a rich source of nutrition for birds; as predators they depend on available food resources and the health of seabird populations can give an indication of the condition of some fish stocks.

The North Sea is an important area at the European level for shipping, extractive industries and cultural pastimes. Containing some of the busiest shipping routes in the world, a significant proportion of western European imports and exports are transported by ship through the North Sea. In the ten year period 1998-2008, tourist arrivals in the EU increased by almost 40% and a significant proportion of tourist activity is concentrated in the coastal zone. There are also many large industrial cities associated with the North Sea.

Oil and gas extraction from the North Sea is a major economic activity. Although total oil production from the North Sea remains over 4 million barrels per day, North Sea oil production has declined since its peak in 1999. The expansion of offshore generation is widely supported as one of the key technologies to achieve Kyoto targets for emissions reduction. A large proportion of the existing and proposed European offshore wind turbine sites are located in the North Sea.

As of 2009 across the EU offshore wind farms, spread across 9 countries, have a capacity to produce 2,063 MW, which is expected to rise to 40-55 GW by 2020.

Marine Protected Areas (MPAs) are a spatial management tool which controls or restricts human activities over a specific area. They are used for commercial and conservation purposes and there is evidence that MPAs from which fishing is excluded can lead to changes in stocks of resident fish. MPAs can be permanent or temporary and are strictly protected by European law. There are many restrictions on fishing activity in the North Sea including spatial areas, 'boxes', closed to fishing of cod, herring, sprat, plaice, Norway pout and sandeels.

Five case studies have been used in this Atlas to demonstrate the varied fishing techniques used and to establish the current state of each stock.

Case study 1: Flatfish Beam Trawling

Flatfish beam trawling targets mainly plaice (*Pleuronectes platessa*) and sole (*Solea vulgaris*). The catches in the North Sea in 2009 were 52,315 tonnes for plaice and 13, 813 tonnes for sole.

Case study 2: Industrial Sandeel Fishery

The industrial sandeel fishery in the North Sea uses small mesh trawls, with a mesh size as small as 5mm. Average landings of sandeel in the North Sea in the last 20 years were 666 000 t and total landings in 2008 were 335 000 t.

Case study 3: Herring Fishery

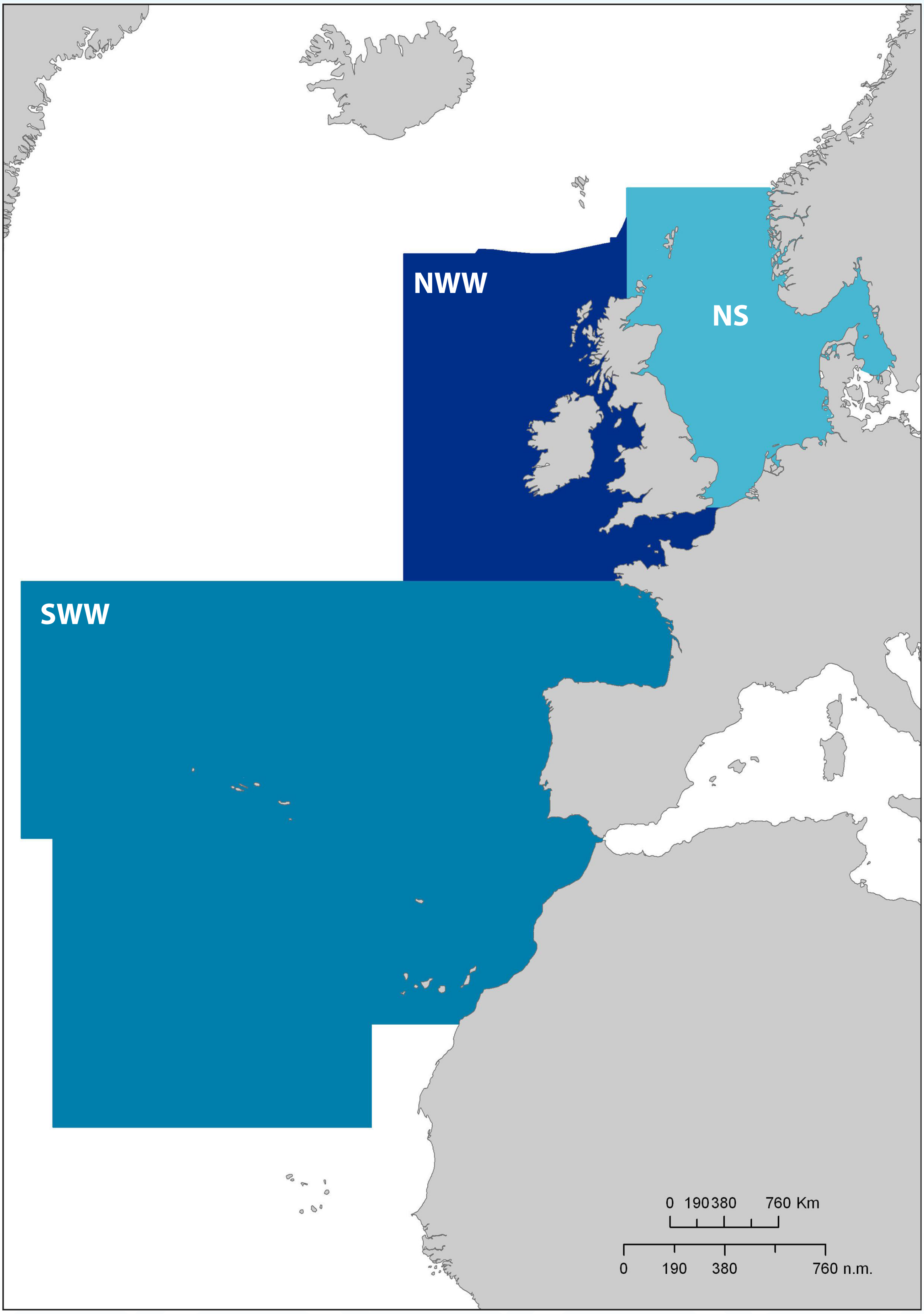
Herring fisheries take place with pelagic trawls catching shoals of the target species. The shoals are located with the use of echo-sounding equipment. Official catches of North Sea herring for human consumption were 183 205 tonnes in 2009

Case study 4: Mixed White Fish Demersal Trawling

The main species taken by the North Sea large mesh (>100 mm) otter trawl fleet are anglerfish, cod, plaice, saithe and whiting. The whitefish fishery has the highest impact in terms of both weight and numbers of cod removed in the North Sea. ICES classifies the cod stock as suffering reduced reproductive capacity and as being harvested unsustainably.

Case study 5: *Nephrops* Fishery

Landings of *Nephrops* have increased in recent years; the increased biomass is probably due to better environmental conditions benefitting recruitment. The current levels of exploitation are considered sustainable.



MEFEPO project regions based on Regional Advisory Council (RAC) areas: North Sea (NS), North Western Waters (NWW) and South Western Waters (SWW).

WELCOME TO MEFEPO

"The fisheries sector can no longer be seen in isolation from its broader marine environment and from other policies dealing with marine activities…..The Common Fisheries Policy therefore requires us all to take a fresh look at the broader maritime picture as advocated by the Integrated Maritime policy (IMP) and its environmental pillar, the Marine Strategy Framework Directive."

Reform of the Common Fisheries Policy, Green Paper (2009)

Overview of the MEFEPO Project

The MEFEPO project consists of a group of ecologists, economists, management experts and fisheries scientists that are trying to make ecosystem based fisheries management work in Europe.

In recent years considerable effort has been devoted to addressing the governance, scientific, social and economic issues required to develop and introduce an ecosystem approach to European marine fisheries. MEFEPO will seek to harness and apply these efforts.

Fisheries management needs to support the 'three pillars of sustainability' (ecological, social and economic). One of the greatest challenges of management is searching for ways of achieving these objectives simultaneously. The economic and social pillars can be considered subsidiary to the ecological pillar since the loss of an ecological resource base will mean that no social and economic benefits can be derived from the seas.

Making the European Fisheries Ecosystem Plan Operational (MEFEPO) is an EU-FP7 funded collaborative project, with 10 project partner institutions from 8 countries: UK (coordinator), Portugal, Netherlands, France, Ireland, Norway, Denmark, and Spain. The project commenced in September 2008 and will finish in November 2011.

In recent years considerable effort has been devoted to addressing the governance, scientific, social and economic issues required to develop and introduce an ecosystem approach to European marine fisheries. This change to an ecosystem approach will require a fundamental shift away from traditional single species fisheries management to a system that incorporates broader marine environment issues and the wide range of stakeholder actors.

Fisheries management needs to support the 'three pillars of sustainability' (ecological, social and economic). One of the greatest challenges of management is searching for ways of achieving these objectives simultaneously. In practice this is difficult to achieve and tradeoffs have to be considered. However, the economic and social pillars should be considered subsidiary to the ecological pillar since the loss of an ecological resource base will mean that no social and economic benefits can be derived from the seas. Thus an understanding of the links between ecological, social and economic systems is essential in order to ensure that management decisions are appropriately informed.

The Ecosystem Approach – A Definition

"The comprehensive integrated management of human activities based on best available scientific knowledge about the ecosystem and its dynamics, in order to identify and take action on influences which are critical to the health of the marine ecosystems, thereby achieving sustainable use of ecosystem goods and services and maintenance of ecosystem integrity."

EU Danish Presidency, 2002

Fisheries Ecosystem Plans (FEPs)

In the US, Fisheries Ecosystem Plans (FEPs) were developed to further the development of the ecosystem approach in fisheries management and as a tool to assist managers consider the ecological, social and economic implications of their management decisions. The FP5-funded European Fisheries Ecosystem Plan (EFEP) project developed a FEP for European waters, using the North Sea as a case study. The EFEP project incorporated social and political sciences, marine ecology, fisheries science and mathematical modelling to identify the effects of various fisheries management scenarios on the ecosystem and their acceptability to a broad range of marine stakeholders including fishers, fish processors, managers, policy makers, scientists and environmentalists. The project also developed a step-wise framework for the transition of management from the current regime to an ecosystem approach, and an outline of how the FEP could be made operational within existing legislation.

MEFEPO Project Objectives

The core concept for the MEFEPO project is the delivery of an operational framework for three regional seas. These are based on the Regional Advisory Council areas; the North Sea, North Western Waters and South Western Waters (see figure on page 4).

MEFEPO will focus on how best to make current institutional frameworks responsive to an ecosystem approach to fisheries management at regional and pan-European levels in accordance with the principles of good governance. This will involve developing new linkages and means of allowing dialogue between the disparate groups of marine stakeholders and developing a decision-making process which integrates a wide breadth of interests.

The MEFEPO project has required the integration of the considerable body of ecological, fisheries, social and economic research which has been developed in recent years to support an ecosystem approach. It has investigated how existing institutional frameworks need to evolve to incorporate this information and promote dialogue between the disparate groups of marine stakeholders and develop a decision-making process which integrates a wide breadth of interests.

MEFEPO
Making the European Fisheries Ecosystem Plan Operational

Project objectives

Objective 1
To show how an ecosystem approach to fisheries can be made operational within three major European regions by identifying the management objectives, and the operational strategies required to achieve those objectives, using economic, social and ecological approaches

Objective 2
To evaluate the different modes of fisheries governance, and their combinations, and their implications on the development of the institutional frameworks used to manage the fisheries to provide a transitional framework towards a mature ecosystem approach to fisheries management

Objective 3
To develop operational FEPs for three major European marine regions targeted at an audience of non-scientists with managerial, policy and RAC roles, and which provides a vision of a mature ecosystem approach and a description of how it can be delivered

Regional Advisory Councils (RAC's)

The RACs were established as a key element of the Reform of the Common Fisheries Policy in 2002 (Council Decision 2004/585/EC) to provide 'new forms of participation by stakeholders'. The RAC's seek to involve stakeholders in the fisheries sector more closely in the decision making process of the CFP and provide a formal mechanism for communication between the European Union and fisheries stakeholders.

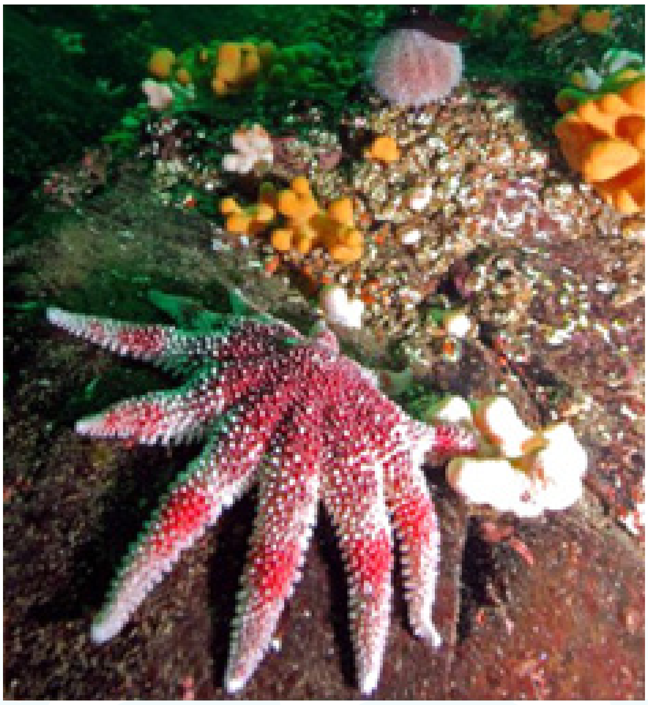
Stakeholders include fishing representatives, conservationists and other organisations such as women's or angling groups.

Five of the RACs have a regional focus (Baltic Seas, Mediterranean Seas, North Sea, North Western Waters and South Western Waters), whilst two are non-regional and consider the pelagic fisheries and distant water fisheries (Pelagic stocks and High Seas/Long Distance Fleets RAC respectively).

The MEFEPO project is using three RAC regions as case studies (see map, page 4):

- North Sea (NS)
- North Western Waters (NWW)
- South Western Waters (SWW)

The focus of this Atlas is on the North Sea (NS).



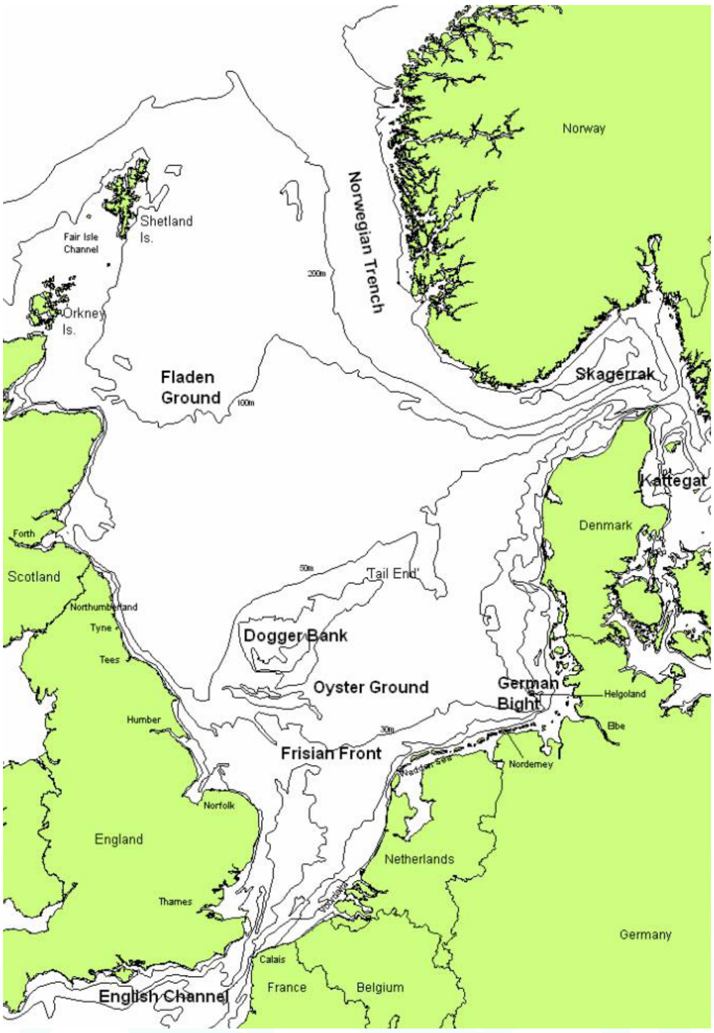
North Sea

The North Sea is a marginal, shallow sea on the European continental shelf. The North Sea is surrounded by England, Scotland, Norway, Denmark, Germany, the Netherlands, Belgium and France. In the southwest, beyond the Straits of Dover, the North Sea becomes the English Channel which connects to the Atlantic Ocean (figure below).

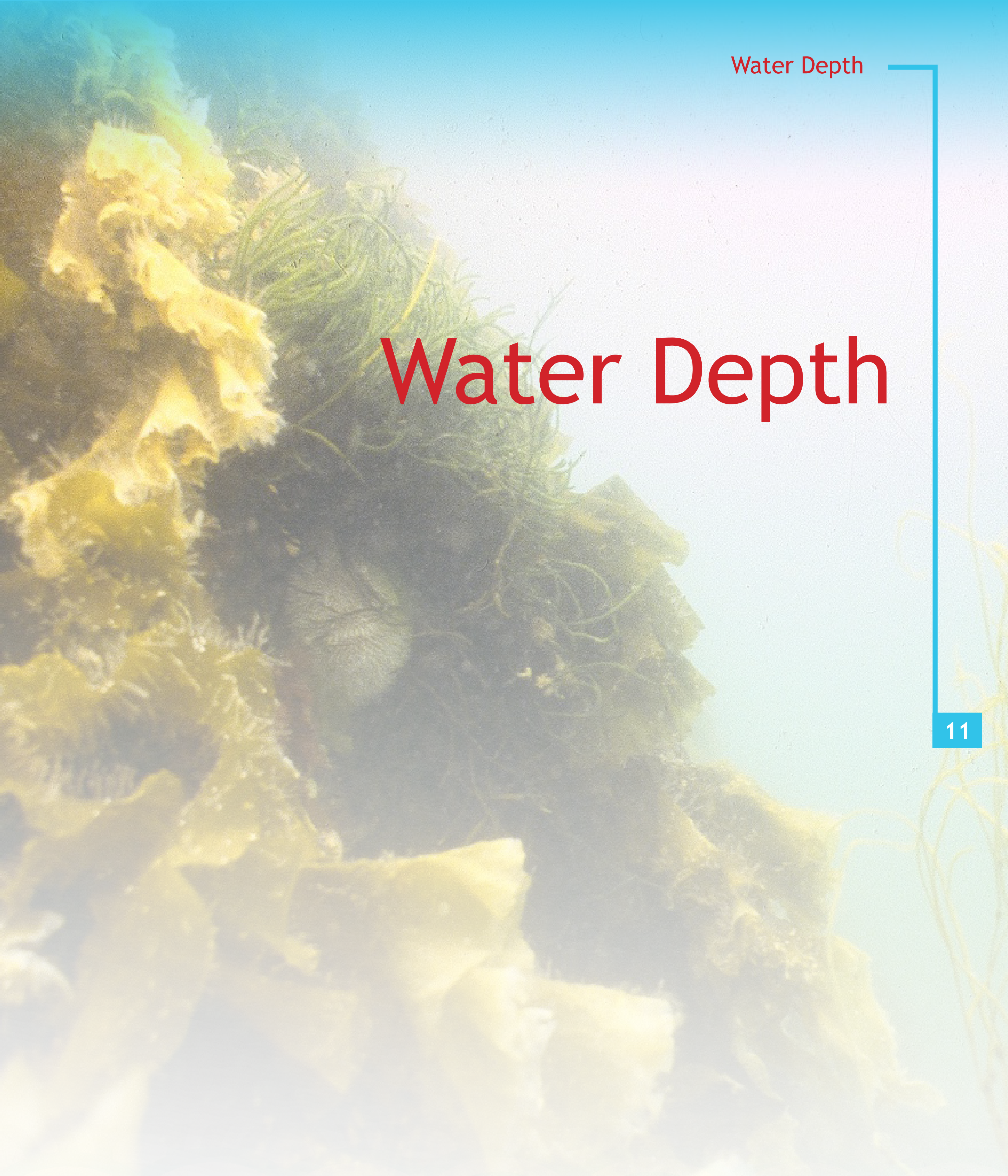
It is more than 970 kilometres from north to south and 580 kilometres from east to west, with an area of around 750,000 square kilometres.

The area is important for marine shipping; it is used for fishing and military purposes; minerals, oil and gas are extracted; and it is a place for tourism. More recently, the NS has also become important for renewable energy installations such as wind farms.

The North Sea is also important for fishing, with many different fishing sectors operating in the area including the flatfish beam trawl, industrial and commercial sandeel, herring, mixed white fish and *Nephrops* fishery (see case studies, page 81-102).



The North Sea with depth contours and selected locations referred to in this report (Source: Rees *et. al.*, 2007).



Water Depth

Water Depth

The North Sea basin is generally shallow and becomes deeper to the north (see opposite). It can be divided into three regions according to depth. These are:

- Southern Bight (51-54°N) with water depths of less than 40m,
- Central North Sea (54-57°N) with water depths of 40-100m (except for the shallower areas on the Dogger Bank and along the western coastline of Denmark),
- Northern North Sea (north of 57°N) (including an area of shelf water 100-200m deep, and the Norwegian Channel with water depths from 200 to >700m in the Skagerrak between Denmark and Norway).

The depth of the water column is an important characteristic of an area as it strongly affects:

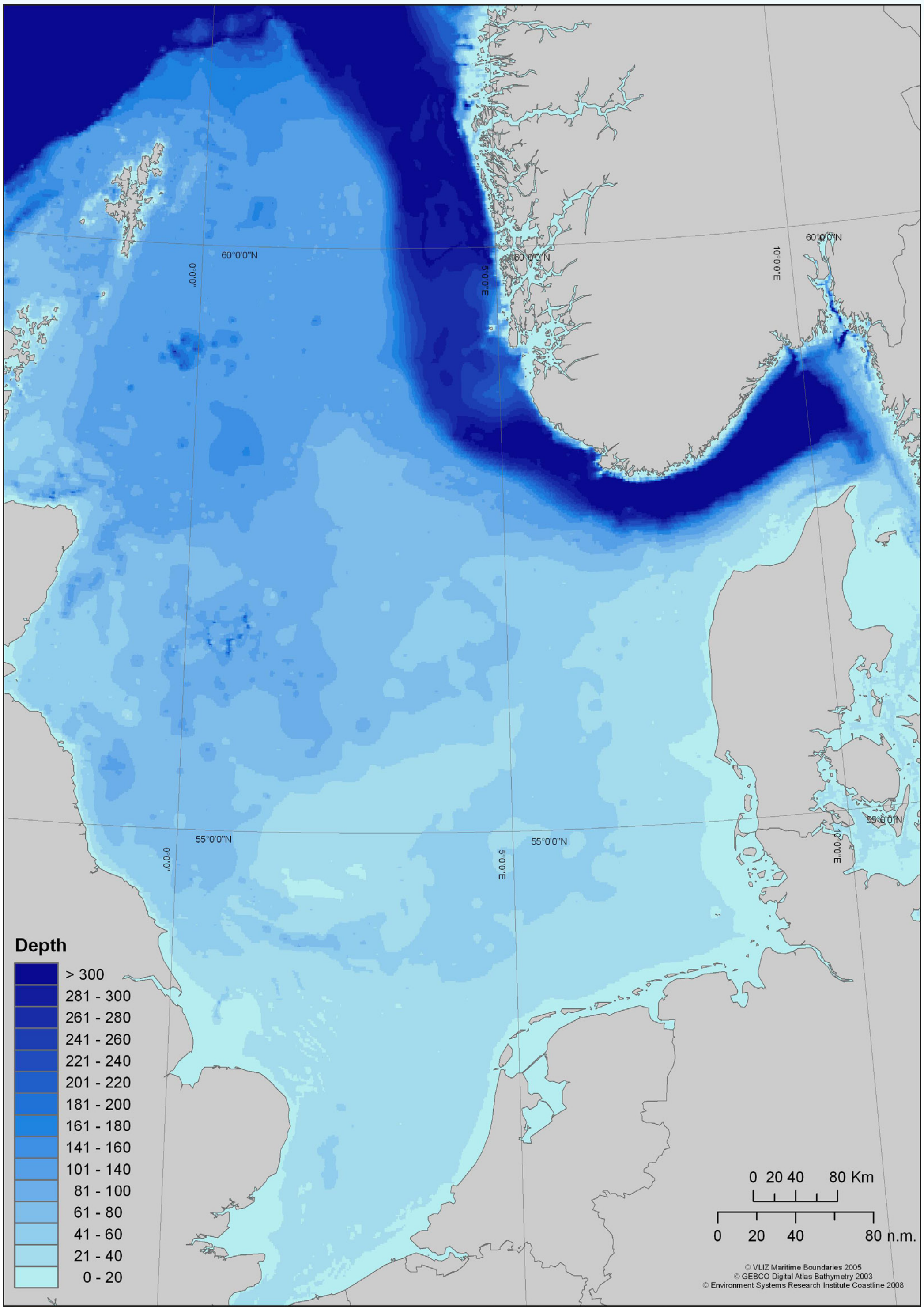
- Circulation patterns
- Surface temperature
- Bottom temperature
- Salinity
- Natural levels of disturbance
- The type of sea floor, e.g. mud or sand
- Formation of thermocline, halocline and pycnocline
- The distribution of biological organisms

The dominant seabed feature of the North Sea is the Doggerbank (right), a large sandbank in the middle of the North Sea. It extends over approximately 17,600 km^2, about 260 km long and 97km broad. It is clearly shallower than the surrounding water, ranging from 15 to 36 metres. Another dominant feature is the Norwegian Trench in the northern part of the North Sea along the coast of Norway, with a width of 20 to 30 km and a maximum depth of approximately 725m.

Stratification:

'Layers' of different temperature or salinity can be formed in the water column. This process is called stratification. The layering tends to occur in deeper waters over the calmer, warmer months when the top layer warms and less physical mixing occurs with the lower layer because there is less wind and fewer storms. The main stratification in the North Sea starts around May, beginning in the north, and extending southwards as the season progresses to around 53.5 °N. South of this area, the strong tidal currents flowing through the relatively shallow water keep the water column mixed all year around.

Stratification prevents mixing of nutrients from deeper water to the upper sunlit areas which restricts the availability of nutrients for algae in the upper, sunlit layers. In winter, storms and stronger winds cause mixing and breakdown stratification, allowing the water column to become mixed and uniform. This is an important process as it provides nutrients for algae to grow in the top layer the following spring.

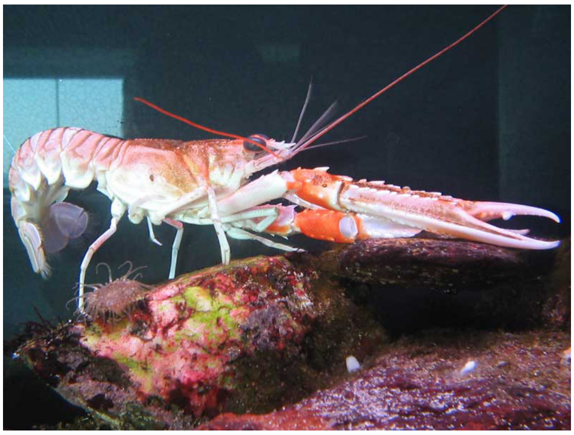


The North Sea is a fairly shallow coastal sea and depths in the southern basin generally do not exceed 50m. The northern areas are deeper but are still generally less than 200m. The Norwegian Trough, in the north-east, is the only region of very deep water with areas exceeding over 700m in depth. Deposits left by retreating glaciers produce offshore sand and gravel banks in the central region which are important spawning areas for a variety of fish species.

Different organisms in the North Sea have adapted to live at different depths, from the barnacles that live in the intertidal zone to the Norwegian lobster that is found in deep waters.

[©Peter Barfield. http://www.marlin.ac.uk/speciesfullreview..php?speciesID=4328#]

Semibalanus balanoides is the most common barnacle species along the North Sea coast. At low tide, barnacles close their shell very tightly to avoid desiccation (drying out). At high tide they open their shells and release their modified legs to feed. These modified legs pulse rhythmically to attract plankton which get stuck to the barnacles legs and are consumed; a feeding strategy known as 'suspension feeding'.



[©Judith Oakley. http://www.marlin. ac.uk/speciesinformationphp?speciesID=3892#]

The Norwegian lobster *Nephrops norvegicus* can be found in the deep North Sea, even in the Skagerrak. These animals live in muddy areas of the sea floor and can build burrows up to 12 inches deep. This species is of commercial importance in the North Sea (see pages 99-102).

Currents and Circulation

Currents and Circulation

The water masses in the North Sea are continuously moving under the influence of tides, winds and storms. The overall current is anti-clockwise, bringing Atlantic water in from the north along the English coast and water from the English Channel along the coast of Belgium and the Netherlands.

Water enters the North Sea through two main routes (see opposite):

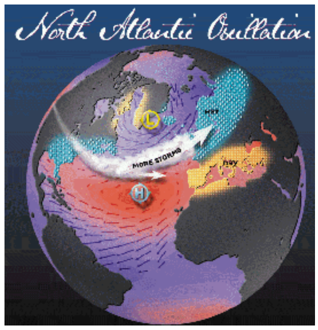
- From the northern North Sea
  - this is the main inflow of water into the North Sea
  - water enters via the Fair Isle Channel and either the northern North Sea Plateau or along the Norwegian Trench
  - inflow through this route is strongly correlated to climatic conditions (the North Atlantic Oscillation)
- From the English Channel
  - this a smaller, warmer and more saline flow than the northern inflow
  - water flow into the North Sea has increased significantly through this route since 1958.

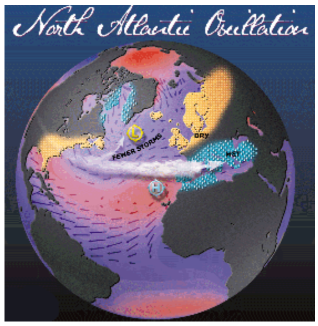
Water leaves the North Sea via the Norwegian coastal current. (see opposite) This current is a combination of wind-driven coastal water from the southern North Sea, saline water from the western North Sea and low salinity water from the Baltic Sea outflow. The source and volume of water entering the North Sea is highly variable between seasons and years, and is strongly correlated to climatic conditions, mainly the North Atlantic Oscillation.

The North Atlantic Oscillation (NAO)

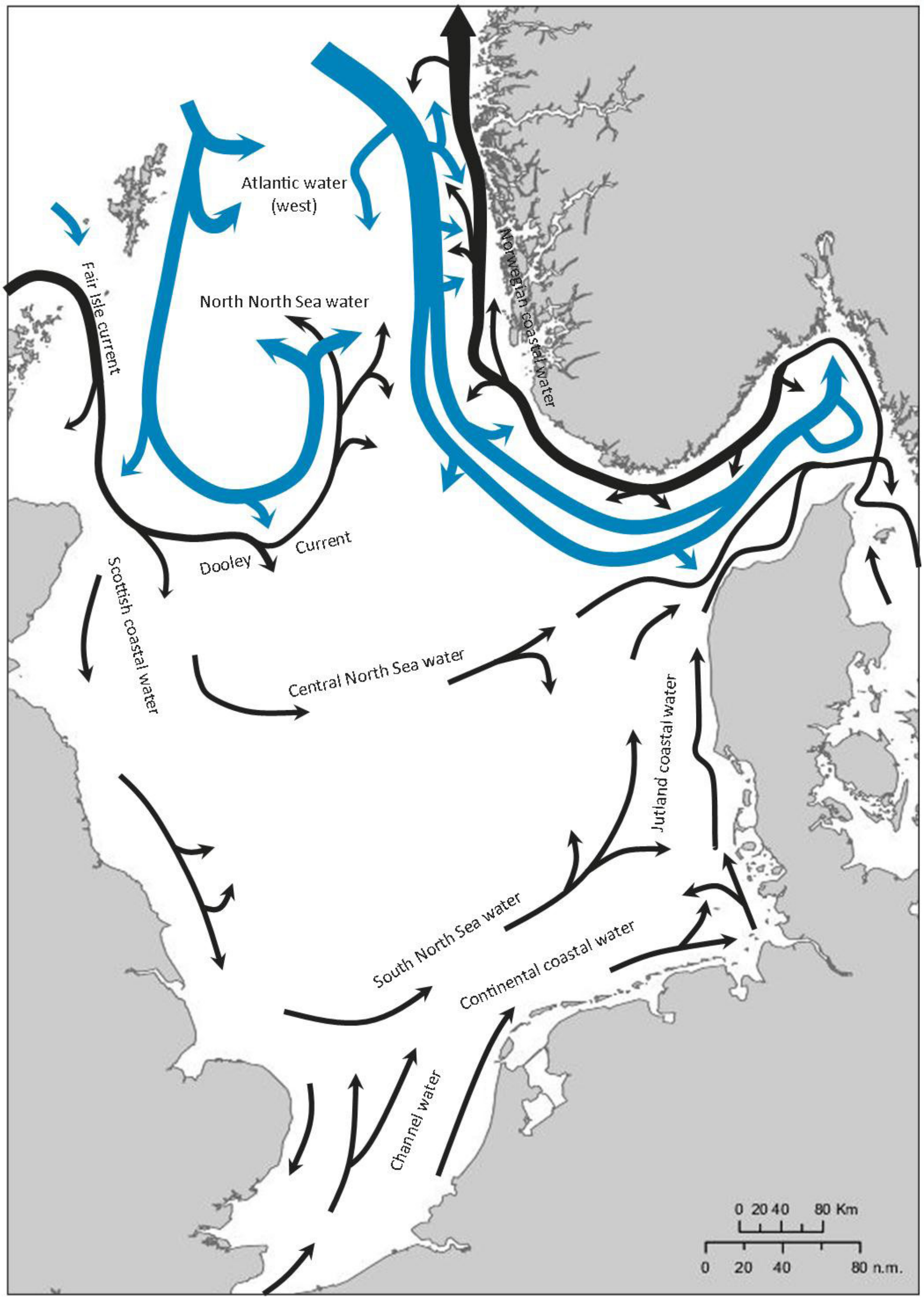
The NAO is a natural climatic phenomenon that occurs in the North Atlantic basin although its effects are far reaching across the northern hemisphere. The NAO is a fluctuation in atmospheric pressure between the Azores high and Icelandic low which controls westerly winds and storm tracks. The NAO has two regimes, positive and negative. The cycle can last decades, although sudden changes in the NAO have been recorded as anomalies. The change in climatic conditions causes physical and biological change across the North Atlantic; an event known as a 'regime shift'. The NAO causes large seasonal and inter-annual variability in the inflow of Atlantic water, both from the north and through the Channel.

The NAO winter index has undergone long term and short term fluctuations. High (positive) NAO index values are associated with strong inflow and transport of Atlantic water through the North Sea. The NAO index shifted to high values from the late 1980s through the first part of the 1990s, followed by a marked drop to a strong negative anomaly in the winter of 1995/96, although it is thought the NAO is still in a positive cycle. These were very marked climatic events that have been associated with changes in plankton composition, fish populations and other biota in the North Sea (see page 18).



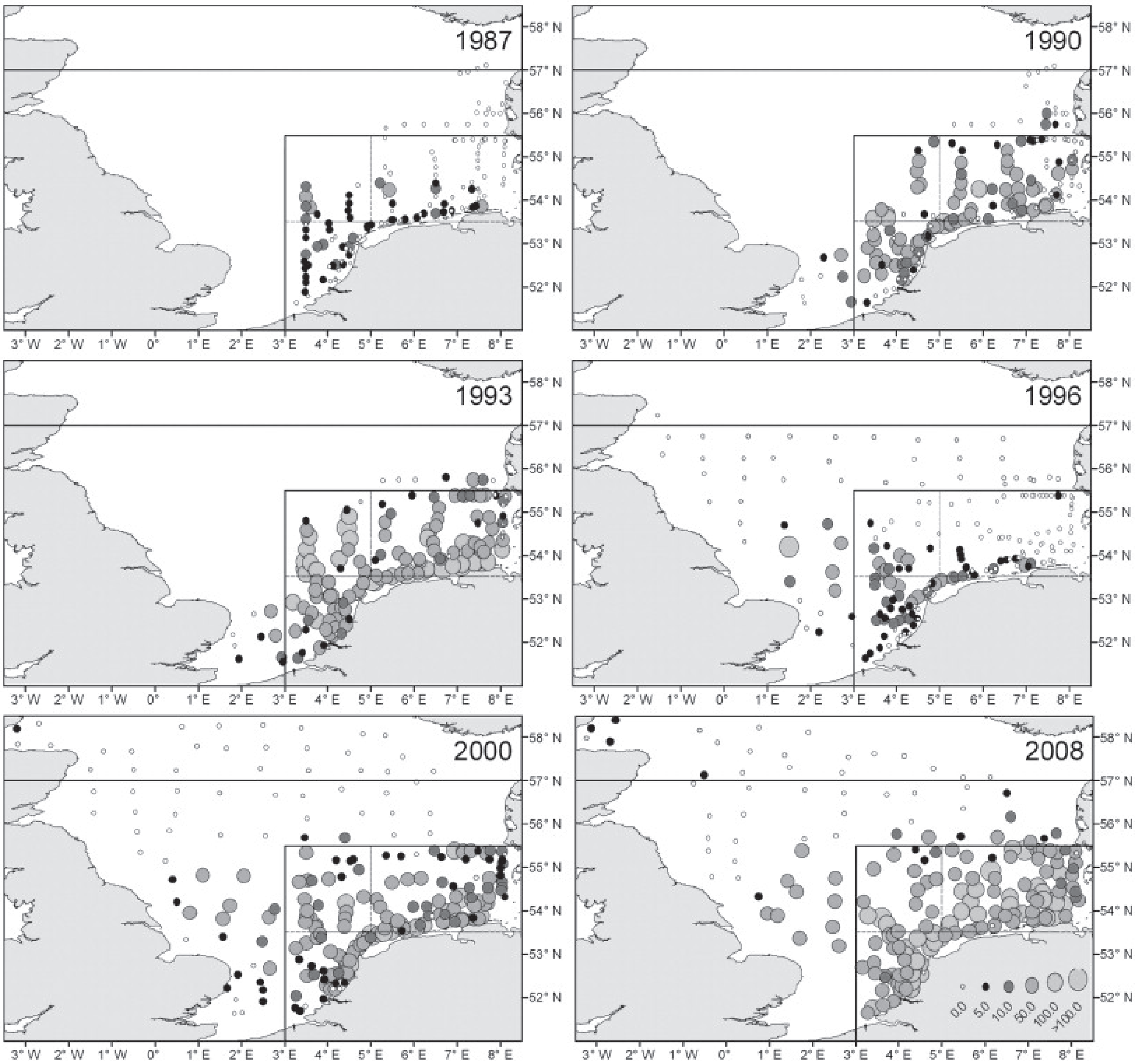


Postive (top) and negative (bottom) NAO index. (Source: Martin Visbeck, Columbia University; http://www.ldeo.columbia.edu/res/pi/NAO/).

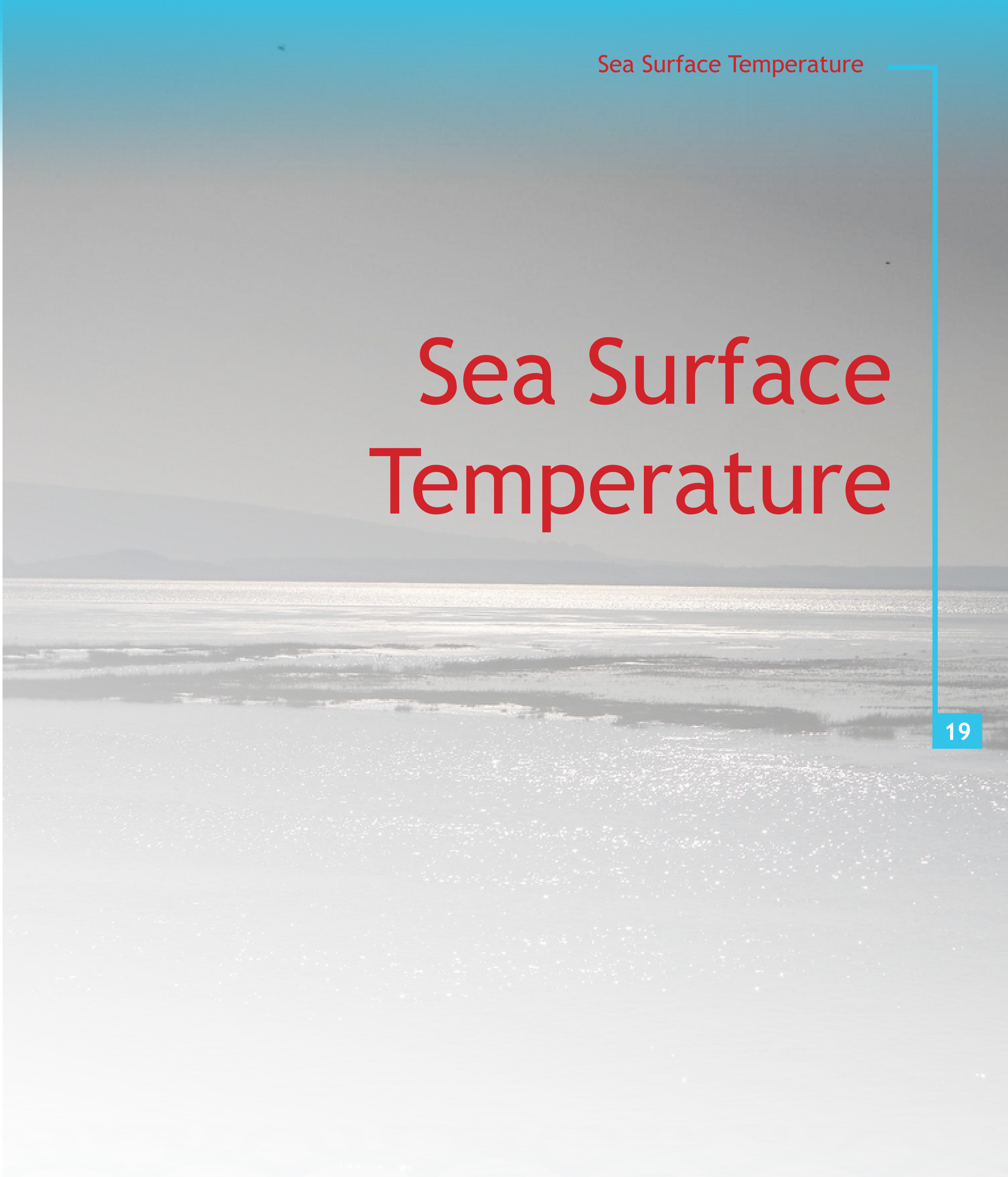


Schematic diagram of circulation in the North Sea. Arrow width represents the magnitude of volume transport. Blue arrows indicate the flow of Atlantic water and black arrows water of other types (Source: Turrell, 1992; OSPAR, 2000). Circulation routes tend to be constant although the amount of water transported through these routes can vary seasonally, annually and decadally.

van Hal *et. al.* (2010) found that two species of fish, solenette (*Buglossidium luteum*) and scaldfish (*Arnoglossus laterna*), have increased their northern range since 1987 (see figure below). In 1988, the NAO switched to a positive regime, causing stronger westerly winds and increases in sea surface temperature. It is likely that these fish species are moving further north in response to warmer conditions as both species retracted during the winter anomaly of 1995/6 due an extremely cold winter. There are concerns that these, and other species, will no longer retreat to their normal range as expected in response to climatic cycles such as the NAO due to climate change (see page 24). It is not yet clear whether solenette and scaldfish have increased their range permanently due to climate change or temporarily whilst conditions are favourable due to a positive NAO regime as, other than the anomaly of 1995/6, there is no conclusive evidence that the NAO cycle has switched from a positive regime since 1988.



The changes in distribution of scaldfish from 1987-2008. Data obtained from the annual Dutch beam-trawl surveys (The sole net survey (SNS) and the Beam-Trawl survey (BTS)). The area below the horizontal line represents the BTS (tridens) area. The SNS and BTS (Isis) areas are represented by the box along the Dutch, German and Danish coast. Dotted lines represent sub areas. (Source: van Hal *et. al.* 2010). Isis and tridens are the names of the ships that collected the BTS data and the areas in which these ships sampled.



Sea Surface Temperature

Sea Surface Temperature

The effects of both surface and bottom water temperatures are usually considered separately as these environments are very different and are affected by different physical factors.

Sea surface temperatures (SST) follow a strong annual cycle (see maps opposite). SST is affected by heating via the sun and heating/cooling through contact with the air, which is accentuated during high wind conditions. It is also influenced by:

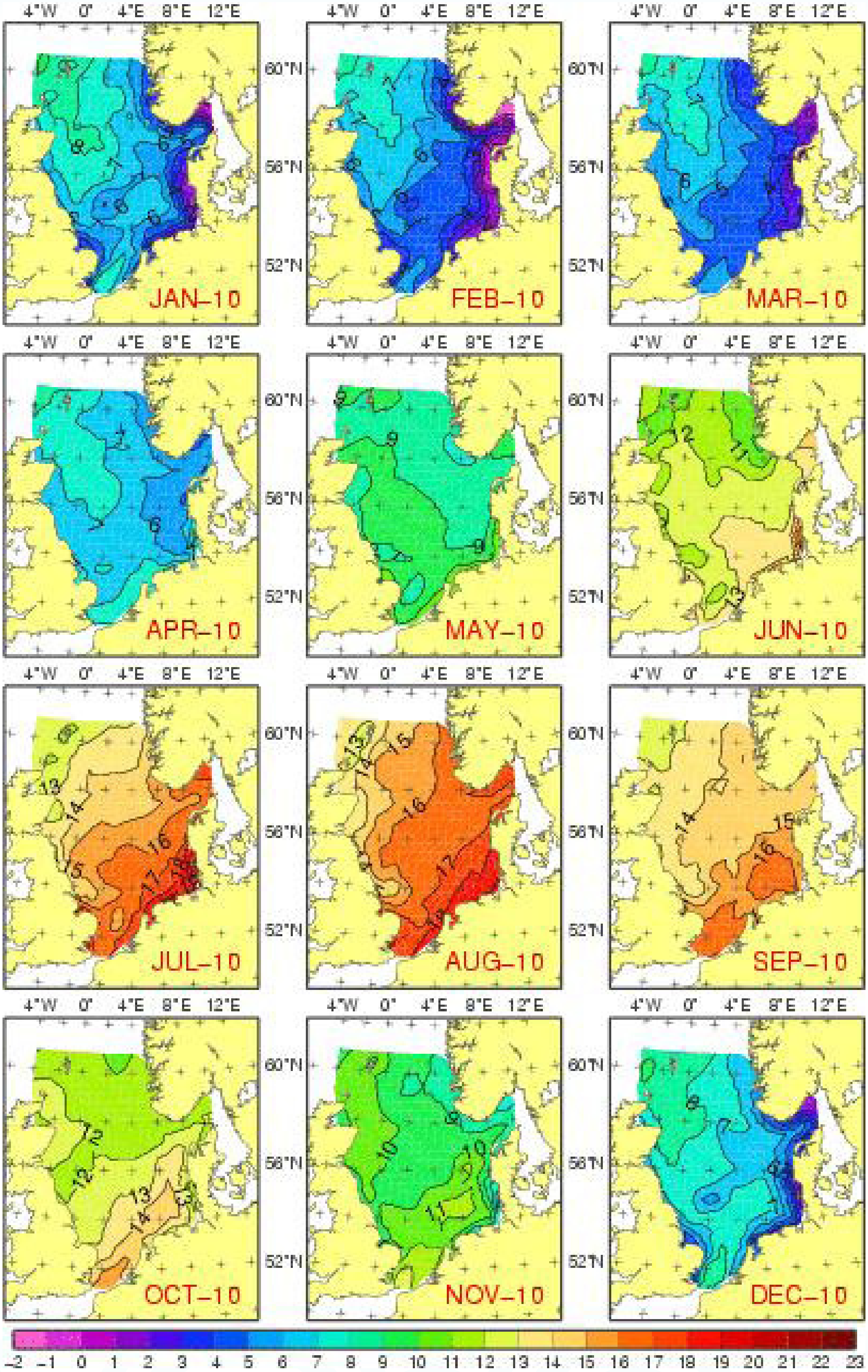
- Mixing of surface water with deepwater caused by wind or tidal currents in shallow areas
- The inflow of freshwaters, in particular cold water following the spring melting of ice and snow
- The temperature of water entering from the Atlantic and Channel.

The temperature and volume of the Atlantic and Channel inflow can vary interannually in response to factors such as large scale atmospheric patterns such as the North Atlantic Oscillation (see page 16).

The temperature of surface waters varies more than the temperature of deeper waters as they are more exposed to parameters such as wind strength and sunlight intensity. This means that there is more 'disturbance' in these areas and the organisms that live in surface waters need to be tolerant of a wider range of temperatures.

Changing temperature has implications for the organisms which live in marine habitats. Most marine organisms are cold blooded and so changes in temperature directly affect biological processes such as their growth, metabolic rate and hence food requirements. Temperature also provides a cue for many organisms triggering events such as migration or breeding. As different species respond differently to changes in temperature, there is the possibility that warming of the seas may lead to biological events becoming out of sync. For example, prey populations may increase earlier in the year in response to temperature triggers, whilst predators maintain long-term breeding patterns. This may prevent larvae or juvenile predators from synchronising with the period of maximum food availability. The temperature of the surface water also affects organisms which require light (such as the plant component of the plankton) and their predators (such as fish larvae and crustaceans in the plankton). Changes in sea surface temperature could also result in warmer water species migrating into the area, disrupting the ecosystem and food chain dynamics (see below).

Blue sharks have been spotted in the North Sea on occasion but as SST temperature warms they may become more frequent visitors. They prefer a temperature range of 7-16°C as they are unable to regulate their internal body temperature. Thus, a warmer North Sea would allow this species to not only expand its range but the longevity of it's stay in the North Sea. The increase in warmer water predators could change the food chain dynamics of the North Sea and effect local fisheries should they feed on commercial fish stocks.



The annual cycle of surface temperatures of marine waters in the North Sea (scale in degrees Celsius). (Source: BSH, 2010).

Climate Change

ICES have stated in a recent climate change update that there is "great confidence within the scientific community that climate change is a reality. Global atmospheric concentrations of the 'greenhouse' gases - carbon dioxide (CO_2), methane and nitrous oxide - have increased as a result of fossil fuel use and changing systems of agriculture".

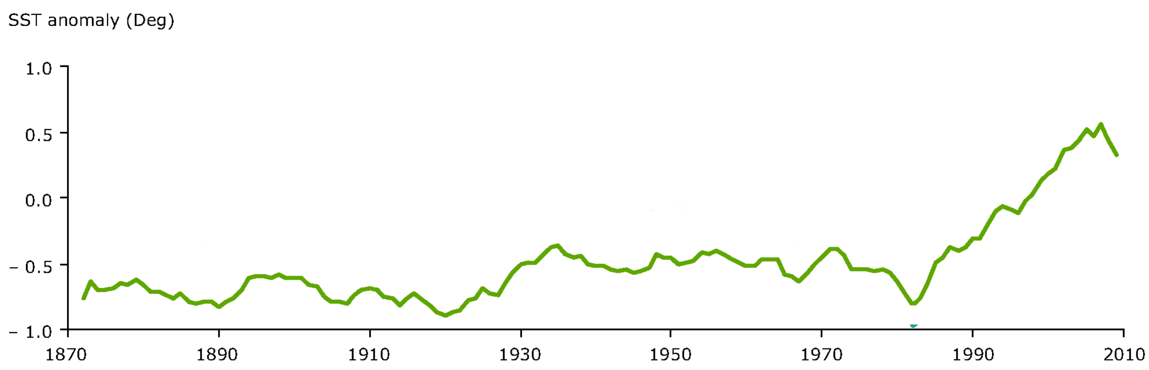
The increase in emissions of greenhouse gases has cause warming of the atmosphere and the oceans, changes in wind patterns and a rise in sea levels. Global temperature will continue to rise parallel to greenhouse gas emissions, causing the melting of ice, resulting in further rises in sea levels.

Ocean acidity is expected to increase in the next few centuries due to the increased input of CO_2 into the sea. Ocean acidification will have major impacts on marine organisms, especially those that use calcium carbonate to make their shells or plates.

Trends in SST in the North Sea

In the last 100 years, global sea temperature has risen, on average, by 0.74°C. Temperature increases are greater at higher, northern latitudes although temperature anomalies can vary regionally and may be patchy.

Over the entire North Sea, both summer and winter sea surface temperatures have been increasing since the 1970s with increased interannual variability in summer temperatures also occurring. On average, North Sea SST has been rising significantly since the 1980's (see below) and has been above its long-term mean (1950-2008) since 1989, with the exception of winter 1996.



Mean temperature anomalies, 1870-2010 in the North Sea. Edited from EEA data (2010).

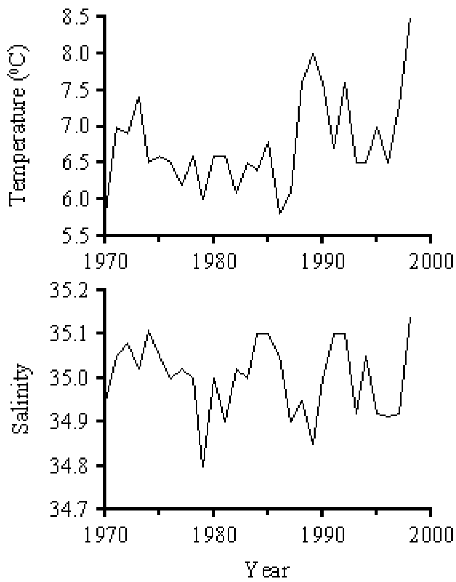
Bottom Water Temperature

Bottom Water Temperature

The temperature of bottom waters (those near or on the sea bed) tends to be more stable than in surface waters and is largely affected by the water bodies entering the North Sea from the Atlantic Ocean. Cold water flows in via the northern North Sea and remains below the surface mixed layer. In the southern North Sea warmer water enters the southern basin via the English Channel. The shallow nature of the southern basin and the English Channel and the strong tidal flows mean that the waters in this region are well mixed and bottom water temperatures follow those of the surface waters.

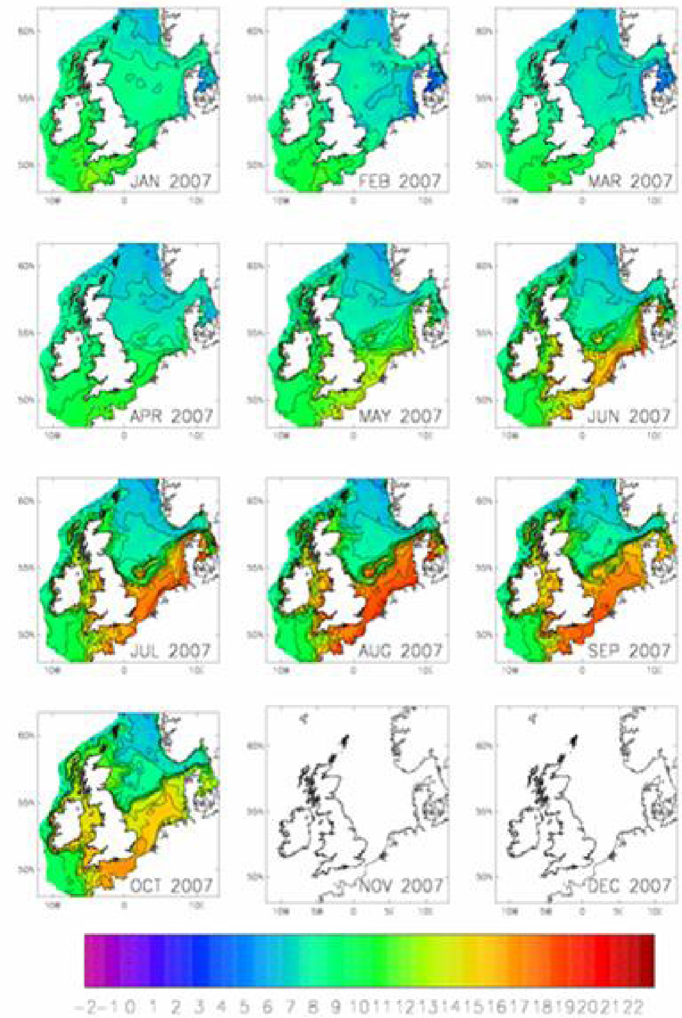
The temperature of the sea bottom shows strong seasonal patterns (see opposite). Long term variability is closely correlated with circulation in the atmosphere and in particular the pattern of wind, which in turn is driven by variation in the distribution of atmospheric pressure.

In the North Sea, the winter bottom temperature has increased by almost 2.5°C over 30 years, with a 2.3°C increase in 1988-1989 alone. On average temperatures have increased by between a quarter and half a degree centigrade per decade although temperature has fluctuated year to year.

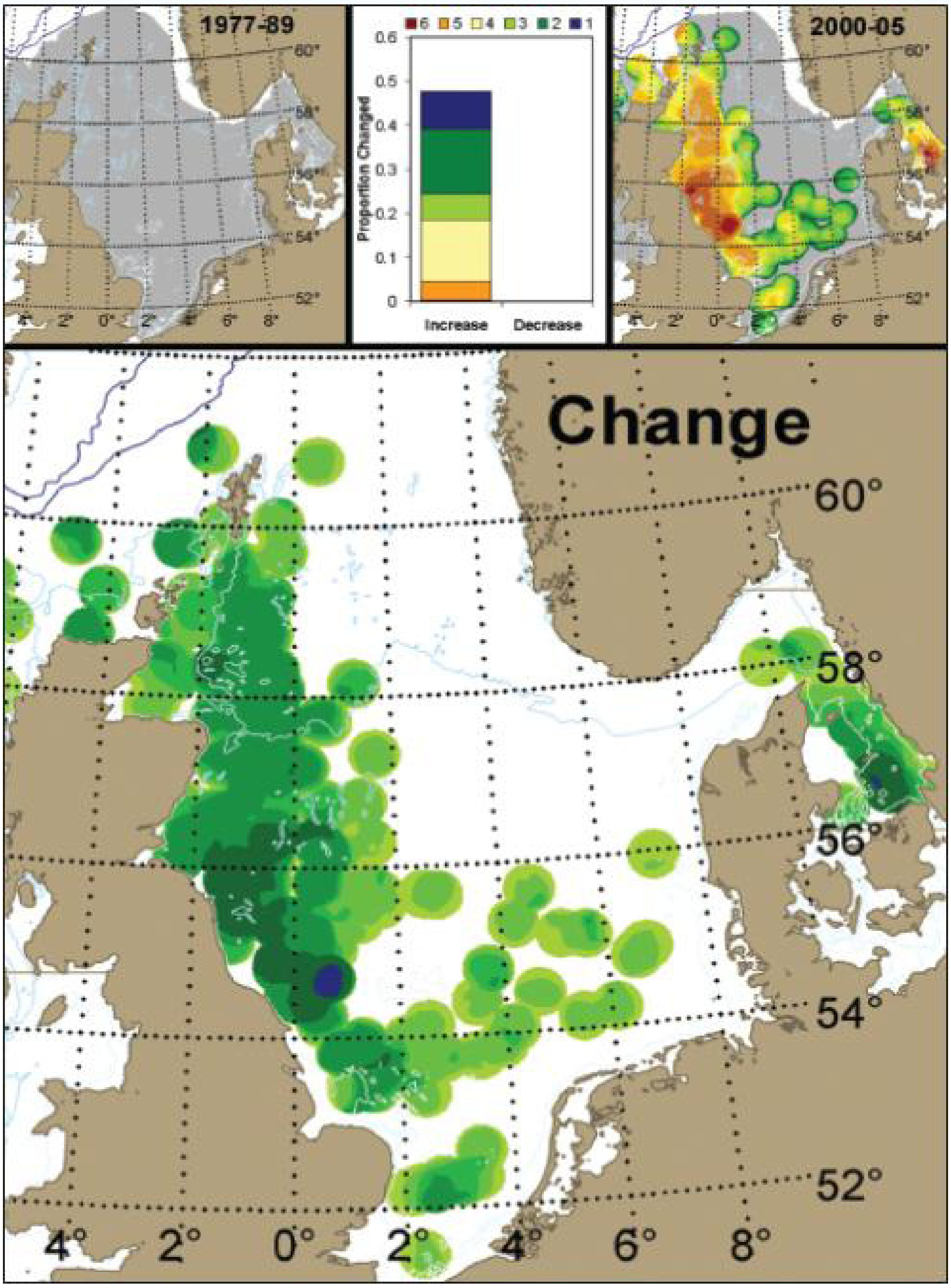


Temperature of near bed water in the northern North Sea (57 30'N 0'E) From ICES International Bottom Trawl Survey (Source: ICES, 1999b).

Climate change is affecting the distribution of fish and other organisms as they move towards their preferred temperature range. If the sea temperature increases, organisms will be forced to migrate north to escape the rising temperatures and those that are slow moving or completely immobile may be at risk of extinction. Analyses indicate that some species are already migrating such as red mullet (see page 26).



Monthly near-bed sea temperatures in 2007 (Source: Skjoldal 2007).



Changes in distribution of red mullet (*Mullus surmuletus*) between 1977-1989 and 2000-2005 in the North Sea. The upper left panel shows distribution in 1977-1989 and the upper right panel shows distribution in 2000-2005. The lower panel shows the change in distribution between the two periods; blue green colours indicate an increase in density, with dark colours indicating the largest change, and yellow and red colours indicate a decrease in density between the two periods with red indicating the largest changes. The upper panel graph shows the proportion of the total survey area where an increase and decrease occurred. (Source: Tasker, 2008).

Salinity

Salinity

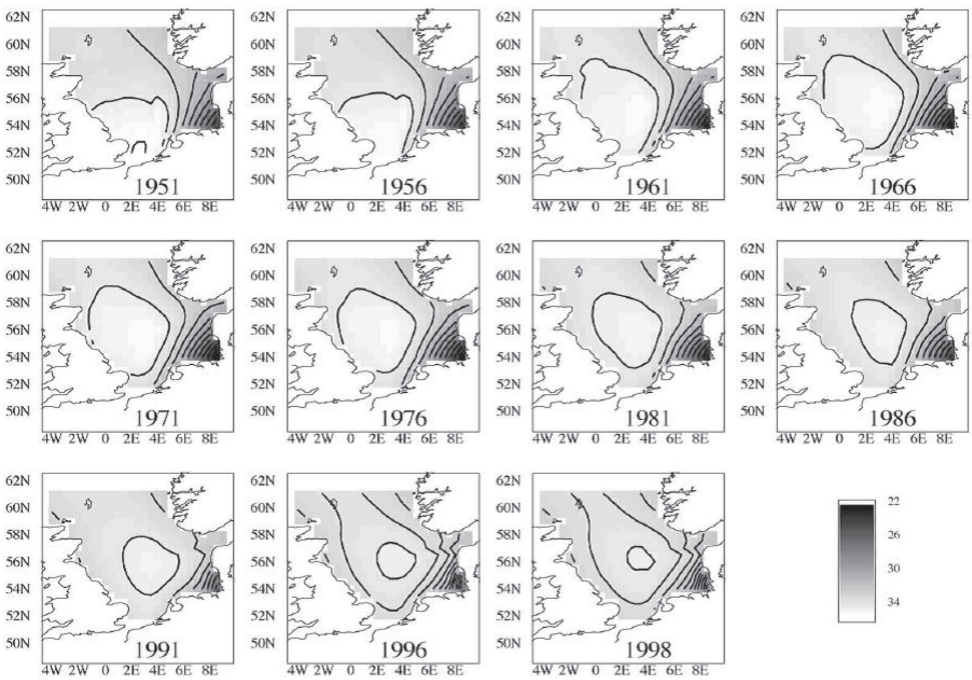
Seawater contains trace amounts of every naturally occurring element and away from coastal inputs the relative amounts of each element are remarkably constant – giving rise to the concept of the consistency of composition of seawater. In coastal seas local inputs alter these balances, the chemistry of inflowing river water being influenced by the local geology for example.

The salinity of the North Sea is influenced by the large volume of freshwater entering from the major rivers draining Europe and this is seen in the lower salinities of the south eastern North Sea. There is seasonal variation in the north east of the region influenced by strong seasonal variation in the volume and salinity of water flowing out of the Baltic due to the spring melt of freshwater ice (diagram left). In coastal areas away from these influences the salinity is typically between 32 and 34.5.

The average concentrations of the main ions in seawater (shown as parts per thousand by weight) are:

Ion:	Concentration (ppt):
Chloride (Cl^-)	18.980
Sulphate (SO_4^{2-})	2.649
Bicarbonate (HCO_3^-)	0.140
Bromide (Br^-)	0.065
Borate ($H_2BO_3^-$)	0.026
Fluoride (F^-)	0.001
Sodium (Na^+)	10.556
Magnesium (Mg^{2+})	1.272
Calcium (Ca^{2+})	0.400
Potassium ($K^{+)}$)	0.380
Strontium (Sr^{2+})	0.013

Salinity is primarily controlled by mixing of waters of different origins and so river run-off is a major factor. In enclosed regions such as large bays evaporation and precipitation (rain!) can add further short term variability.



Salinity in the North Sea at a depth of 10m during February (5 year intervals from 1951 to 1998). (Source: Beare *et. al.*, 2002).

Adaptation to saltwater

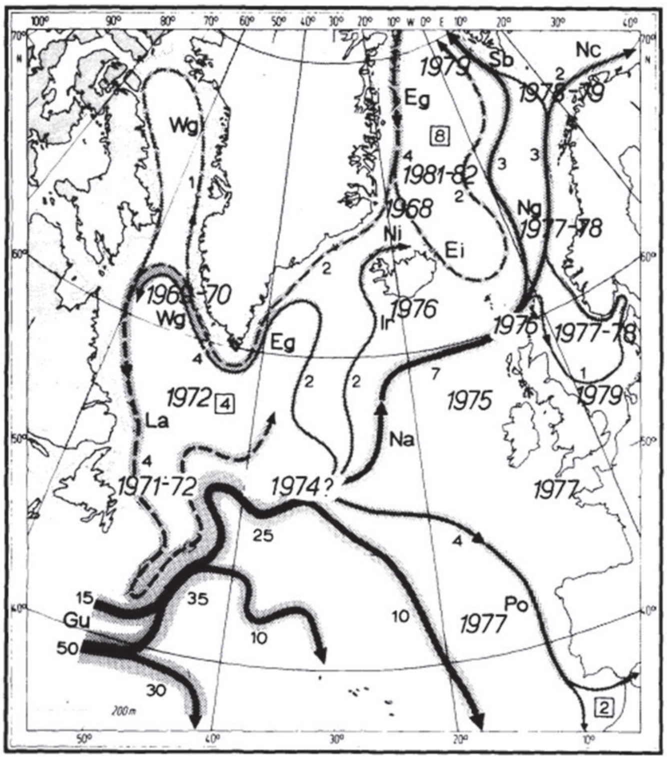
The saline nature of the marine environment means that marine organisms have had to adapt physiologically to survive the loss of water and the inflow of salt via osmosis. Marine organisms have different methods of regulating this balance, namely osmoconformation and osmoregulation.

[© sue scott http://www.marlin.ac.uk/lzspeciesreview.php?speciesid=2657]

Osmoconformers cannot actively maintain their internal salinity, thus their body salt concentrations mirror that of their environment. Invertebrates, like starfish (pictured), are osmoconformers. If they are placed in water more or less concentrated than seawater, their tissues shrink or swell, this damages their cells and they can die. As a result starfish and other osmoconformers are rarely found in estuaries or river mouths where fresh and salt water meet and salinity fluctuates greatly.

Osmoregulators maintain their internal salinity lower than the environment. Elasmobranchs (e.g. sharks and rays) do this by increasing the amount of organic ions, mostly urea, to keep their total ion concentration comparable to saltwater. Fish, however, drink water and actively excrete concentrated salt. To achieve this, they have special cells that concentrate salt and then excrete it against the salinity gradient, which costs energy. Birds and reptiles have salt glands in the head, which secrete salt solutions. For example, Kittiwakes (pictured) excrete salt through their nasal glands.

[© Dr Russell Wynn http://www.marlin.ac.uk/speciesinformation.php?speciesID=4669#]



The Great Salinity Anomaly

Variations in the climate in the North Atlantic greatly influence the formation and fate of waters produced by the melting of the ice sheets of the Arctic each spring. Periodically these factors come together to produce a body of water of greater or less than 'normal' salinity. In 1968 an unusually large amount of remarkably low salinity water was formed in the Labrador Sea and this 'Great Salinity Anomaly' moved around the North Atlantic over the next 14 years. It entered the North Sea with the Atlantic inflow via the Shetland Gap in 1977 and reached the southern bight in 1979.

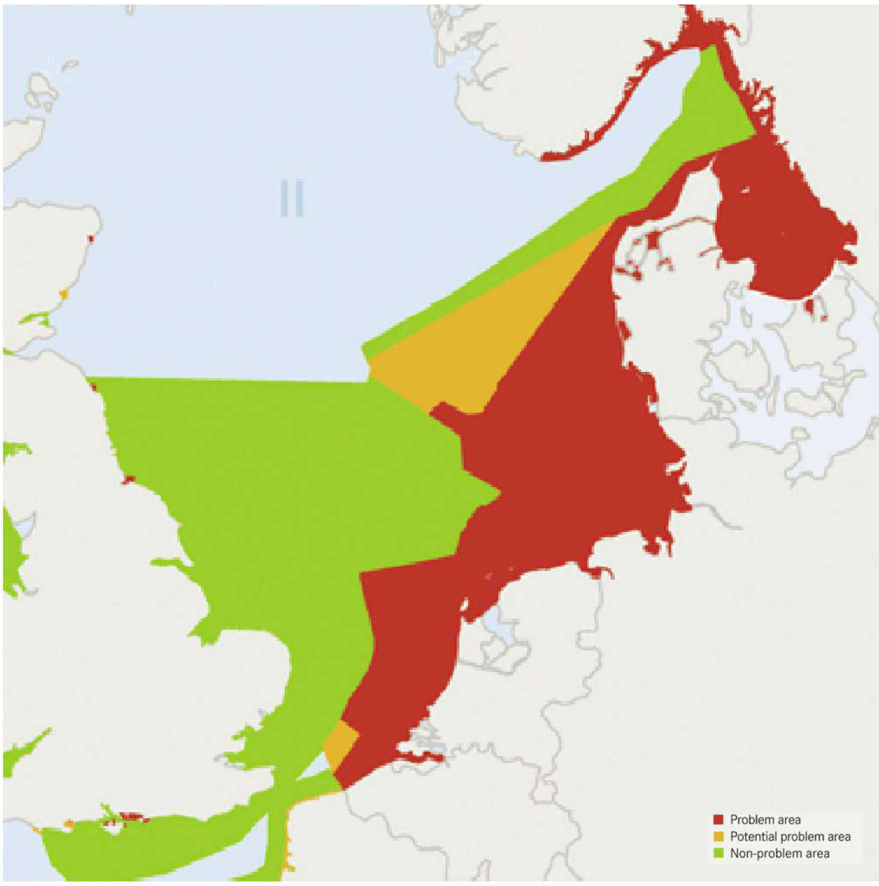
Nutrients

Nutrients

Marine plants need nutrients just like garden plants and crops do. The principle nutrients required are nitrogen (usually in the form of nitrate) and phosphorous (in the form of phosphate). One group of microscopic plants, the diatoms, also require silicon.

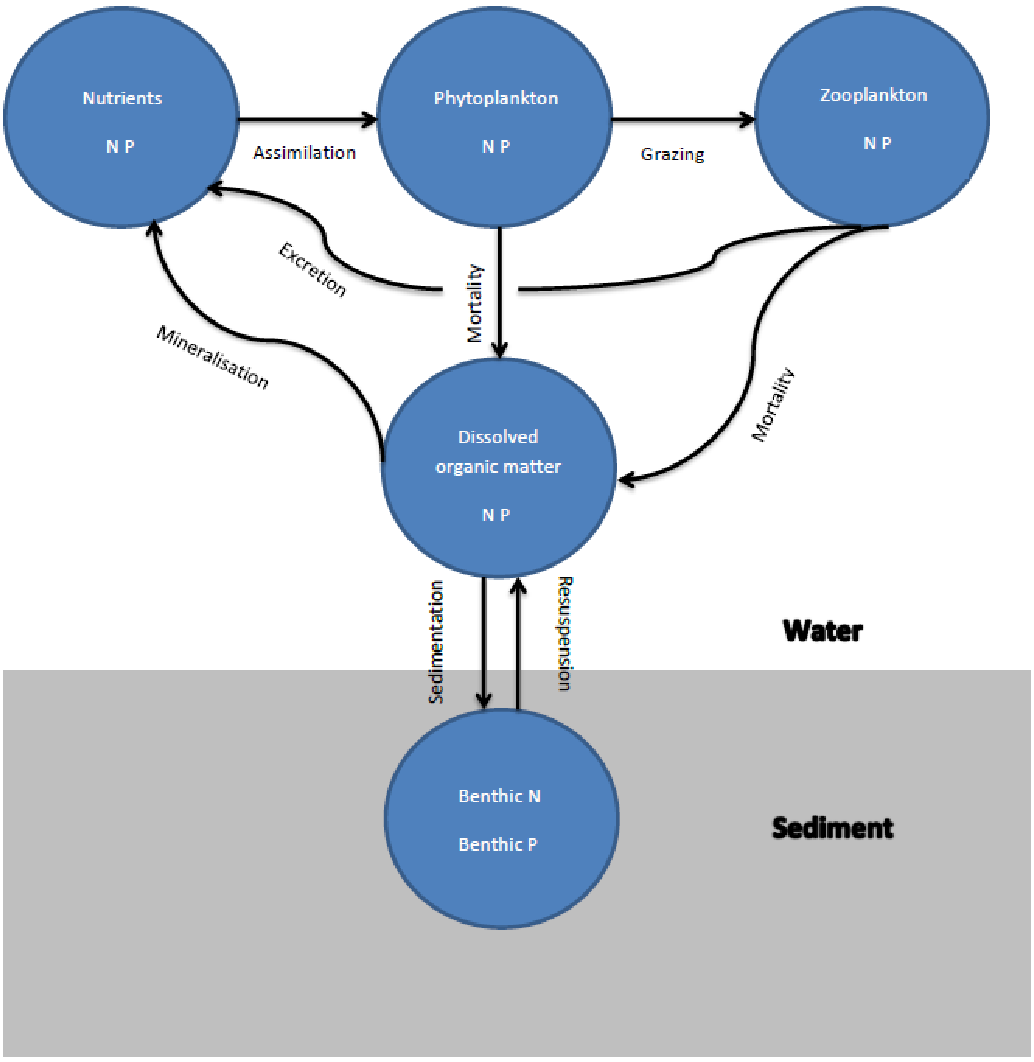
Marine plants need 16 times more nitrogen than phosphorous and in most marine areas nitrate is the nutrient in shortest supply. Iron may also be limiting in some oceanic areas. By late spring, the diatoms can exhaust the natural silicon supply, preventing their further growth and allowing other phytoplankton species to bloom. Some phytoplankton blooms can be harmful to both the environment and to humans because some algal species can release harmful toxins, while others species simply explode in numbers as a result of high nutrient supply. Algal blooms can occur as a result of excessive nutrient input, a phenomenon known as eutrophication. The resulting blooms can then exhaust the oxygen supply within the area, causing localised mortality of fish and invertebrate species (see page 54 for more details).

The eastern North Sea is not considered a problem area in terms of eutrophication. The western and southern North Sea are considered to be areas that are already experiencing eutrophic conditions or are at high risk of eutrophication (see diagram below).



The eutrophication status of the North Sea between 2001-2005. Problem areas have larger nutrient input as a result of human activity. The input of nutrients such as nitrogen and phosphorus can lead to the development of harmful algal blooms (Source: OSPAR, 2010).

Nutrients are transferred from the water to the sediments when plants and animals die and decomposers break down this organic material and release nutrients back into the water column (see below). Nutrients may also be resuspended into the water column due to impacts on the sedbed, for example increased shear stress by storm events or contact from fishing gears.

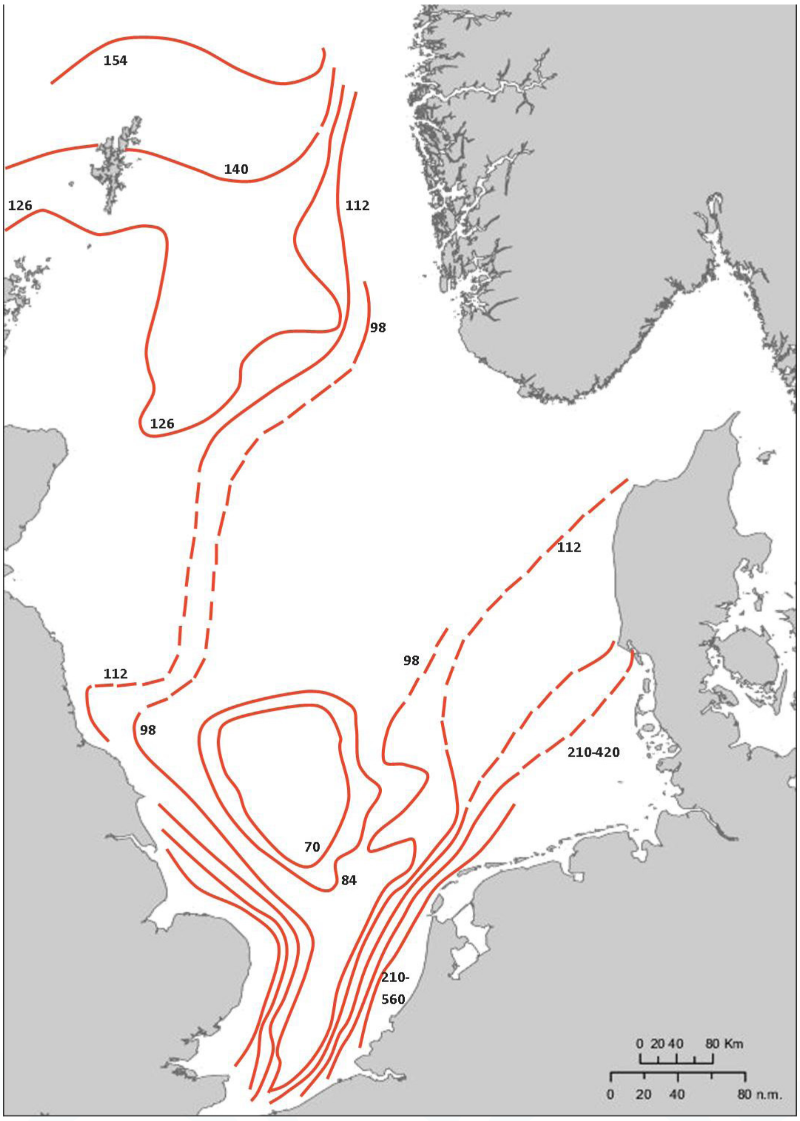


Schematic of the cycle of nutrients in marine pelagic and benthic ecosystems. N represents Nitrate and P represents Phosphate.

Nutrients enter the North Sea with the inflowing Atlantic waters, from rivers, by discharges of nutrient rich effluents from industrial processes, and with human waste water (sewage).

The North Atlantic is a major source of nutrients for the North Sea, however the highest concentrations of nutrients enter the sea via rivers. Nutrient concentrations in river water are often 50 times higher than Atlantic water, so high concentrations of nutrients from human activities are mainly found in coastal waters and semi-enclosed estuaries, bays or fjords with limited water exchange (see diagram below)

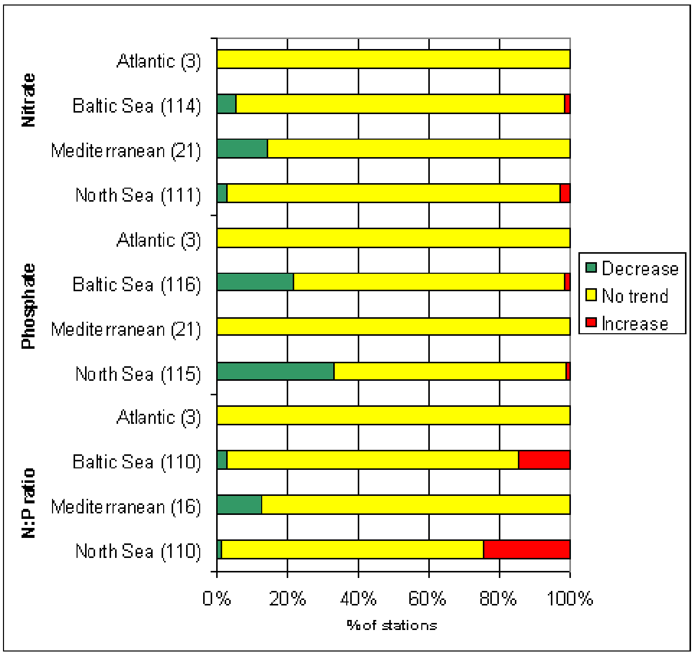
Given the importance of river inflows, variations in nutrient inputs occur from year to year and closely reflect patterns of river runoff, with higher inputs in wet years. The inputs are proportional to the amount of water discharged by the rivers. For example, 75 % of the nitrogen in the coastal zone of the North Sea flows enters via the river runoff of the Rhine and Elbe which are the two largest rivers.



Concentration of Nitrate (mg/l) in the North Sea surface water in winter (Source: Brockmann *et. al.*, 1988)

Around 30% of the nitrogen entering the North Sea comes from the atmosphere. Of this 81 per cent is wet deposition, i.e. it is washed out by rain. Around 38% of this nitrogen derives from agriculture and the remaining 72 per cent from combustion sources such as during the burning of fossil fuels (Hertel *et. al.*, 2002).

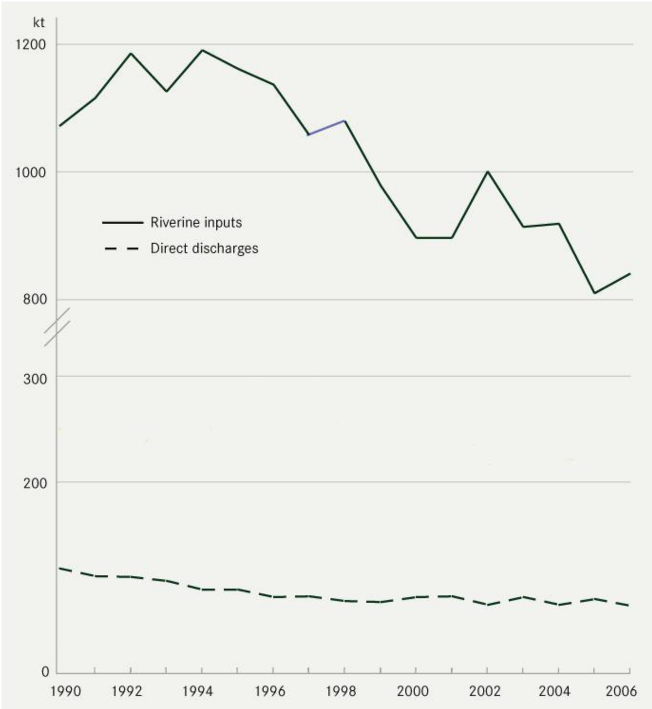
Nutrient levels in the North Sea and Baltic have increased as a result of human activity; both nitrate and phosphate are elevated but nitrate has increased proportionally more. As nitrate is generally the limiting plant nutrient in marine waters this implies a potential for change in the ecology of the system at the base of the food chain, with the power to propagate across the ecosystem. At present the scale of these changes is limited due to control measures introduced in the 1990s but in some areas, such as enclosed bays, the effects can be seen.



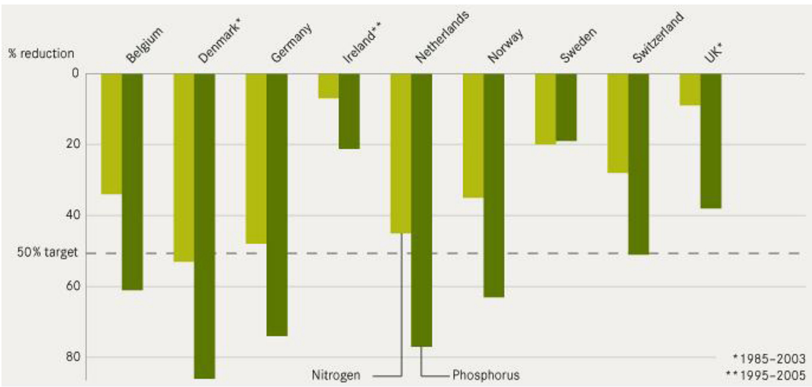
Trends in winter nitrate and phosphate concentrations, and N/P ratio in coastal waters of the North Atlantic, the Baltic Sea, the North Sea and the Mediterranean (Source: EEA, 2002).

A few examples of the many different types of phytoplankton found within the North Sea. This image was taken using an electron microscope which can magnify objects up to 2 million times.

The level of nitrate flowing into the seas from European rivers has reduced between 1990-2006 although only one country bordering the North Sea has yet reached its target of reducing Nitrogen outputs by 50% (see below). The introduction of control measures has caused phosphate inputs to decline, with five countries either reaching their 50% reduction target or exceeding it (Source: OSPAR, 2010).



Riverine inputs (solid line) and direct discharges (dashed line) of Nitrogen into the North Sea from 1990-2006. (Source: OSPAR, 2010).



Reductions in nitrogen and phosphorous inputs from human activities achieved in 2005 in comparison to 1985 (Source: OSPAR, 2010).

Sea Floor Habitats

Sea Floor Habitats

Most of the North Sea seabed is made up of sediment of varying sizes. Gravel, shingle, sand and mud are descriptive terms that describe sediments composed of increasingly smaller particles. In many places the sediments are moved by waves and currents and this tends to result in sediments that are fairly uniform in size. In some historic locations sediment of a different size is being deposited on top of the resident sediment; these are referred to as poorly sorted sediments. An example would be a gravel bank deposited by the retreating glaciers at the end of the last ice age that is now having modern mud deposited on it which results in 'muddy-gravel'.

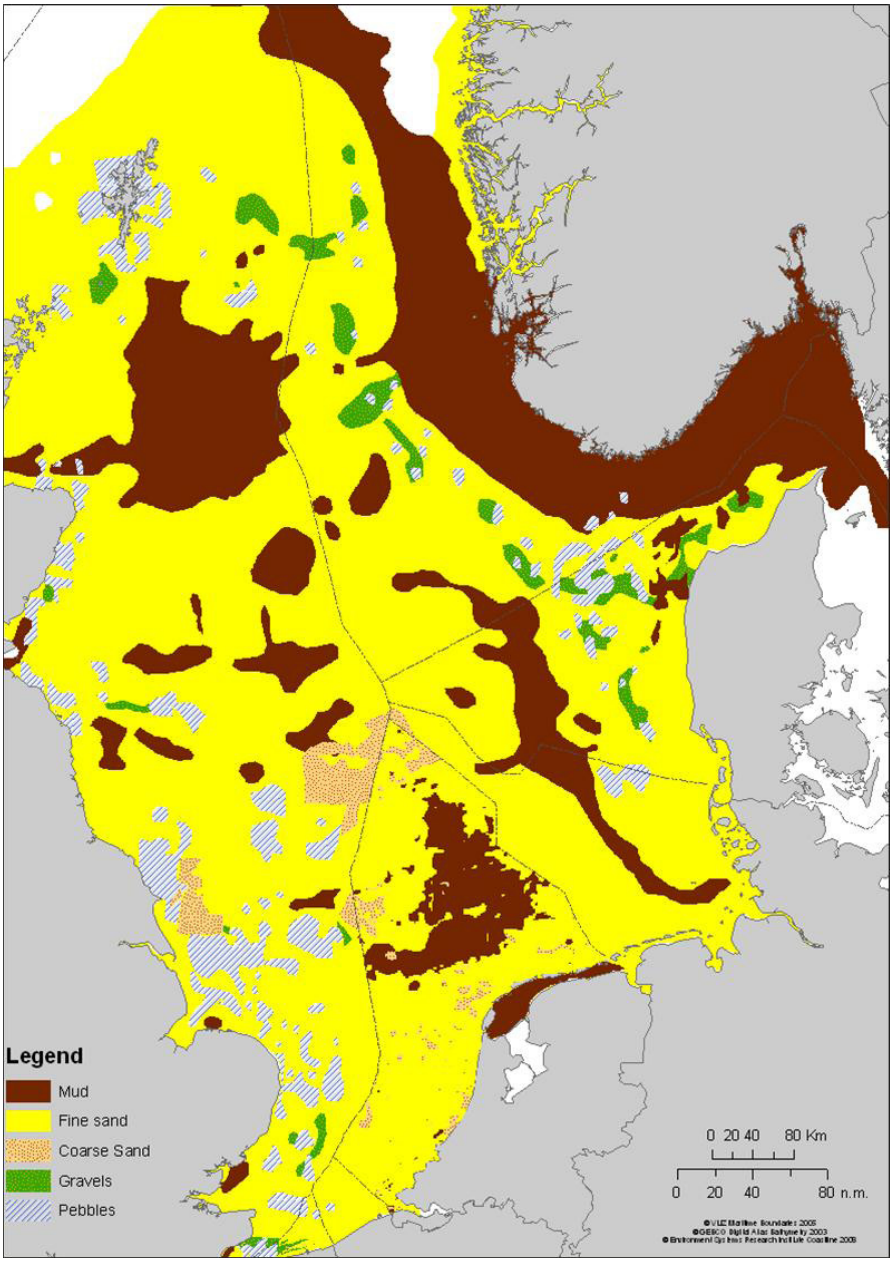
The marginal areas around the North Sea are eroding hard rock which often extends below the low tide level to form underwater rocky reefs and cliffs. These are most common in the northern North Sea where offshore islands and rocky foreshores are common, in contrast to the sandy beaches in the south-eastern North Sea.

Helgoland, Germany is an example of a rocky shore.

Knokke beach, Belgium is a good example of a sandy beach on the South East coast of the North Sea.

In the southern North Sea rocky coasts are limited in extent and Helgoland is the only rocky island. In some places boulders and the shells or tubes of marine organisms also form undersea reefs such as sabellaria reefs.

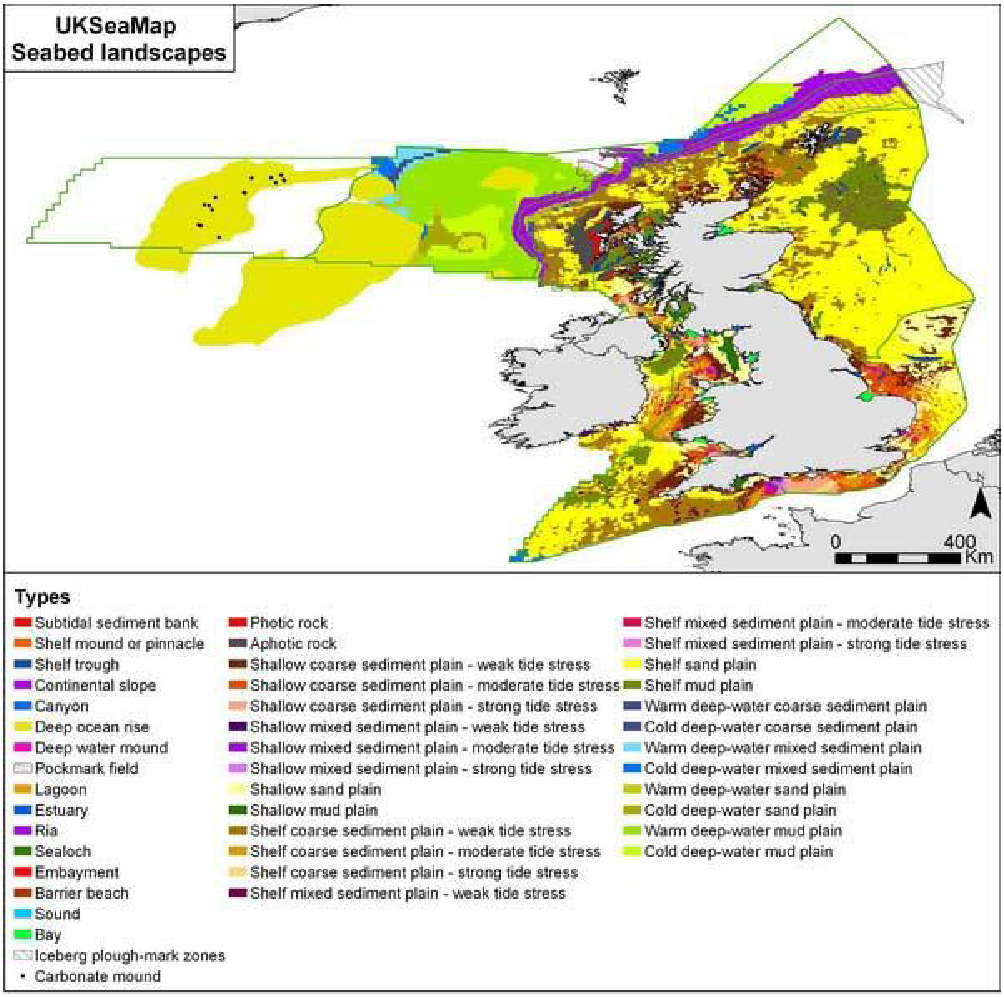
[© JNCC, picture taken by Roger Covey]



Sediment map of English Channel and North Sea, modified by Carpentier *et. al.* (2008). Detailed coverage of the Dutch Maritime area added by MARGIS project (Larsonneur *et. al.*, 1982; Augris *et. al.*, 1995; Duphorn *et. al.* 1970; Figge, 1981; British Geological Survey, (BGS) 1977-1993; Danish Geological Survey (GEUS), 1992).

There have been several initiatives to map the marine landscapes and habitats of the North Sea. Landscape classifications are based on physical information such as the sediment size, the strength of water currents and depth, whilst habitat classifications include information on both the physical and biological characteristics of an area.

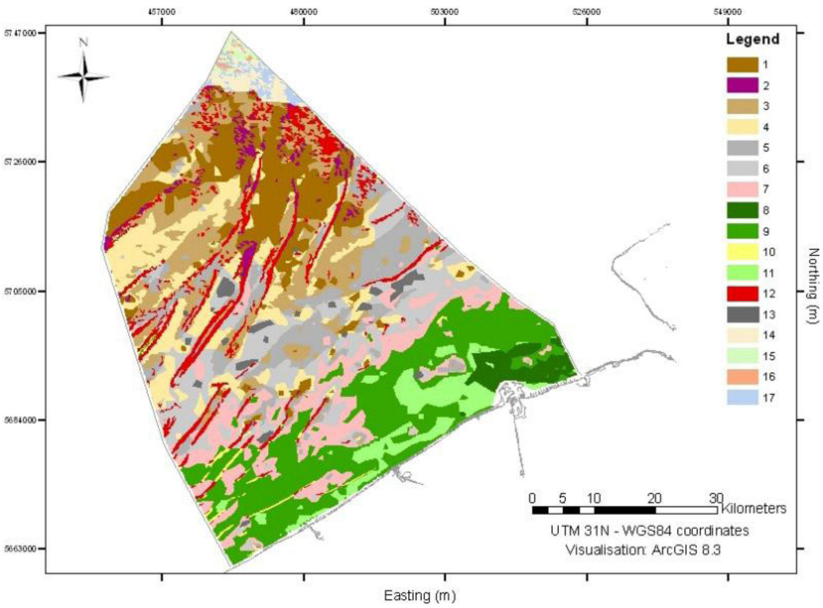
Marine landscape maps are currently the most detailed maps at large scales. Whilst several North Sea countries have produced marine landscape maps for some or all of their national waters (e.g. UK (below), The Netherlands, France and Belgium) there is not yet complete coverage across the North Sea.



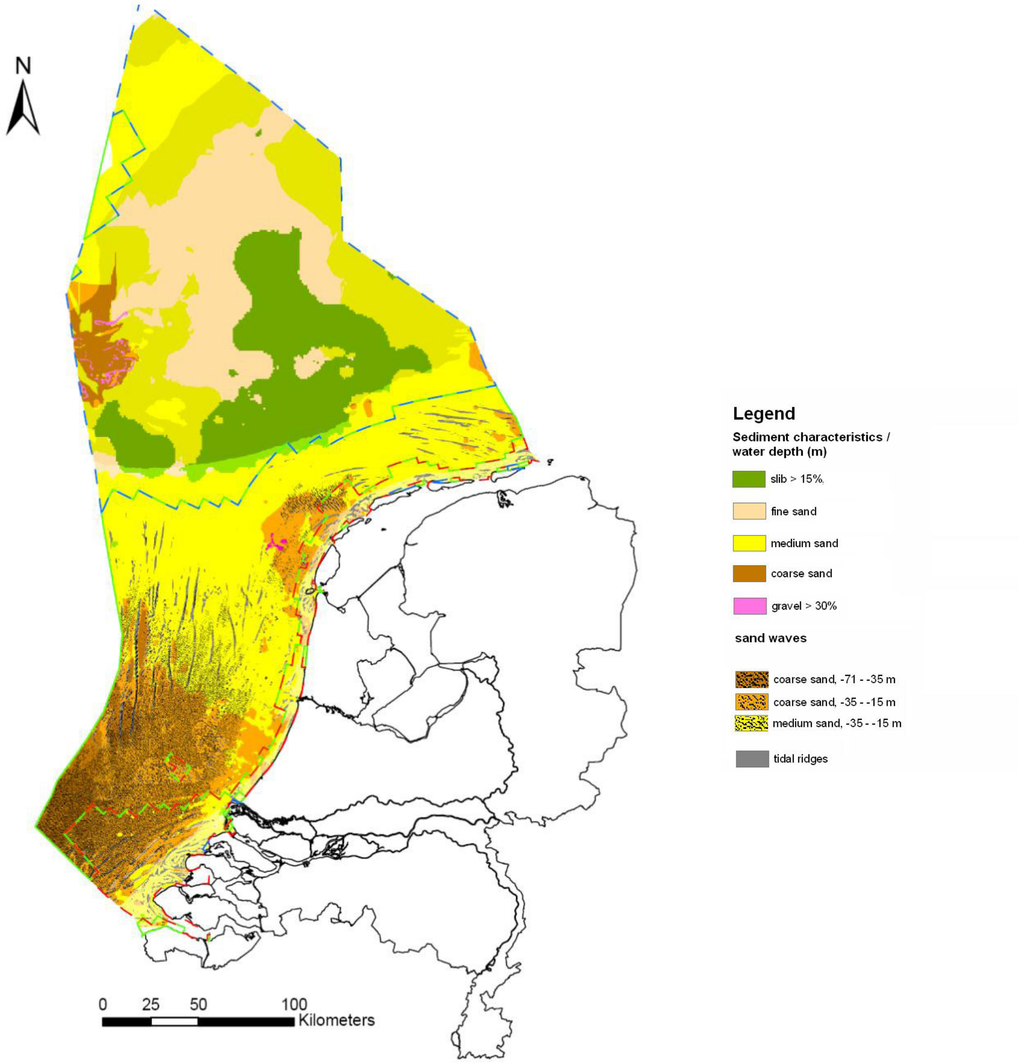
The distribution of marine landscapes around the UK derived from the combination of sediment and bathymetry maps with information on tidal stress and a limited amount of ground truthing (Source: Conner *et. al.*, 2006).

As a result of the strong association between the physical nature of the sea floor environment and the organisms that live there, seabed habitat mapping exercises are also being used to predict the distribution of ecological assemblages of species. While it is possible to fly an aeroplane or a satellite over the Earth and accurately map the main terrestrial habitats this is not the case for the sea floor. The nearest equivalent is to use echo sounders to acoustically map the seafloor.

The basic premise is that different types of sediment or rock covered in seaweed will send back different strengths of echo. This approach has had some success but acoustic mapping of the seafloor is very expensive (in ship time) and challenges remain in matching sound signatures to habitat types and ensuring sufficiently detailed data to identify habitats that naturally occur as patches e.g. deep water corals, rocky reefs.



The distribution of marine landscapes in the Belgium part of the North Sea derived from acoustic surveys and classifying different types of seabed (1-17) primarily on the basis of their acoustic properties. The legend refers to a code describing different landscape types. Number one refers to areas with coarse grain sand and number seventeen refers to steep slopes with sand dunes (Source: Schelfaut, 2005).



Marine landscapes of the Dutch sector of the North Sea showing the seafloor characterized by combinations of sediment and depth data with limited additional information on the distribution of mobile features and the tidal current stress (see above). The landscapes are therefore less integrated than those predicted in the UK map but based on the same information. The legend provided is a concise version to represent the types of landscapes present. For the full legend please see Doornenbal *et. al.*, 2007.

Organisms in/ on the sea floor (benthos)

Organisms in/on the sea floor (benthos)

The benthos is a term used for the sea floor environment. The majority of the North Sea floor is covered by sediments of various sizes. These often support diverse and highly productive biological assemblages. The main organisms found within the benthos are various species of marine bristle worms (polychaetes), burrowing clams (bivalve molluscs), sand shrimps (amphipods), sea urchins and brittlestars. Species of mobile scavengers, such as crabs, starfish and fish also range across the various habitats.

A single square metre of North Sea muddy seafloor may contain over 6000 individuals from over 300 species making these systems comparable to tropical forests in terms of biodiversity and temperate pastures in terms of productivity.

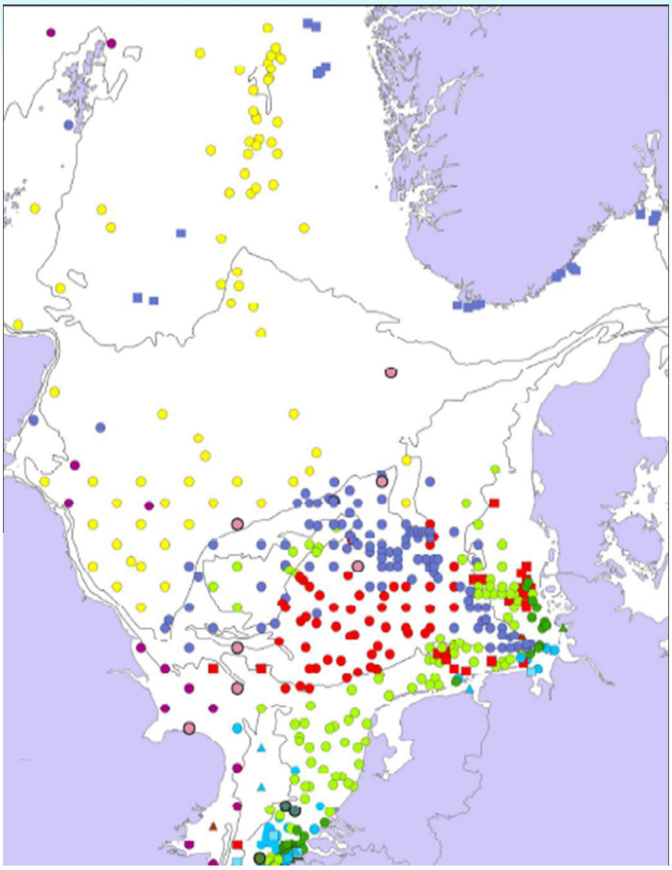
[© Fiona Crouch. http://www.marlin.ac.uk/speciesfullreview.php?speciesID=3470]

Nereis diversicolor is a polychaete worm found in sandy benthic environments. It's movements within the sediment oxygenates the sediment, making it habitable for other species.

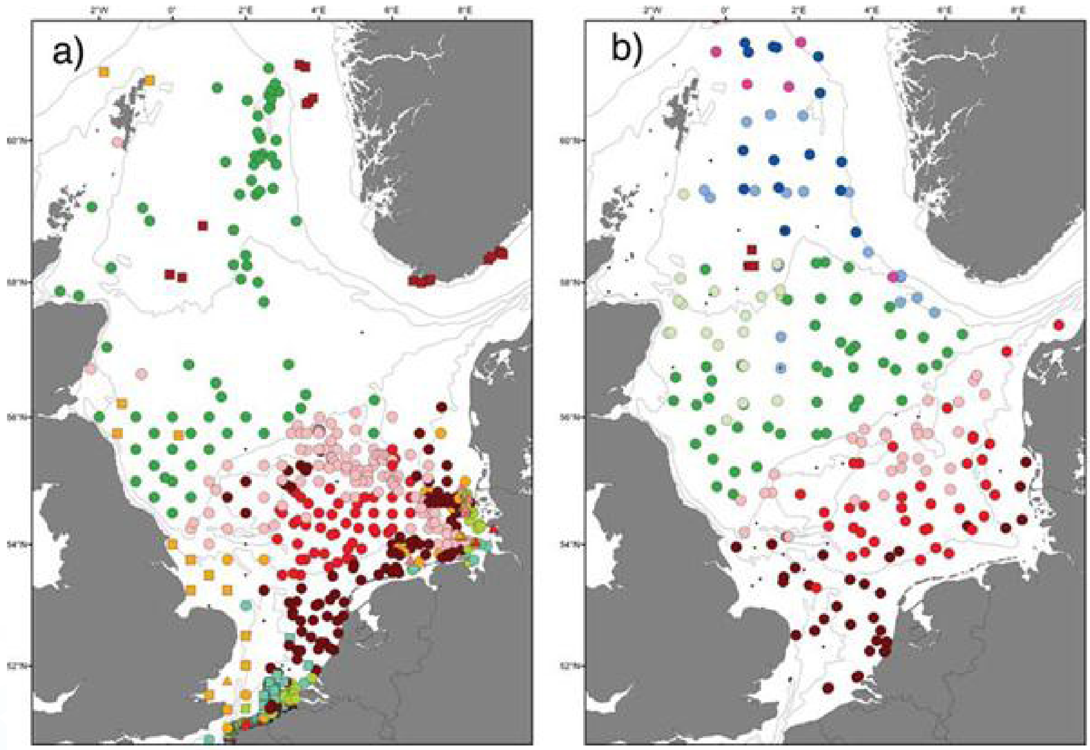
Bottom dwelling organisms are generally sedentary, at least as adults, and can be categorised into ecological communities. Petersen (1914) carried out a wide ranging survey of the shallower parts of the North Sea using a quantitative grab sampling technique in the early 1900s, and classified the benthos into seven distinct 'communities'. He implied no biological linkages between the species in these 'communities', merely that they tended to occur together in space.

More recent studies in the North Sea have confirmed the link between particular assemblages of species and the distribution of sediment types and other physical factors, principally temperature, depth and bottom current stress (Duineveld *et. al.*, 1991, Kunitzer *et. al.*, 1992) and these distributions have remained broadly similar over a period of 14 years (Rees, 2007). The most recent surveys using advanced statistical techniques identify 20 different ecological assemblages (map opposite, top). Another survey found a total of 22 assemblages in the North Sea;13 infaunal and 9 epifaunal (map opposite, bottom). These analyses highlight the importance of physical factors in controlling seafloor ecology and have provided the impetus to develop predictions of the distribution of seabed areas that share similar environmental conditions, referred to as marine landscapes (see the chapter 'Sea Floor habitats' for more information). These two studies also highlight the complexity of an ecosystem the need for long term studies to fully understand an ecosystem.

Biological interactions can be as important as physical factors in the control of seafloor ecology. The presence of certain species can determine the presence or absence of others. For example, tube building worms that live within the sediment stabilise the sediment making it habitable for other species. When mobile organisms, such as some annelid worms, move around they mix the sediment and solutes which oxygenates the sediment; a process called bioturbation. Without bioturbation many other species within the seabed would not survive or would have to occupy the very top layer of sediment where predation risk is high.



Distribution of the 20 ecological assemblages of sea floor organisms identified in the North Sea in 2000. Each assemblage represents a different mix of species of sea floor inhabiting animals and sites with the same symbol (i.e. belonging to the same cluster) contain similar types of species, in similar abundances (Source: Rees *et. al.*, 2007).



Distribution of (a) Infauna and (b) epifauna. Each assemblage has a different mix of species in or on the sea floor and sites with the same symbol/colour contain similar types of species in similar abundances (Source: Reiss *et. al.,* 2009).

Keystone Species

Species that have a key role in the stability of an ecosystem are known as keystone species or ecosystem engineers. Keystone species have a critical role in the maintenance of an ecosystem and the removal of these species can be catastrophic to the local ecosystem. Ecosystem engineers are organisms that either create or modify an ecosystem.

[© Mark Thomas http://www.marlin.ac.uk/lzspeciesreview.php?speciesid=2480]

Sandeels are considered a keystone species in the North Sea as many top predators including marine mammals and seabirds are dependent on them as a food source. Sandeels are commercially fished in the North Sea and overexploitation could lead to the collapse of many marine food webs.

Sea kelp are ecosystem engineers as their presence provides the building blocks of kelp forests which can provide habitats for many species. The kelp forest pictured is situated off the North East coast of England.

[http://www.northseawildlife.org.uk/north-sea-marine-wildlife/north-east/]

Marine "Forests"

In shallow water, where light penetrates, hard substrates such as cliffs and reefs are colonised by seaweeds, especially the large brown seaweeds of the kelp family. These seaweeds float up, creating an underwater forest with shade adapted red algae growing as an understory and harbouring an array of mobile animals.

Seaweed 'forests' are similar to those on land with the larger plants forming the 'canopy' and lots of smaller 'shrubs' beneath. These areas support a high diversity and density of animals due to the physical complexity of the habitat they create.

In deeper water the kelps are unable to grow; shade adapted red algae persist but in deeper water still they too become light limited. Beyond this point, known as the circa-littoral zone, animals dominate and the reefs are carpeted in a living carpe of animals including sponges, hydroids (left), bryozoans (horny corals) and clams. These animals are all 'filter-feeders' a collective term for organisms that feed by filtering microscopic food particles from the water column.

Benthic Life

Boulders and gravels may support a community including attached algae and/or filter-feeding animals. Any finer particles deposited in between the large ones will also be colonised by worms and other burrowing forms. The fauna of such habitats is often ephemeral, comprising fast growing and rapidly breeding species. This is likely an adaptation to the movement and deposition of fine sediment onto the large particles caused by disturbances such as storms, which can cause widespread mortality via dislodgement and smothering.

Sediment can vary in size and composition and this can effect what species can colonise an area. Some species prefer only fine sediment while others may only be found in coarse sand. Certain species can survive in many different sediment types. The main species found in sediment are amphipods, bivalves and polychaete worms.

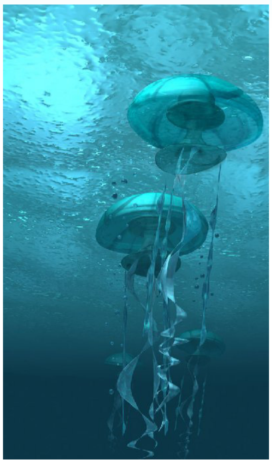
Anemones: These animals colonise rocky areas and some species can be found in rock pools on shores. They are related to jellyfish and capture particles using 'stinging cells' on their tentacles.

Brittlestars: These organisms can attach to many different types of seafloor including among sponges, on stones, gravel and coral reefs. Some species even live within the sediment with their arms protruding out to catch prey.

Burrowing bivalves: These organisms are usually found within the first 2-3 centimetres of sandy sediment. They are suspension feeders and feed by extending their siphon above the sand. Their siphon can grow back should a hungry fish bite it off!

Plankton

Plankton



Plankton is the collective term given to organisms that drift in the sea, too small and too weak to swim against the currents. Most plankton are microscopic bacteria, single celled animals and plants but also include a large number of animals some of which are visible to the naked eye and include jellyfish up to 2 metres long.

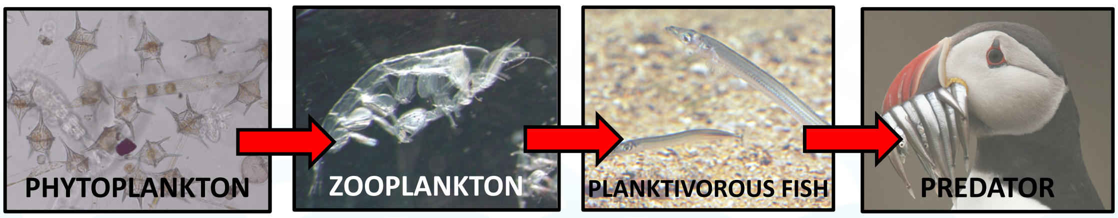
Some plants and animals spend their whole lives as plankton, drifting in the water. Many invertebrate and fish such as lobster and cod have young planktonic larvae that live as adults on the seafloor. Conversely, jellyfish occupy the seafloor as larvae and become plankton when they become adults.

The Continuous Plankton Recorder (CPR) Survey's marine monitoring programme collects data from the North Atlantic and North Sea on the ecology and biogeography of plankton (see diagram opposite). The unique dataset provides a wide range of environmental and climatic indicators and is used by marine scientists and policy makers to address management issues such as harmful algal blooms, pollution, climate change and fisheries.

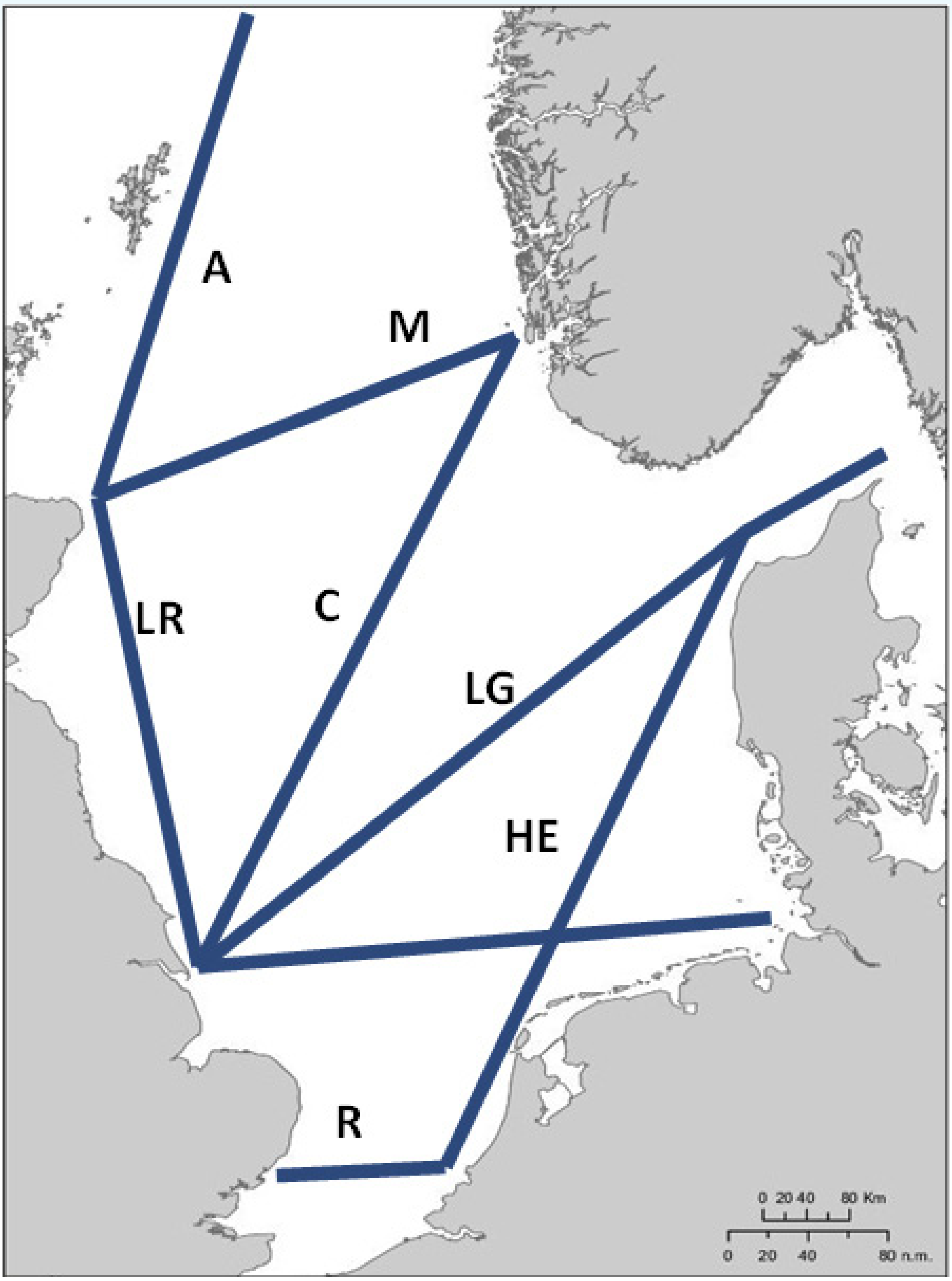
The phytoplankton (plant component of plankton) community has been studied since 1958 and has shown changes in this period. These changes have not been consistent across the North Sea which indicates the importance of smaller scale processes such as local availability of nutrients and predation levels as well as local physical disturbance such as storms.

Storms can cause temporary mixing of a stratified water column (see page 12). During this time plankton can be mixed below a survival threshold in which it is too cold for some zooplankton to survive or there is no light available for phytoplankton. Once the water stratifies again after a storm, plankton still below the threshold will not be able to cross into the upper waters and will most likely die. Phytoplankton abundance has increased in the north-western and eastern North Sea whilst diatoms and dinoflagellates have decreased in these regions and increased in the north-eastern North Sea. (Leterme *et. al.*, 2008).

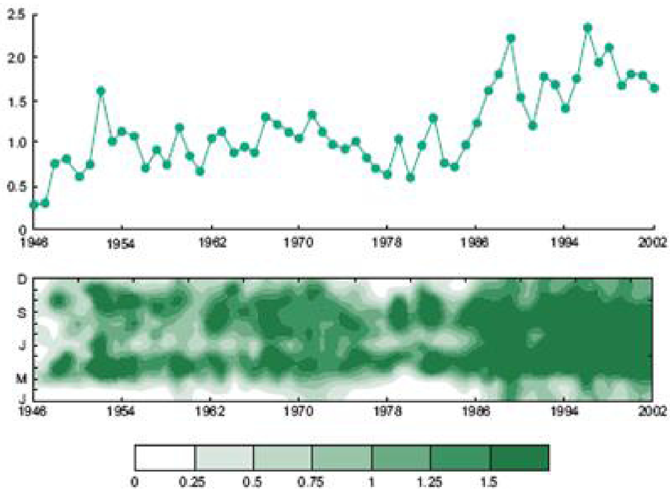
Plankton are ecologically important as photosynthetic bacteria and single celled plants (phytoplankton) are the base of the ocean food chain (see diagram below). They are consumed by microscopic and planktonic consumers, which in turn, are food for fish. Some of these animals and plants will die and sink carrying organic material to the sea floor and so fuelling the benthic ecosystem.



A simple marine food chain.



Continuous Plankton Recorder tow routes sampled during 1999. The routes of the Continuous Plankton Recorder remain similar every year. Consistently trawling the same routes is important as this makes the yearly data comparable and changes can be seen each year in all the defined areas trawled.

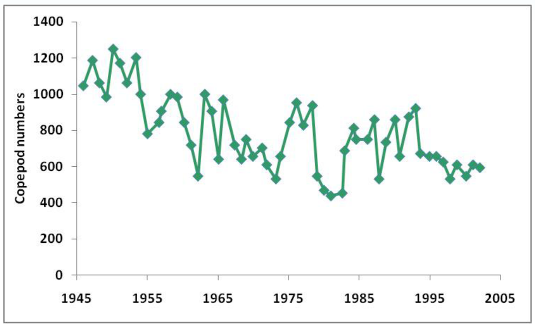


Mean annual phytoplankton colour and a contoured plot of monthly means of phytoplankton colour averaged for the period 1946-2002 (Source: Reid *et. al.*, 1998). There has been a general upwards trend in the amount of phytoplankton growth in the North Sea during this period.

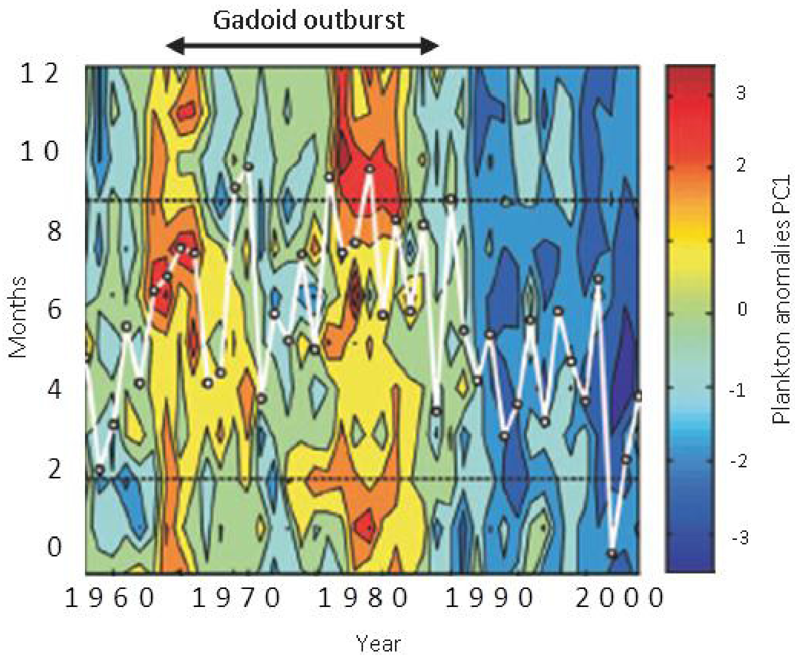
It is now widely accepted that a major change in the pattern and dynamics of phytoplankton in the North Sea occurred around the mid-late 1980s (see above). This is often referred to as a regime shift and appears to reflect a change in the patterns of climate in the North Atlantic. The changes in phytoplankton dynamics can have knock on effects in zooplankton and fish populations.

Zooplankton diversity is highest in the south-eastern part of the North Sea, south of the Flamborough Front. The northern areas tend to be dominated by species with an affinity for the Atlantic Ocean and which have been carried into the North Sea by the Atlantic inflow.

Major shifts in the composition and timing of zooplankton population dynamics have occurred in recent years (see opposite). Overall in the north-eastern Atlantic there has been a 10 degree latitude shift northward in species distributions, with southern species extending further north and northerly species retreating. This is thought to be the result of climate change causing an increase in surface and bottom temperatures within the North Sea.



Total numbers of copepods in the North Sea has shown a long term decline over the last 50 years. However, the overall mass of zooplankton has not decreased, highlighting the importance of identifying organisms to species level in order to recognise and understand changes in the ecosystem.



This diagram shows that the mix of species in the zooplankton of the North Sea has changed over time; the different colours reflect different mixes of plankton. The shift to a generally 'blue' pattern after 1985/86 reflects the regime shift that occurred around this time but also coincides with a decline in recruitment (the white line) in gadoid fish (e.g. cod, haddock, whiting). This shows how environmental signals (the regime shift) effect phytoplankton, zooplankton and conditions for fish larvae.

Harmful Algal Blooms (HABs)

Some species of phytoplankton can produce toxins that they secrete into the surrounding water to deter predators. Under some circumstances that are not yet fully understood, these species can increase to high densities and produce high levels of toxins (see table below). These occurrences are called harmful algal blooms (HABs). The toxins can affect species including fish, seals and birds and can also affect humans who ingest contaminated shellfish or fish. Examples include those connected with Paralytic Shellfish Poisoning (PSP). Algal blooms need not release toxins to be harmful. A large bloom can cause oxygen depletion, especially in enclosed or semi-enclosed areas such as bays and estuaries. Oxygen depletion leads to anoxic conditions in which only organisms that do not require oxygen can survive.

Species/genus	Associated harmful/detrimental effects	Time-series
Ceratium furca	Hypoxia/anoxia	1948-
Coscinodiscus wallesii	Production of mucilage	1st recorded 1947 (invasive)
Dinophysis spp	Diarrhectic shellfish poisoning (DSP).	1948-
Gonyaulux spp	Unspecified toxicity	1965-
Noctiluca scintillans	Discolouration and hypoxia/anoxia	1981-
Phaeocysttis spp	Production of foam and mucilage. Hypoxia/anoxia.	1946- (presence/ absence)
Prorocentrum micans	Diarrhectic shellfish poisoning (DSP). Discolouration and hypoxia/anoxia	1948-
Pseudo-nitzschia spp	Amnesic shellfish poisoning (ASP)	1948-
Nitzschia closterium (now cylindrotheca)	Production of foam and mucilage. Hypoxia/anoxia.	1948-
Chaetoceros spp	Gill clogging	1948-
Skeletonema costatum	Gill clogging	1948-

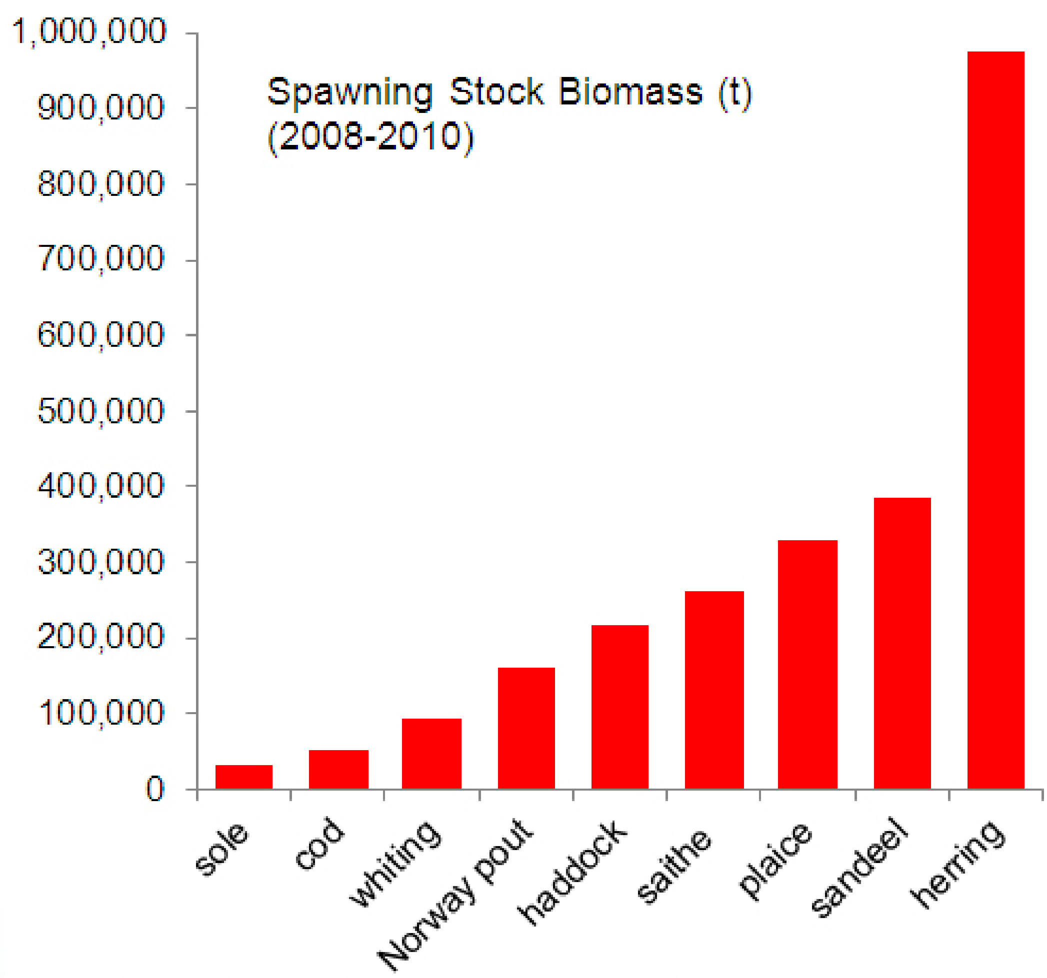
The frequency of such HABs is thought to be increasing, however this may simply be the result of better reporting. In temperate seas, a phytoplankton bloom occurs every spring, generally followed by a smaller bloom in autumn. The size of the bloom will be determined by seasonal changes in light penetration and nutrient content of the water column through mixing and turbulence followed by nutrient depletion as phytoplankton blooms. HABs may be related to water surface temperatures in spring, as early seasonal stratification may favour phytoplankton, growth in the water column (Joint *et. al*., 1997).

Fish

Fish

Over 230 fish species are known to inhabit the North Sea. A distinction can be made between those mainly living in the water column (pelagic) and those living on the bottom (demersal species). Some fish remain more or less stationary, while others show a distinct migratory behaviour. Many species have seasonal migration from feeding areas to spawning areas; this may be within the North Sea (e.g. plaice), or to areas outside the North Sea (e.g. herring) or even up rivers (e.g. eel).

The current most dominant commercial fish species in biomass are herring, sandeel, plaice, saithe and haddock (Van Densen & Hintzen, 2010). The sandeel fishery began in the 1970's. In 1997 landings reached over one million tons and since then landings have fluctuated significantly between 1.2 million tons and 180 000 tons, with 2003 marking the first year of significant decline (ICES, 2011). Cod has been overexploited in the North Sea and there have been seasonal area closures within the North Sea to aid recovery of this species. Blue fin tuna was a lucrative fishery in the 1800's to the early 1900's but this species is now extinct in the North Sea.



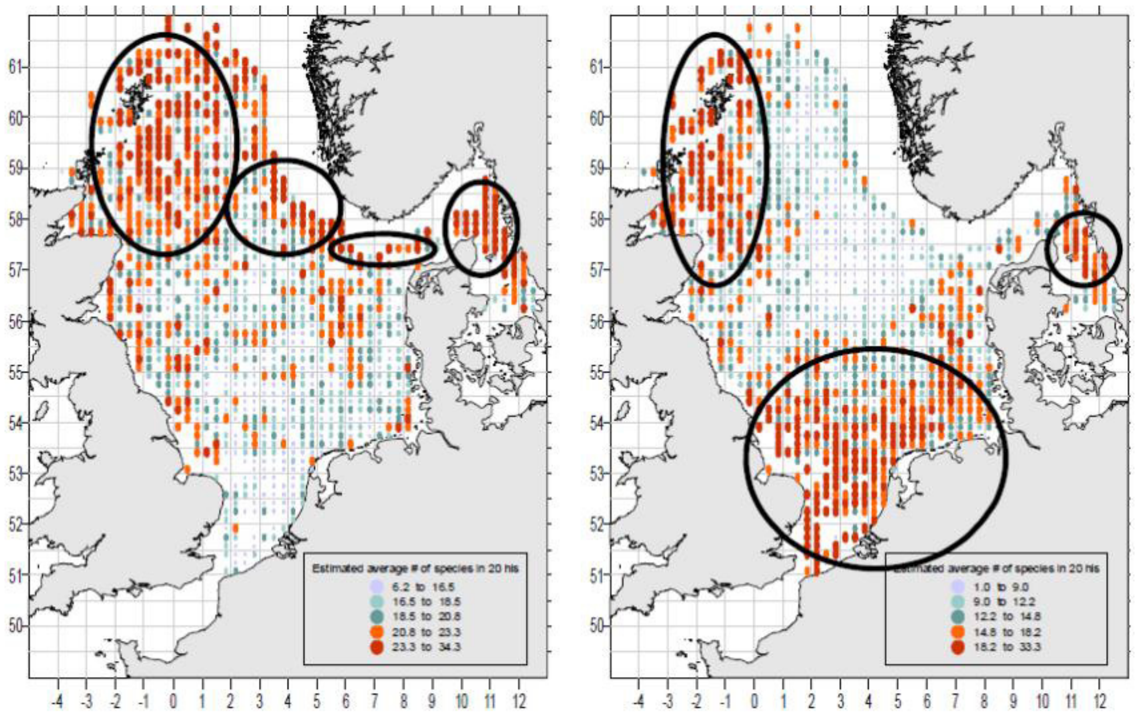
The average SSB of commercial and industrial fish species in the North Sea between 2008-2010.

Schooling

Some pelagic species like herring, form an interactive social group, called a shoal or school. The difference between the two is how tight the organisation is. A shoal is a loose social group whereas within a school fish synchronize their swimming so that all fish move at the same speed and in the same direction. Schooling behaviour makes fish vulnerable to fishing as a whole school can be caught at once.

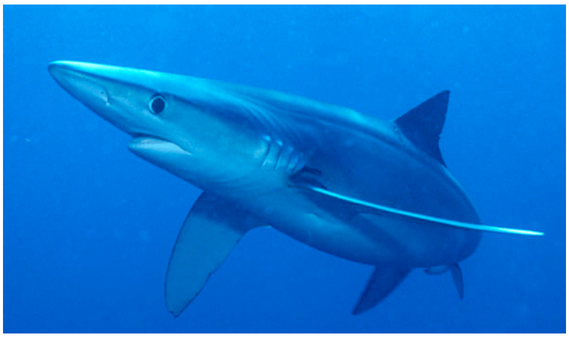
Feeding

Prey feeding among fish species is varied and their diet can include smaller fish, zooplankton and invertebrate benthic species such as polychaete worms and bivalves. The diet of demersal species tends to be dominated by benthic organisms whilst the diets of pelagic species mainly consists of zooplankton. However, many species are generalists, which feed on a range of different species, sometimes even their own. Feeding methods differ, some species filter the water for food, others dig in the sediment, hunt actively or lay still on the bottom waiting for prey to pass by.



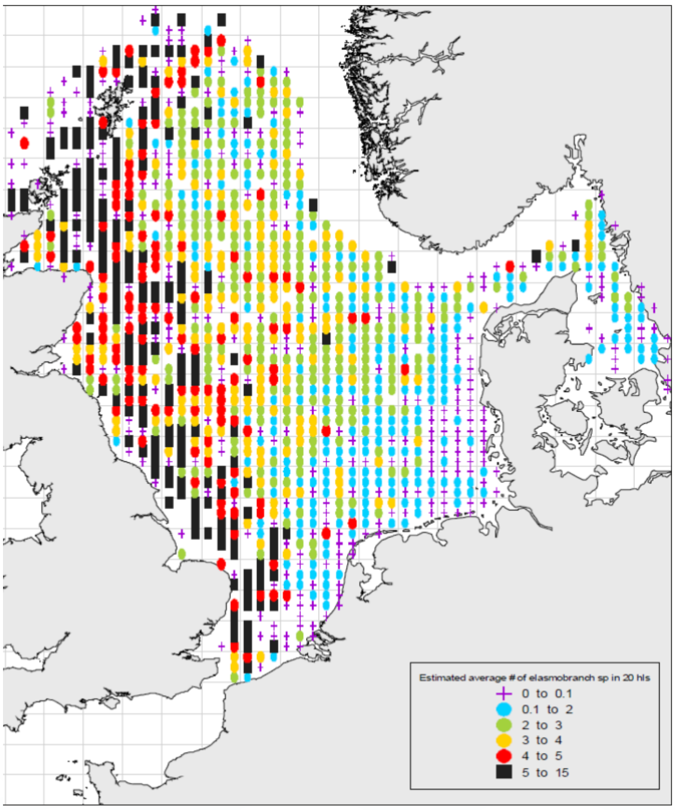
Fish species richness is lowest in the central North Sea and highest in Scottish waters, the Kattegat and the Channel. Species with a more northern distribution reach their greatest diversity in waters typically deeper than 100m and species with a more southern distribution in waters less of 50m. The left map below shows northern species and the right map southern species (Source: Daan 2006).

Elasmobranchs



A blue shark. This species is a visitor to North Sea waters.

A specific group of fish, the Elasmobranchs, are cartilaginous, meaning they have skeletons made of cartilage instead of bone. In the North Sea, the group consists of about 7 shark species, and 10 ray and skate species. These species are specifically vulnerable to fishing because they have a low reproductive rate and a long maturation time. In the North Sea they are primarily caught and landed as by-catch species, but some small inshore fisheries target rays and skates. The figure below the average number of elasmobranchs after 20 hauls of the international bottom trawl survey between 1977 and 2004 (Daan *et. al.* 2005).



The number of elasmobranchs in the North Sea, on average, between 1977-2004 (Source: Daan *et.al.* 2005).

Marine mammals

Marine Mammals

The marine mammals of the North Sea are whales, dolphins and seals. As some of the largest and most charismatic animals inhabiting the North Sea they are often the focus of much public interest. Although they were once subject to extensive commercial hunting, only a few countries, including Norway and Iceland, still hunt whales. In most regions they have become the subject of a growing eco-tourism industry.

While the great whales, such as the fin whale, eat plankton, the toothed whales and seals are top predators, sitting at the apex of marine food webs. The health of these marine mammal populations depends on both the extent of direct impacts on their populations, and a healthy food web to support them. There are no resident baleen whales in the North Sea but fin whales and minke whales have been spotted on occasion.

A small pod of dolphins.

Whales and dolphins have varied diets and eat fish, squid and benthic animals. They tend to be opportunistic feeders, with their diet dominated by what is locally available. The main areas of distribution have changed over time; this is thought to reflect climate and fishing induced changes in food availability.

ASCOBANS

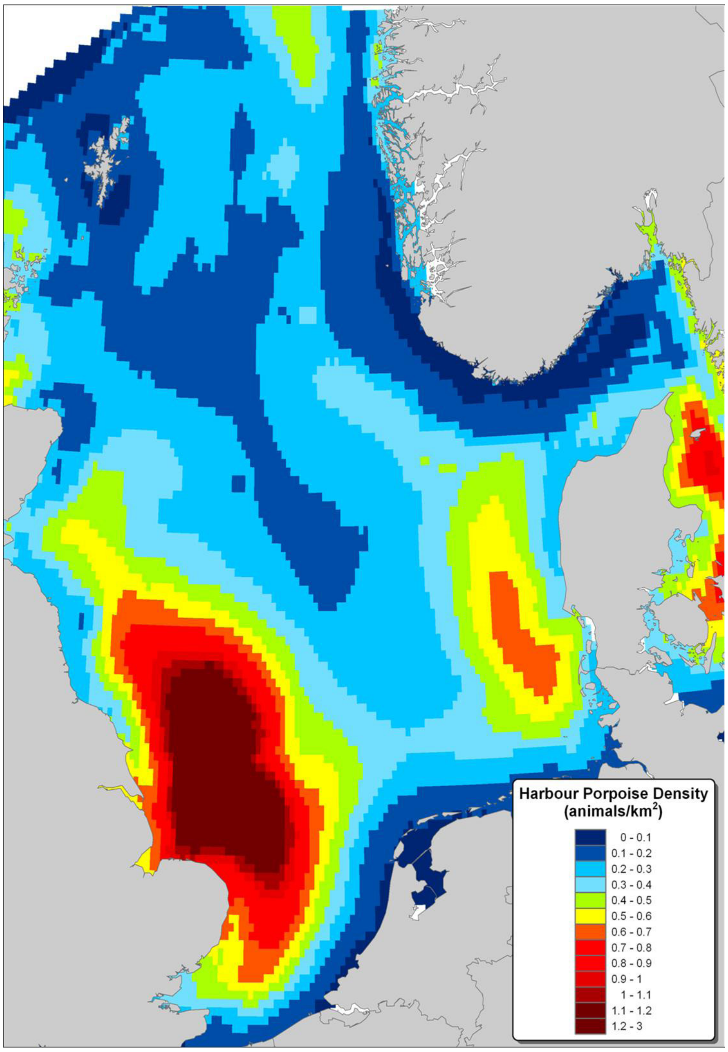
The primary agreement addressing the conservation of whales and dolphins is the Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS), which came into force in 1994. The main human threat to whales and dolphins is bycatch which is the accidental entanglement in fishing gear which can lead to drowning if the animals cannot surface to breathe. Other threats include pollution, acoustic disturbance and potential conflicts with fisheries for food resources.

Whales and Dolphins

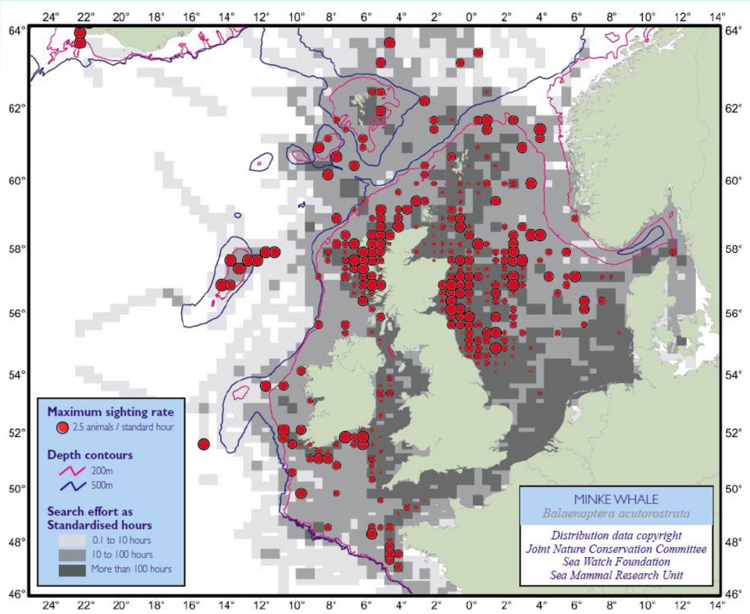
Over ten species of whales and dolphins are regularly sighted in the North Sea, although only four of these are considered to be truly resident species:

- Harbour porpoise
- Bottlenose dolphin
- White-beaked dolphin
- Minke whale

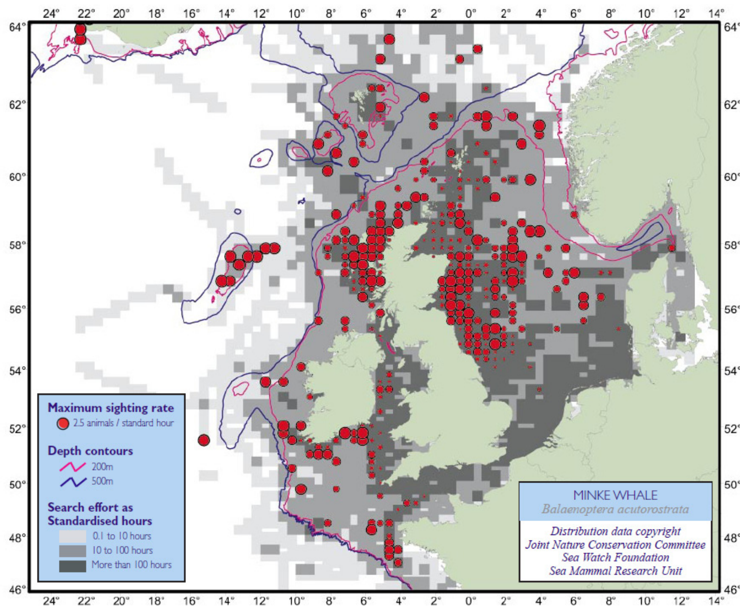
The harbour porpoise is the most abundant species of whale or dolphin and estimates from 2005 suggest that there are over 250 000 harbour porpoises in the North Sea and Channel (see map below). Bottlenose, white-beaked and minke whale pods are numerous on the north east coast of the UK (see maps on page 62).

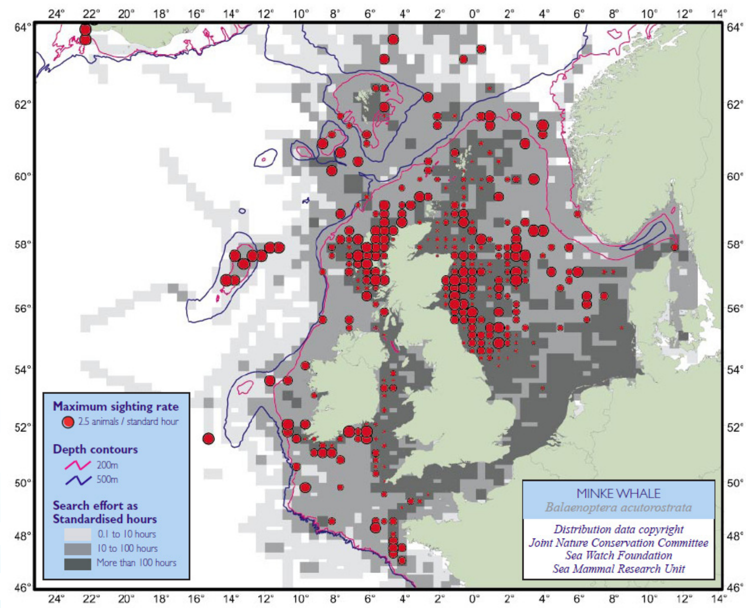


Estimated distribution and abundance of Harbour porpoise, June 2005 (Hammond & Macleod 2006). (Source: Project SCANS-II, supported by the EU LIFE Nature programme under project LIFE04NAT/GB/000245 and by the governments of all range states: Belgium, Denmark, France, Germany, Ireland, The Netherlands, Norway, Poland, Portugal, Spain, Sweden and the UK).



Distribution of bottlenose dolphin (top), white-beaked dolphin (middle) and minke whale (bottom) (source: Reid *et. al.* 2003).



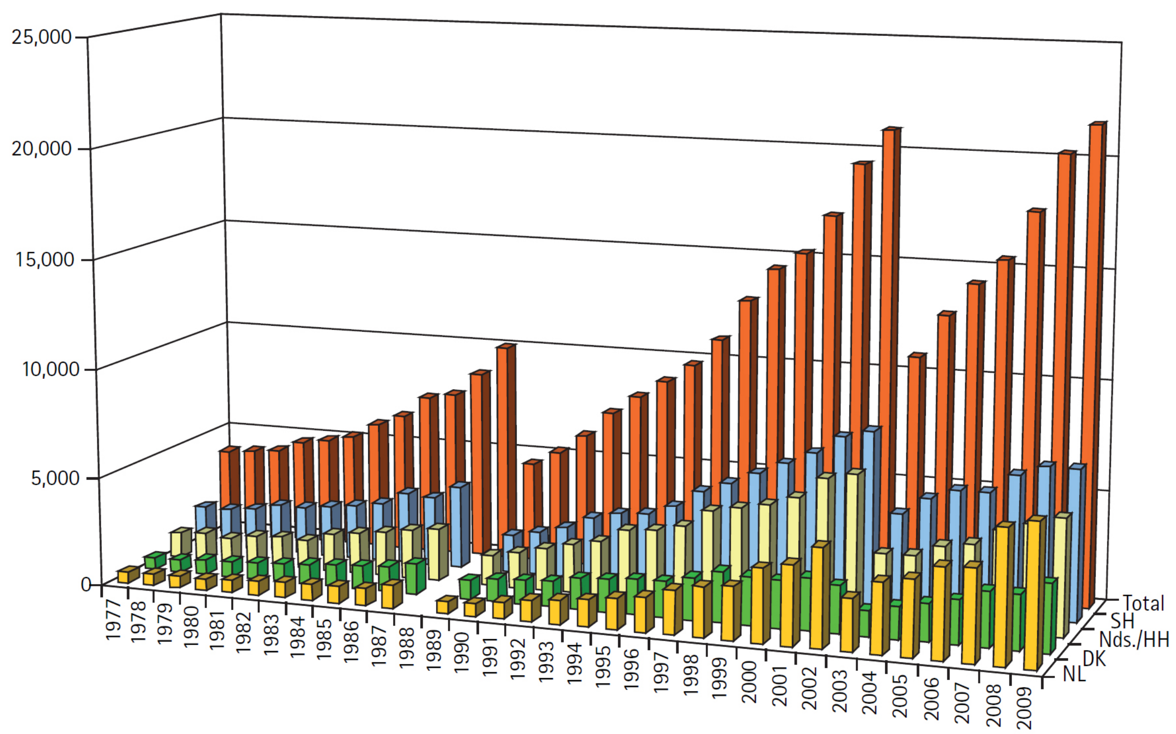


Seals

Two seal species breed within the North Sea, the harbour seal and the grey seal. Both species are coastal due to the need for haul out sites, although they can make extensive foraging trips at sea. Harbour seals occur throughout the North Sea, whereas grey seals almost exclusively occur around northern Britain.

Both species have undergone large changes in population numbers over the last century. The low point in population numbers was in the 1970s when a combination of hunting and pollution had reduced the populations. Since then numbers of both species have increased considerably.

The harbour seal population has been significantly affected by two outbreaks of the phocine distemper virus (PDV) in 1998 and 2002. The impact of the PDV outbreaks are apparent from counts of seal numbers in the Wadden Sea (see graph below).



Harbour seal numbers in the Wadden Sea. NL- Netherlands; DK- Denmark, Nds- Niedersachsen; SH- Schleswig-Holstein (Source: Trilateral Seal Expert Group, 2008; Wolff *et. al.* 2010).

A Grey Seal. These seals occur almost exclusively around northern Britain.

A harbour seal. These seals breed and are found throughout the North Sea [© OneKind 2010.]

Seabirds

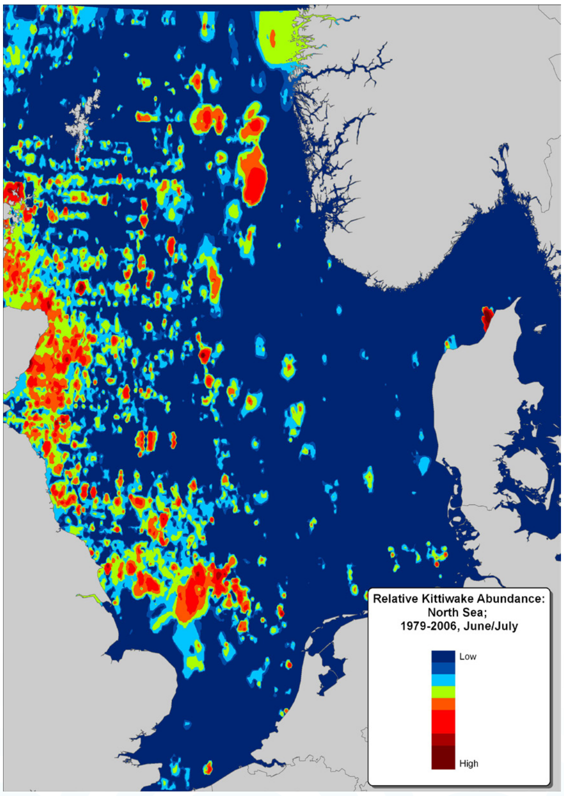
Seabirds

Seabirds are one of the most noticeable parts of the North Sea ecosystem. Approximately 2.5 million pairs of sea birds, made up of 28 different species, breed on coasts in the region. The North Sea is an important breeding site for some of these species, for example kittiwakes. Kittiwake breeding site distribution is shown on the map below.

A great black backed gull

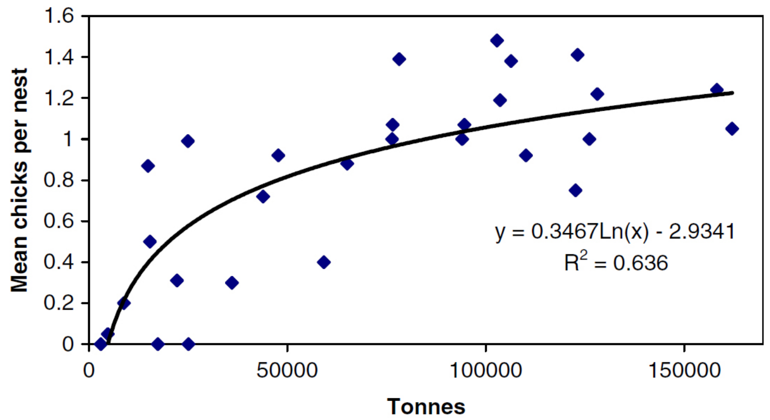
As predators, birds depend on available food resources and the health of seabird populations can give an indication of the condition of some fish stocks. In the past few years it has been observed that sea birds in and along the North Sea coast have been declining and there have been reports of significant dead birds washing up on beaches lining the North Sea. It is thought that the decline in sandeels as a result of overexploitation is the reason for the decrease in sea bird numbers.

Breeding season distribution of kittiwakes. The estimated relative abundance of kittiwakes during June and July based on at sea observations compiled between 1979 - 2006 (Source: European Seabirds at Sea, data made available by Joint Nature Conservation Committee, Royal Society for the Protection of Birds, DHI, Norwegian Institute for Nature Research, FTZ & Vogelwarte Helgoland, Netherlands Seabird Group, Research Institute for Nature and Forest (INBO), IMARES, University College Cork, Royal Netherlands Institute for Sea Research (NIOZ), Texel).



A breeding pair of kittiwakes.

Sandeels form an important part of the diet of many seabirds in the North Sea, especially during the breeding season. Different species show varying sensitivity to sandeel numbers depending on how easily they can use alternative prey. Black-legged kittiwakes are considered especially sensitive to changes in sandeel availability as they can only forage close to breeding colonies and have limited diving ability. Thus kittiwake breeding success tends to decline in areas when local sandeel abundance drops.



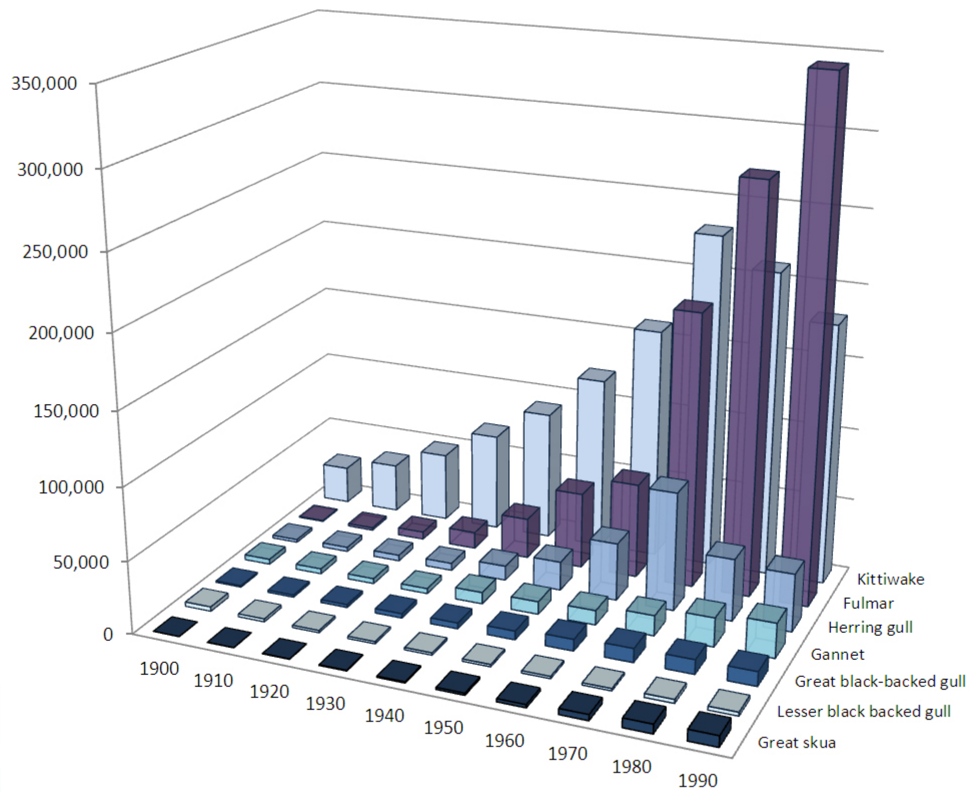
Breeding success of kittiwakes, *Rissa tridactyla*, at Foula in relation to estimated biomass of Shetland sandeels (Source: Furness, 2007).

Several years of the poorest breeding success of kittiwakes on record have occurred since 2003. This may be caused by climate change, as it is thought that climate change affects sandeel breeding success in the North Sea (see graph above), although the impact of fisheries on sandeel stocks is uncertain. Climate change could cause long term effects on the distribution and abundance of seabirds around the North Sea through impacts on seabird ecology and in particular effects on the food resources of seabirds.

There have been big changes to the numbers of seabirds over the last century, mainly due to the changes in fishing and discarding over this period. It was estimated that in the 1990s discards (including offal) from fishing boats made up 30% of the total diet of seabirds in the North Sea. The changes in the size and composition of seabird communities are illustrated by changes in the scavenging seabird community off northeast Britain (see figure below). The fulmar has shown the greatest increase in numbers and area of distribution over this time. Future changes in discarding practices could affect sea bird populations.

The increase in seabirds feeding on discards and offal generally favours larger scavenging species. Increases in large scavenging seabirds sometimes cause reductions in smaller seabirds breeding in the same area through competition for nesting sites or direct predation. For example, in the early 1950s in the German Wadden Sea, terns comprised 60% of the seabird community and large gulls 40%. By the early 1980s the seabird community was dominated by large gulls which made up 83% of the breeding population (Becker & Erdelen 1987).

Given the high public interest in seabirds they are often used a 'barometer' of ecosystem health and the public have been encouraged to contribute to the monitoring of their populations. While there has been a growing body of internationally coordinated effort to record seabird numbers and spatial patterns at sea, counts at breeding sites provide a long term record of population health. Around the UK , the British Trust for Ornithology organizes regular estuarine, coastal and breeding colony counts and these data are then made available to researchers and monitoring programmes (www.bto.org).



Number of breeding pairs of seabirds off northeast Britain (Source: ICES 1999).

Distribution of Human Activities

Distribution of Human Activities

The North Sea is surrounded by densely populated developed countries with long maritime histories. The North Sea has been a centre for a range of human activities over the centuries and wars have been fought over control of the strategic shipping lanes that cross the North Sea. To this day the North Sea remains an important area at the European level for shipping, extractive industries and cultural pass times. A new chapter in human relations with the North Sea is opening as a source for renewable energy generation.

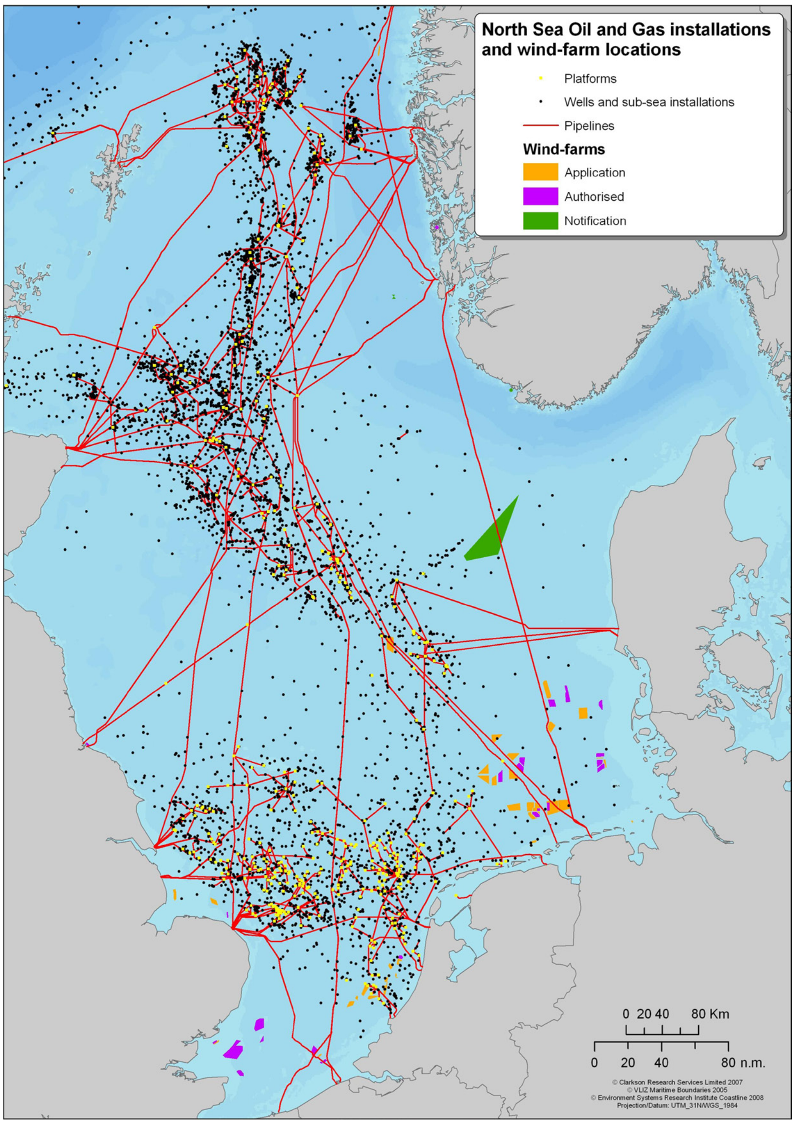
Offshore wind farms

The first offshore wind turbines were installed at Vindeby in Denmark in 1991 (see picture below). In 2009, EU offshore wind farms across 9 countries, had the capacity to produce 2,063 MW; capacity is expected to rise to 40-55 GW by 2020 (www.ewea.org). A large proportion of the existing and proposed European sites are located in the North Sea. The expansion of offshore generation is widely supported as one of the key technologies to achieve Kyoto targets for emissions reduction. The European Commission's 2008 Strategic Energy Review supported the vision of a large expansion in offshore power generation and the development of a North Sea offshore grid. The establishment of significant offshore wind farms around the North Sea should be viewed as a realistic prospect.

An offshore wind farm. Offshore windfarms generally generate more energy than inshore wind farms as offshore winds tend to be stronger and more consistent.

Oil and gas

Oil and gas extraction is a major economic activity in the North Sea. The main areas for oil extraction are in the northern North Sea in the UK and Norwegian sectors. The main area for gas extraction is in the shallower southern North Sea in the UK, Dutch and Danish sectors. Although total oil production from the North Sea remains over 4 million barrels per day, North Sea oil production has declined since its peak in 1999.



Location of oil and gas installations in the North Sea (Source: Clarkson Research Services Limited for data on the oil and gas installations, windfarm data is from OSPAR).

Tourism

Tourism is a rapidly expanding industry within the European Union, in the ten year period 1998-2008, tourist arrivals in the European Union increased by almost 40% and a significant proportion of the tourist activity is concentrated in the coastal zone.

The impacts from tourism on the marine environment are concentrated in coastal areas, although limited impacts extend offshore. The main impact is related to habitat loss and modification due to coastal development (e.g. harbours). There can be further direct impacts on coastal habitats by intense use of sensitive habitats such as wetlands and coastal dunes. Direct offshore impacts are mainly related to boating activities. Recreational fishing, and in some cases diving, can lead to direct ecosystem impacts through the removal of organisms.

The impacts of tourism are not all negative. Tourism can provide an important source of income to coastal areas, and tourism that depends on good environmental conditions provides incentives to protect or improve the environment.

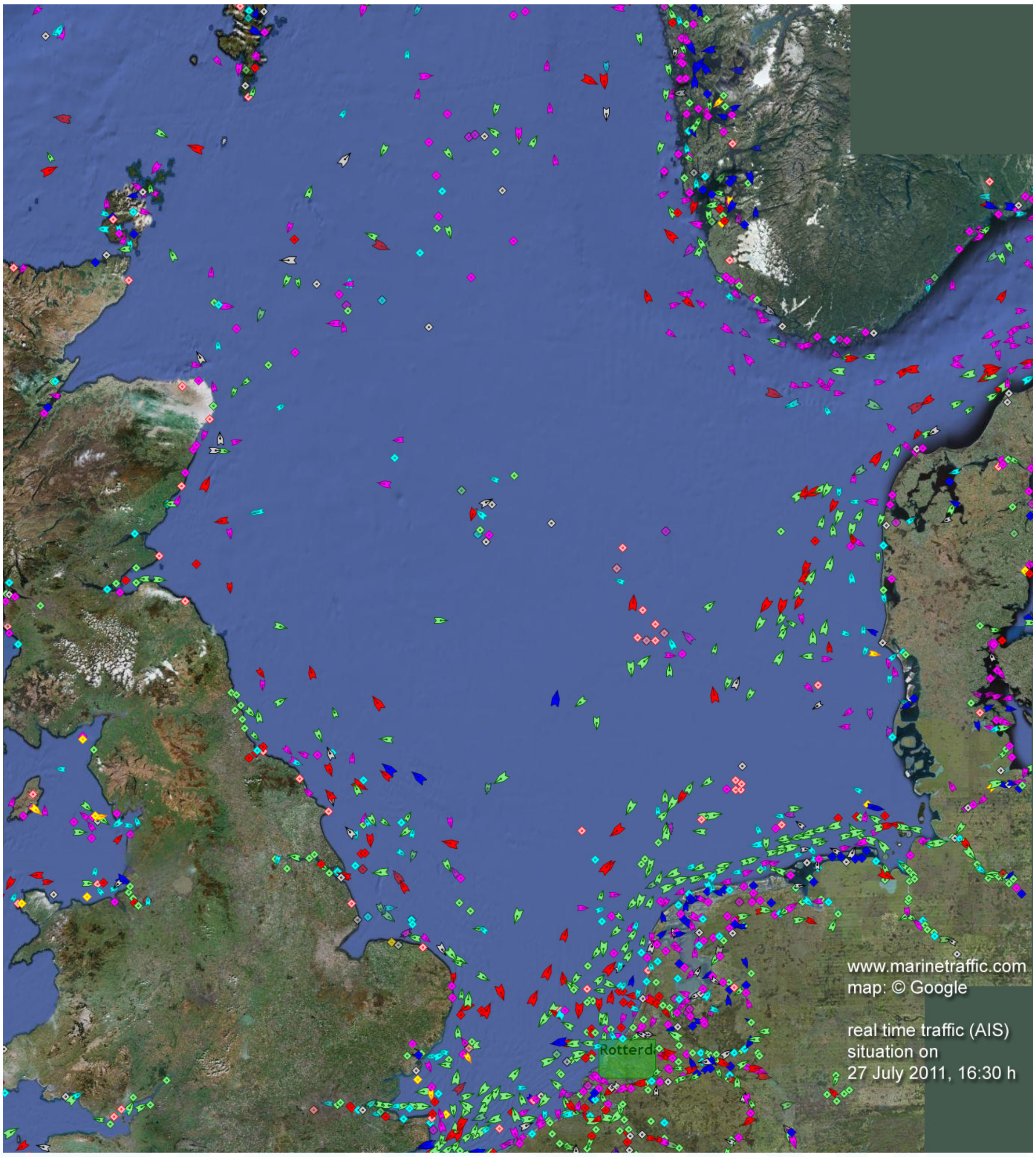
Recreational boating is a good example of a tourist activity potentially impacting the marine environment

Aquaculture

Marine aquaculture of fish or shellfish is undertaken by most states bordering the North Sea. Salmon is the main finfish cultured in the North Sea although an increasing range of species, such as cod and turbot, is likely to be cultured as production and husbandry practices improve. Shellfish culture in the North Sea is confined to molluscs, including blue mussels, oysters and scallops. Marine aquaculture can have a number of impacts on the marine environment; the main impacts are nutrient release, chemicals applied for 'medicinal' purposes, farmed sites acting as a source of disease and escaped farmed animals compromising the gene pool of wild populations.

Shipping

The North Sea contains some of the busiest shipping routes in the world, a significant proportion of western European imports and exports of goods and materials are transported by ship through the North Sea. Shipping, and its attendant infrastructure and activities, can have a number of impacts due to routine and exceptional events. The impacts of shipping are increasingly regulated. For example the use of tributyltin antifoulants (TBTs) has been increasingly restricted under both international (IMO) and regional (EU) regulations. Under EC regulation 782/2003 from 1st January 2008 the application of TBT based antifouling paints on EU flagged vessels has been banned, and ships with TBT based paints are banned from visiting EU ports. This is due to TBT being harmful to some marine organisms. For instance, female dogwhelks are known to develop male sex organs (imposex) in the presence of TBT, which can have serious repercussions on the reproductive success of this species. The North Sea has been established as a Special Area under MARPOL Annex I (oil) establishing a code of conduct for tankers travelling through Special Area waters.



Live view of marine traffic in the North Sea on ®(www.marinetraffic.com). This is an example of the level of boating and shipping activity in the summer. Different colours represent different boat types/sizes. Note that activity is concentrated in coastal regions.

Aggregate extraction

Aggregates, such as sand and gravel, extracted from the North Sea are an important source of material for the construction industry. In 2006, 87.5 million tonnes of marine aggregates were extracted by countries bordering the North Sea (European Aggregates Industry). Aggregate dredging can have a number of direct and indirect effects on sea floor communities due to direct removal of organisms and material, resuspension of material and possible alteration of sediment transport. The extent and duration of impacts varies depending on local sediment types and natural levels of disturbance. Aggregate extraction only occurs in localised licensed areas, and although local impacts can be notable, the impact on a regional level is limited.

Aggregate extraction of gravel in the North Sea.

Litter

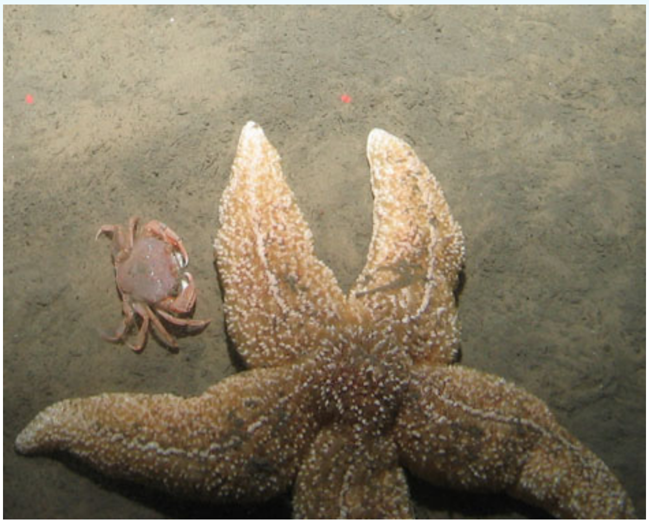
According to OSPAR, marine litter is one of the most pervasive pollution problems affecting the marine environment. Litter is defined as "any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment". With 600-1400 items per 100m of beach in the northern North Sea and 200-600 items per 100m in the southern North Sea, the North Sea region has been found to be the most littered area surveyed by OSPAR (Lozano & Mouat, 2009).

Marine Protected Areas

Marine Protected Areas (MPAs)

Marine Protected Areas (MPAs) are a spatial management tool which controls or restricts human activities over a specific area. They are used for a variety of purposes including:

- Commercial purposes (fisheries)
  - to protect a commercial species
- Conservation
  - of a non-commercial species protected by legislation
  - of a habitat protected by legislation



Examples of benthic life in the Dogger Bank, now a nominated special area of conservation (SAC). © JNCC

MPAs have been implemented to protect fish stocks in several ways (see map opposite) and include:

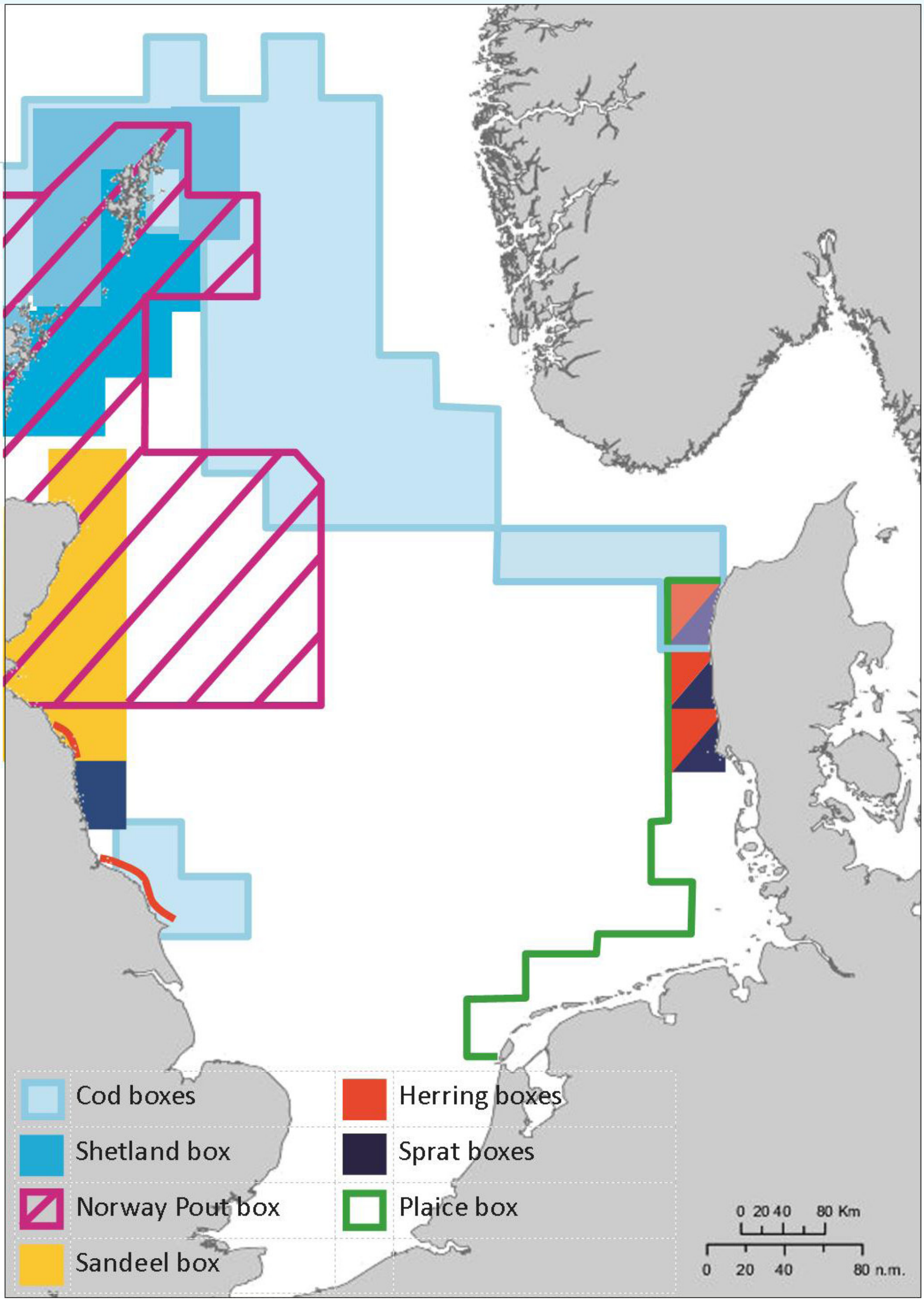
- Time-limited restrictions on fishing to protect juvenile fish (e.g. Plaice Box)
- Time-limited restrictions on fishing to protect spawning grounds (e.g. Cod Box)
- Real time closures to protect high densities of undersized fish (e.g. Sprat Box)
- Time-limited restrictions to protect other ecosystem components (e.g. Sandeel Box)

There is evidence that MPAs in which fishing is excluded can lead to dramatic changes in stocks of resident fish. This evidence comes from studies of reef fish in the tropics but also non-migratory and territorial fish and shellfish, including lobsters, wrasse and rays in the NE Atlantic. These studies have not shown benefits to species which are mobile or migratory, such as cod, and modelling studies suggest that very large areas would need to be closed to fishing before direct benefits occur for these species (Dekker *et. al.* 2009). Protection of areas of habitat that provide high quality feeding or breeding grounds may provide benefits, but indirect effects are not easy to measure.

MPAs can be permanent (e.g. to protect an area of coral reef) or temporary (seasonal or real time) (e.g. to protect spawning stocks or aggregations of juvenile fish).

The most common types of MPA used for conservation purposes in the North Sea are those designated as Special Areas of Conservation (SAC) or Special Protection Areas (SPAs). SACs are strictly protected sites designated under Article 3 of the EC Habitats Directive and SPAs are strictly protected sites classified in accordance with Article 4 of the EC Birds Directive. Together, the SACs and SPAs form the Natura 2000 network.

These sites are used to protect specific habitat types (e.g. 'reefs' or 'sandbanks which are slightly covered by sea water all the time') or the habitats of certain species (e.g. grey seal or harbour porpoise). Fishery management measures in such areas are taken under the Common Fisheries Policy, based on scientific advice and after broad consultation with stakeholders although this process does not always function as expected. In 2011 less than 1.5% of the EUs marine surface area was included in the Natura 2000 network.



Fishery Exclusion Areas ('boxes') in the North Sea. Fishery exclusion areas are a fisheries management tool whereby a sea area is closed (either permanently or seasonally) to a certain fishing gear or vessel size, or for a certain target species usually for the purpose of fish stock management or recovery.

Habitats protected under the Habitats Directive:

- Open sea and tidal areas
- Sandbanks which are (slightly) covered by sea water all the time
- Estuaries (pictured right)
- Mudflats and sandflats not covered by seawater at low tide
- Coastal lagoons* (pictured below)
- Large shallow inlets and bays
- Reefs
- Submarine structures made by leaking gases

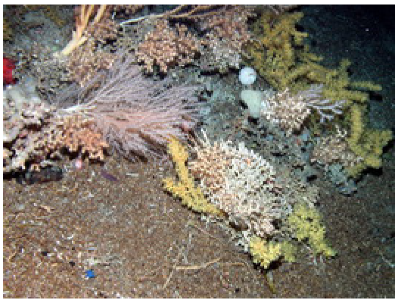
*priority habitats. These habitats are especially sensitive to disturbance thus they are considered as top priority for protection against harmful human activities such as waste disposal.

The Loch of Stenness is a lagoon off the coast of the Isle of May. This is a special area of conservation thus human activities are restricted. Lagoons are rare in the UK and are sensitive to disturbance so they are considered priority habitats for protection.

[© P&A Macdonald/ SNH. http://www.scotland.gov.uk/] Publications/2011/03/16182005/44

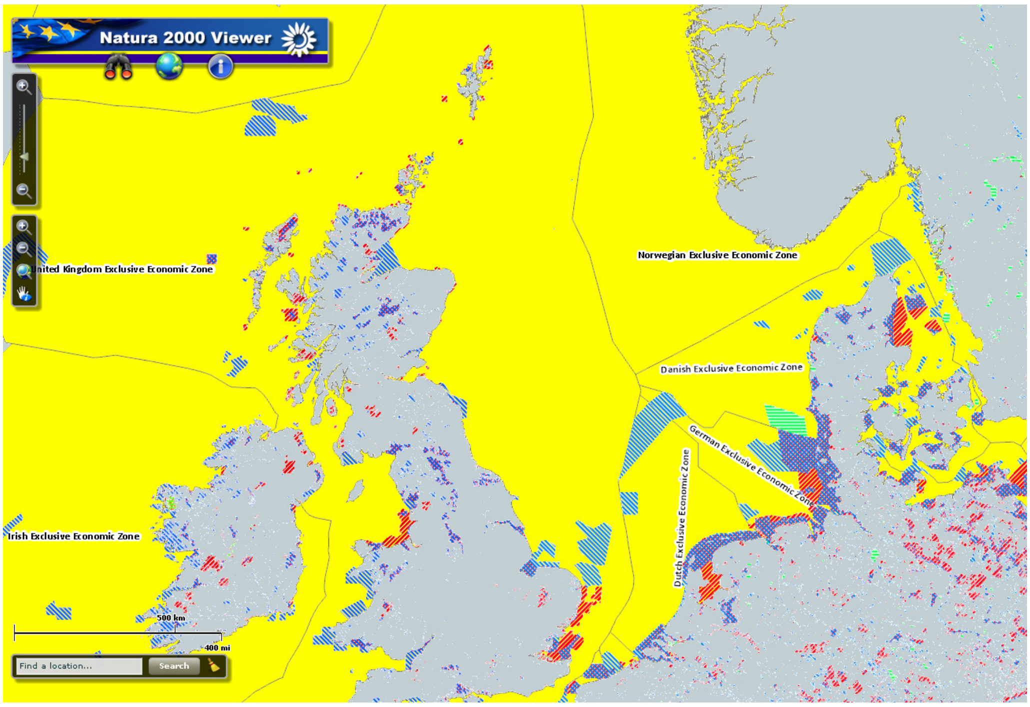
Habitats considered 'threatened and declining' by OSPAR:

- Coral Gardens (pictured top right)
- Intertidal *Mytilus edulis* beds on mixed and sandy sediments
- Intertidal mudflats
- Littoral chalk communities
- *Lophelia pertusa* reefs
- Maerl beds
- *Modiolus modiolus* beds
- *Ostrea edulis* beds
- *Sabellaria spinulosa* reefs (pictured bottom right)
- Sea-pen and burrowing megafauna communities
- *Zostera* spp. beds



[Both images © Jncc]

In May 1992 European Union governments adopted legislation designed to protect the most seriously threatened habitats and species across Europe. This legislation is called the Habitats Directive and it complements the Birds Directive adopted in 1979. At the heart of both these Directives is the creation of a network of sites called Natura 2000 (see map below). The EU marine Natura 2000 network will be made up of both SACs and SPAs. These sites were due to be designated by 2010 and management is to be implemented by 2012.



EU marine Natura 2000 viewer for the North Sea (Source: http://natura2000.eea.europa.eu/).

Although not covered by the Natura 2000 network, the Norwegian fisheries management regime has developed a comprehensive set of management measures over several decades, including the use of a variety of MPAs. Some of these area based measures were originally introduced for reasons other than protecting biodiversity, i.e. protection of small scale static gear fisheries from the competition of large scale trawlers, but have in some cases provided decades of protection.

To date, area based management measures have been introduced to Norwegian fisheries for protection of spawning grounds, juvenile fish (permanent and seasonal closures) and vulnerable bottom habitats (i.e. coral reefs); for rebuilding of depleted stocks (i.e. coastal cod, redfish, sandeel) or as a management measure for stationary stocks (i.e. lobster and seaweed); and to reduce competition between gears and fleets. Areas are designed according to their specific regulatory needs, while at the same time seeking to minimize the regulatory burden to fishers. Generally speaking the following parameters are addressed:

- physical extension of area, coordinates, depth contours
- should restrictions be permanent (long term) or temporal (short term)?
- should restrictions apply all year or to specific periods of the year?
- should restrictions be gear, fleet or fishery specific?

Examples of SPAs/SACs in North Sea waters in the UK.

Puffins on the Farne Islands. The Farne Islands are special protected areas (SPAs). These islands are open to tourists although access is restricted to certain times of the year.

An example of the diversity found on the rocky reefs off the coast of Northumberland, UK. These reefs are a designated special area of conservation (SAC) thus there are restrictions on human activities in this area.

Flatfish Beam Trawling

Flatfish Beam Trawling

The main target flatfish species are:

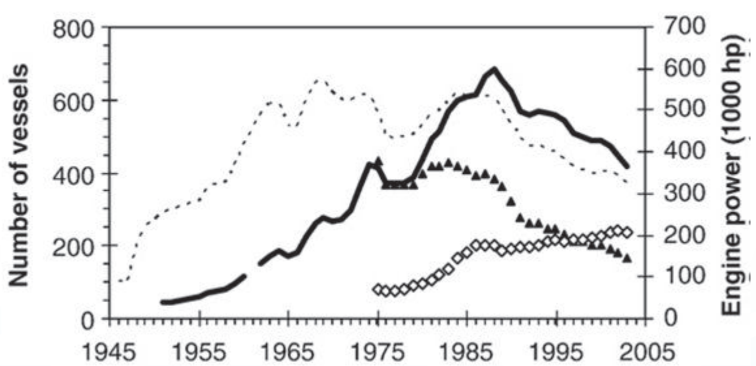
- Plaice (*Pleuronectes platessa*) (pictured) (Minimum landing size of 27cm) Total landings (NS) 2009: 52,315 tonnes
- Sole (*Solea vulgaris*) (Minimum landing size of 24 cm) Total landings (NS) 2009: 13,813 tonnes (ICES catch statistics on European plaice and common sole, region IV)

Beam trawls are dragged along the sea floor and utilise tickler chains to disturb and chase the target species up in the water column, where upon they are caught in the net. Beam trawlers operating in the North Sea are separated into two fleets:

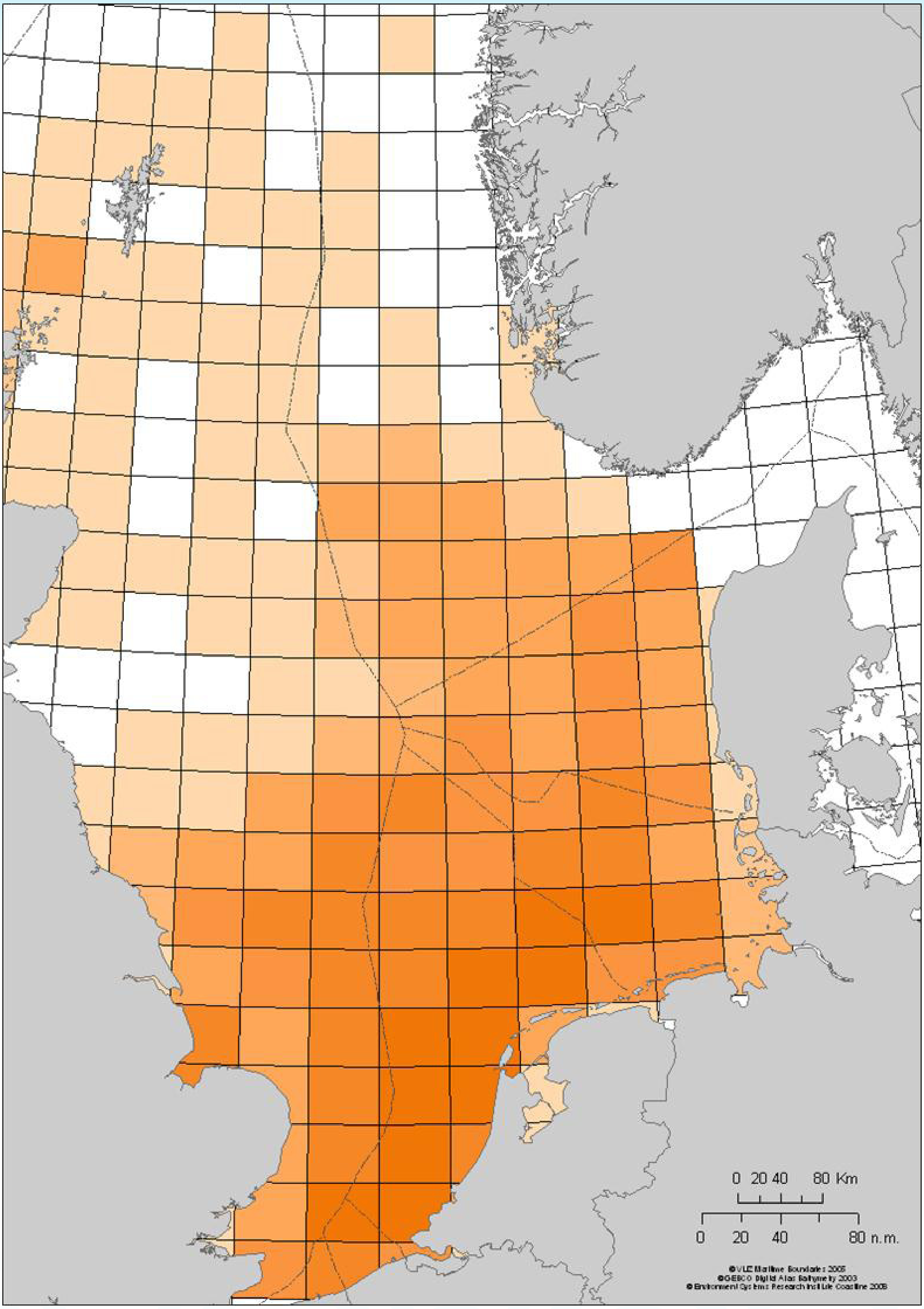
- Vessels with engine size >300 hp (up to a max of 2000 hp) with 2×12 metre beams (excluded from the 12 miles zone and the plaice box)
- Vessels with engine size <300 hp with and 2×4.5 metre beams.

The map opposite shows the average distribution of beam trawl effort (both groups) for 1997-2004 which tends to be concentrated in the southern North Sea. The distribution has changed over the years: from the 1970s to 1990s, effort was concentrated from the coastal and offshore areas of the southern North Sea into coastal areas of Germany and Denmark, and northern offshore areas of the Dogger Bank and the central North Sea. Since the 1990s, effort has become more concentrated in more southern fishing areas. The changes reflect a change in the targeting from sole to plaice in the 1970, and back to sole in the 1990s and seems partially driven by the availability and market prices of both species (Rijnsdorp *et. al.*, 2008).

The Dutch beam trawl fleet is one of the major operators in the mixed flatfish fishery in the North Sea but has decreased in recent years (see graph below). In 2008, a further 23 large Dutch beamtrawlers were decommissioned, although part of this decrease is counteracted by an increase in technical efficiency of around 1.65% a year (Rijnsdorp *et. al.*, 2008). Dutch fleet decreases are also due to the reflagging Dutch vessels to the UK and approximately 85% of plaice landings from the UK (England and Scotland) is landed into the Netherlands by Dutch vessels fishing on the UK register.

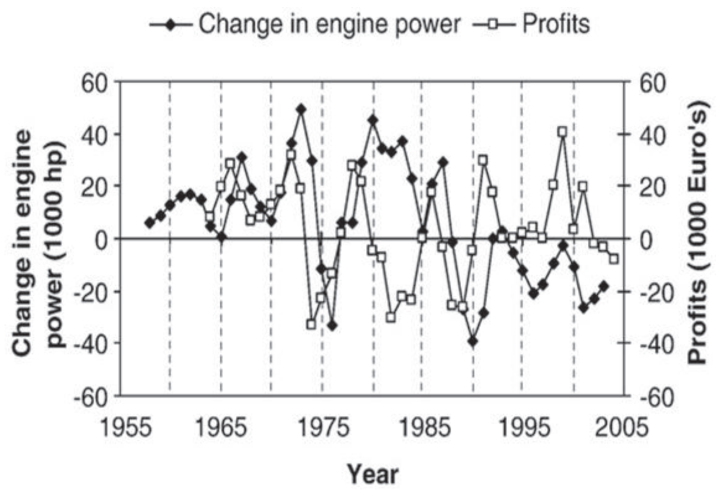


Developments in the Dutch fleet of demersal motor trawlers since 1945: number of vessels (dashed line), total engine power ('000 hp, heavy line), number of Euro-cutters (225–300 hp: ◊) and number of large trawlers (~2000 hp: ▲) (Source: Rijnsdorp *et. al.*, 2008).



Average Beam trawl effort for 1997-2004 based on International data collated within the EU-project MAFCONS. (Source: Greenstreet *et. al.*, 2007).

A cyclical pattern, with a period of 6.8 years, is visible in the economic results of the Dutch beam trawl fishery (graph below). The oil crises around 1974 and 1982 are visible as dips in the profit. Peaks in profit coincided with the recruitment of exceptionally strong year classes in 1963 (sole and plaice), 1985 (plaice), 1987 (sole), 1996 (plaice) and 1997 (sole).



Change in the total capacity of the Dutch fleet (1000 hp) relative to the previous year and the net result of the fishery (Source: Rijneveld & de Wilde, 1987; Rijnsdorp *et. al.*, 2008).

Landings:

Other landed species in the beam trawl fishery are:

- Flatfish species
  - turbot (*Psetta maxima*)
  - brill (*Scophthalmus rhombus*)
  - dab (*Limanda limanda*)
  - lemon sole (*Microstomus kitt*)
- Roundfish species
  - cod (*Gadus morhua*)
  - haddock (*Melanogrammus aeglefinus*)
  - whiting (*Melangius merlangus*)
  - monkfish (*Lophius piscatorius*)
  - tub gurnard (*Trigla lucerna*)
  - sea bass (*Dicentrarchus labrax*)
- Skates and rays (e.g. thornback ray (*Raja clavata*))
- Molluscs (e.g. common whelk (*Buccinum undatum*))
- Crabs (e.g. edible crab (*Cancer pagurus*)).

A monkfish

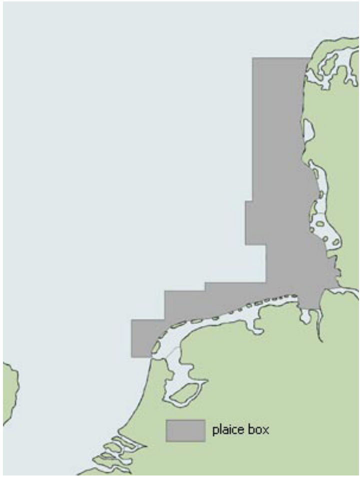
An edible crab

Discarding

Fish and benthic species of non-commercial interest are discarded from beam trawl catches, as well as any undersize commercial species. Discard estimates of undersized plaice in the Dutch beam trawl were 54% in weight and 82% in numbers; for sole this was 10% to 13% in weight and 23% to 29% in numbers (Van Helmond & Van Overzee, 2008). The overall discard rate is estimated at 71%–95% and survival rates of discarded sole and plaice were estimated at less than 10% (Van Beek *et. al.*, 1990).

An example of bycatch caught via trawling and discarded.

Plaice Box



Map by Gerbrand Gaaff

To reduce the discarding of undersize plaice, a section in the main nursery area of the species is closed to the larger beam trawlers (pictured left). During 1989-1993 the box was closed only during the second and third quarter and in 1994 the box was closed in all but the first quarter. Since 1995 the box has been closed to large beam trawlers all year round. A reduced growth rate and possibly a higher rate of natural mortality may have counteracted the reduction in fishing effort (Pastoors *et. al*., 2000).

Ecosystem effects of fishing

Beam trawls are dragged along the sea floor, they therefore have an impact on the animals that live on or in the benthos, e.g. worms, burrowing bivalves and soft corals. These benthic animals are often damaged or exposed to predators and scavengers who feed in the tracks of the trawl immediately after the gear has passed. Some sea floor animals are more resilient to the effects of fishing than others. For instance, thornback rays are very sensitive to trawling but starry rays survival rates are high. Some species can benefit from fishing, e.g. scavenging birds.

Risks for the beam trawl fishery are high fuel prices, relatively low stock numbers of plaice and sole, pressure of public opinion and NGOs, mainly owing to the impact of fishing on the seabed habitat and high discards rates.

New technology

Developments are underway in the fishery industry to change gears and methods, to reduce fuel consumption and lower the impact on the ecosystem. These include:

- Outrigging: instead of two beams, using two trawls which are connected to each other.
- Fly-shooting: anchor seine fishing in deeper water. An anchor is set with a fishing line, the boat then sails in a circle while releasing the net and the other fishing line. When returning to the anchor, the second fishing line is hauled. The flatfish are thereby driven into the net by the fishing lines as they roll along the sea floor.
- Pulse trawling: a beamtrawl, without tickler chains. An electric pulse is used to scare the fish up. This reduces impact to the seabed and fuel consumption.
- Sumwing: A wing like beam, which flies above the seabed. Shoes of the original beam trawl are no longer needed. This reduces impact to the seabed and fuel consumption.
- Sumwing with pulse: a combination of the two methods described above.

The first two methods are mainly for catching plaice, the others also catch sole.

Industrial Sandeel Fishing

Industrial Sandeel Fishery

The main target species are:
- Lesser sandeel (*Ammodytes marinus*) (pictured)
- Small sandeel (*Ammodytes tobianus*)
- Great sandeel (*Hyperoplus lanceolatus*)
- Smooth sandeel (*Gymnammodytes semisquamatus*)

The industrial sandeel fishery in the North Sea is dominated by vessels from Denmark and Norway, although other countries do participate on a smaller scale such as the UK, Faeroe Islands and Sweden. An average of 666,000 tonnes of sandeel from the North Sea has been landed in the last 20 years; landings for 2008 were almost half that average at 335 000 tonnes (ICES, 2008a).

The lesser sandeel industrial fishery is the largest single species fishery in the North Sea and are caught using trawls with mesh sizes as small as 5mm. The footrope of the trawl is lightly weighted so that it makes minimal contact with the seafloor thus this fishery has minimal impact within the benthic environment. The fishery is seasonal (April to August) as sandeels over-winter buried in the sand.

Landings from the industrial fisheries are reduced to extract fish-meal and oil that are principally used as feed in agriculture and aquaculture; some oil is also added to human food (e.g. biscuits and margarine). Five species of sandeel occur in the North Sea but the majority of commercial landings are of *Ammodytes marinus*.

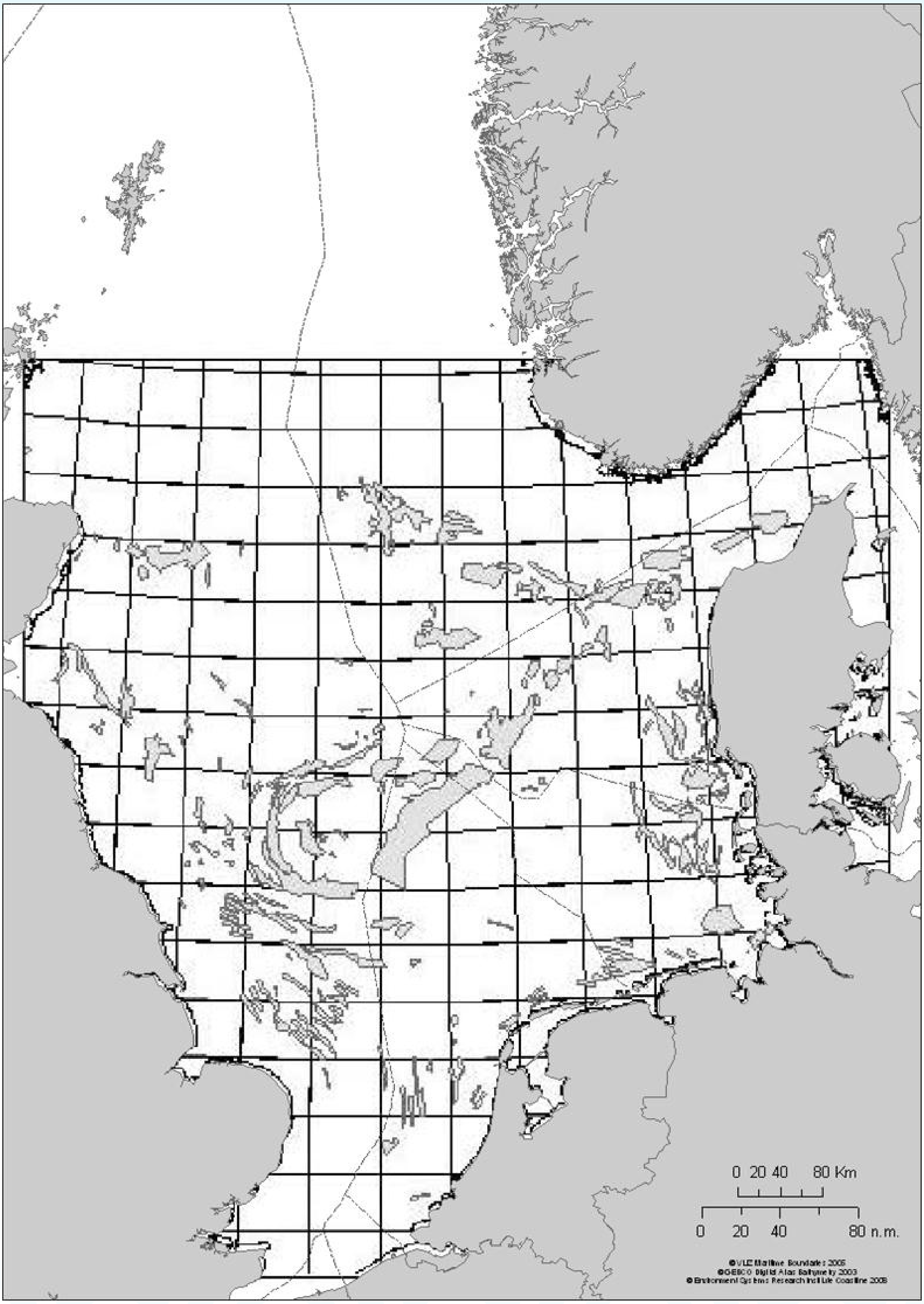
Life history

Sandeels are short lived compared to other commercial fish species in the North Sea with a lifespan of <10 years. They are an important component of food webs in the North Sea and important prey species for many marine predators, including seabirds and fish.

Sandeels are a shoaling species which makes them easy for fisheries to target and minimises by-catch of other species. They bury in the sand during the night and feed mainly on plankton in mid-water during daylight hours; this behaviour is known as diurnal migration. They are present throughout the North Sea, although they prefer sandy habitats so their distribution can be patchy. Tagging experiments have demonstrated that there is little movement between spawning and feeding grounds and spatial and temporal management restrictions have been introduced considering the life history characteristics of this species.

By-catch

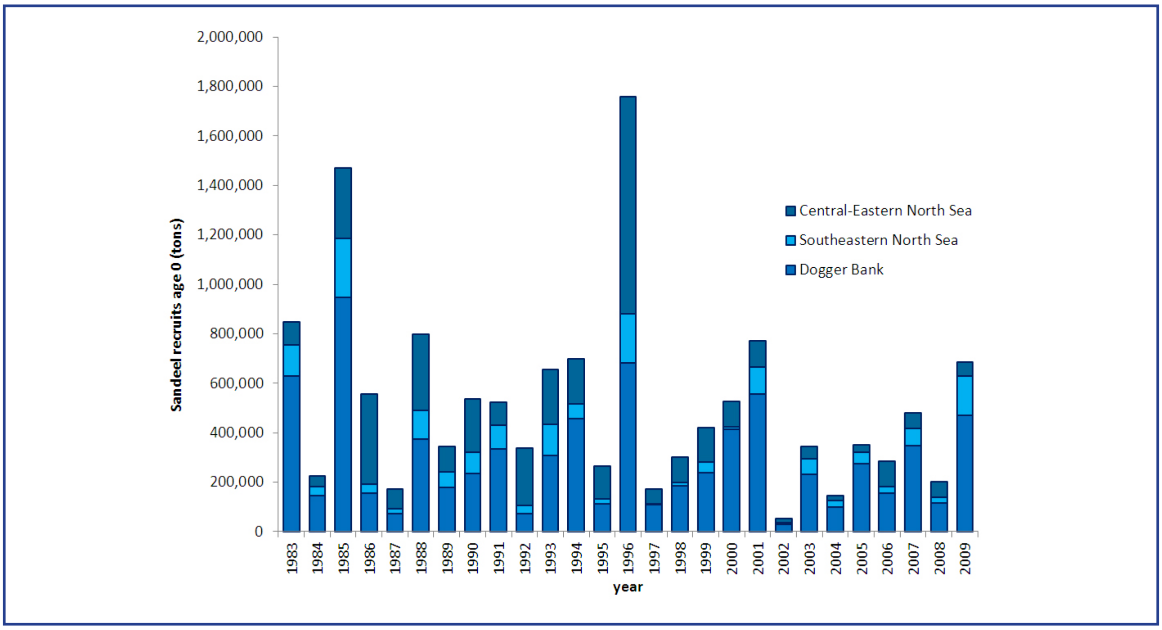
The sandeel fishery is generally considered a "clean" fishery with little by-catch. Any undersized and non-consumption by-catch are landed for reduction purposes. By-catch suitable for human consumption is retained if quotas allow.



Spatial distribution of sandeel fishing grounds in the North Sea (Source: INEXFISH, 2008).

Recruitment failure

The number of young sandeels settling was historically low in 2002, as a result the spawning stock biomass reduced to a critically low level (see graph below). The planktonic copepod *Calanus finmarchicus* is an important prey species for juvenile sandeels. It has been suggested that climate change has induced early egg production in *C. finmarchicus* which has led to the decoupling of food availability of the early life history of lesser sandeels (Van Deurs *et. al.*, 2009). This may be a key contributing factor to the decline in sandeel biomass.



Area closures

Removal of sandeels may cause a reduction in food availability for predators such as larger fish, seabirds and marine mammals. To preserve enough sandeel for coastal breeding populations of birds, all commercial fishing in the Firth of Forth (see page 77) area has been prohibited since 2000, except for a maximum of 10 boat days in May and June for stock monitoring purposes. The closure is still in effect and there is presently no decision on whether a full commercial sandeel fishery will be reopened in the Firth of Forth area.

Time closures

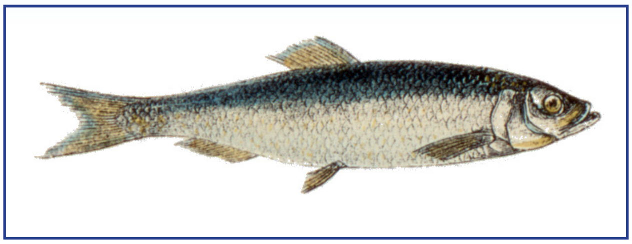
The sandeel fishery is a seasonal fishery; since 2005 Danish vessels have not been allowed to fish sandeels before 31st of March. Fishing with trawler gear with a mesh size <16mm is prohibited from the 1st of August until the end of the year. Within the allowed period for sandeel fishing, the Danish and the Norwegians have closed the fisheries in recent years. Denmark closed the fishery from 16th of May to 8th of June 2007 and Norway from 6th of May to 16th of May.

Effort management

An effort management regime was introduced by the Fisheries Council in 2004. The level of fishing effort allowed is determined by the strength of incoming sandeel recruitment (as measured by sampling in winter-spring), replacing the previous blanket TAC approach. In the worst case scenario (at lowest recruitment) effort can be 0.

Herring Fishing

Herring Fishery



Main target species: Herring (*Clupea harengus*)
Minimum landing size: 20cm
Landings: Official catches of North Sea herring for human consumption were 183 205 tonnes in 2009 (ICES catch statistics, Atlantic herring, Area IV).

Herring lay their eggs in dense beds on the sea bed and need specific, gravely substrates to spawn. This makes herring particularly susceptible to anthropogenic activities affecting the sea bed such as offshore oil and gas industries, gravel extraction and eutrophication causing oxygen depletion.

Herring fisheries take place with pelagic trawls catching shoals of the target species. Shoals are located with the use of echo-sounding equipment. The echogram provides information on the location, size and position of a shoal in the water column, which makes this fishery very efficient in targeting fish. Theoretically, the use of echo-sounding equipment should result in low by-catch.

Distribution of the fishery

The map opposite show a the distribution of herring landings for the years 2000 to 2004. Most of the landings are from the northern North Sea. The stock is fished throughout the year, with peak catches between October and March. Landings of herring in the autumn are predominantly from off Orkney and the Shetland islands, Buchan, off Peterhead, northwest of the Dogger Bank and from the coastal waters of eastern England. Landings in the spring are concentrated off the Lincolnshire and East Anglia coasts in the south-western North Sea. During the summer and early autumn, landings are greatest in the north-western North Sea, around Shetland and Orkney, and in the western central North Sea (ICES fishmap).

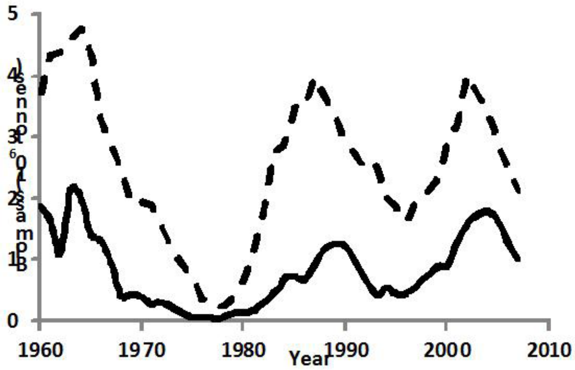
Stocks

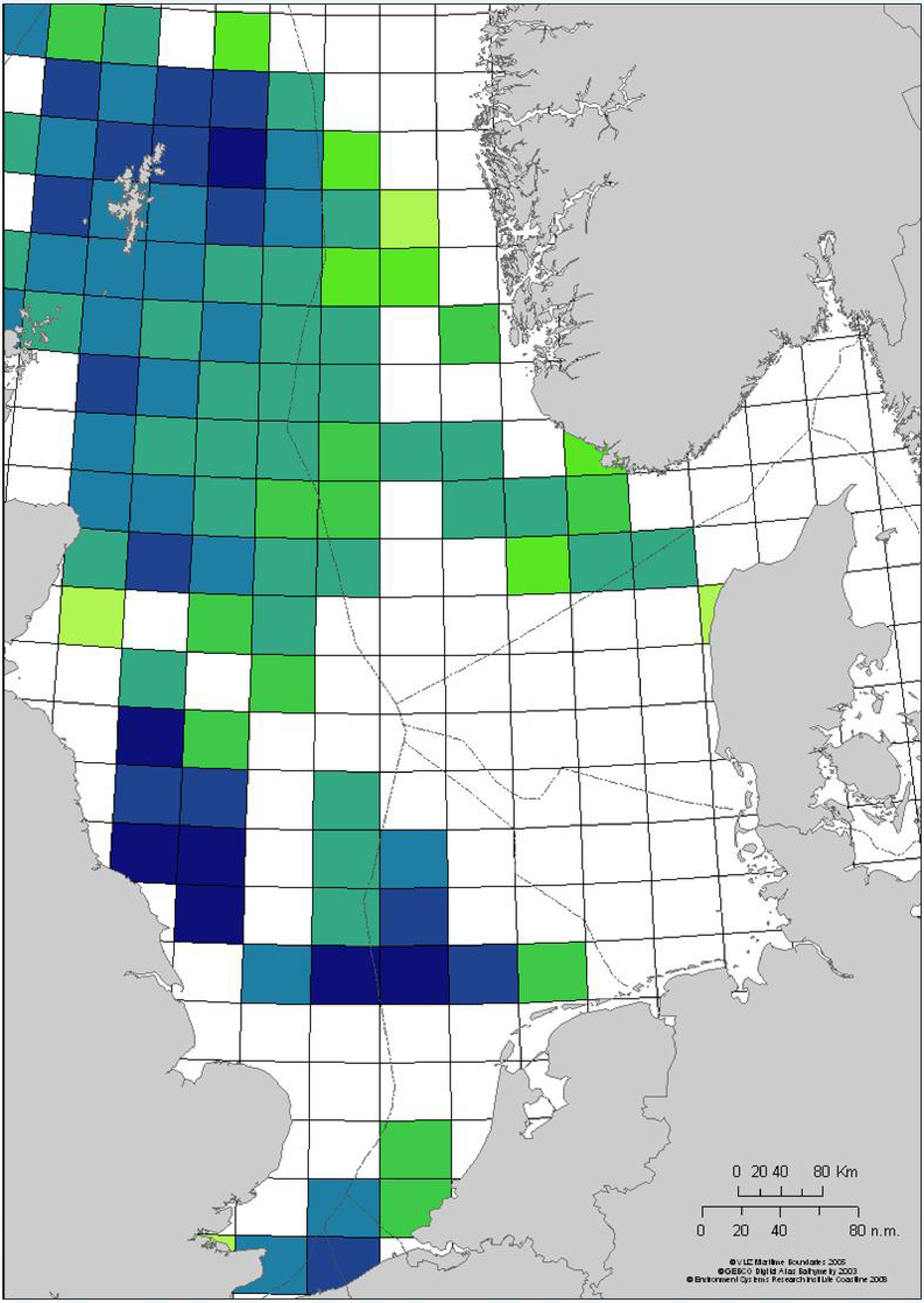
North Sea herring is not a single stock; it consists of multiple sub-populations. The main sub-populations are the autumn spawners which spawn along the English and Scottish Coast. The Downs herring spawn in winter in the Channel and there is also a spring spawning sub-population that occurs mainly in inshore waters.

Atlanto-Scandic herring and Skagerrak/Baltic herring can also be caught in the North Sea in smaller numbers.

Population development

The North Sea herring stock collapsed in the mid 1970s (see graph), and the fishery was closed in 1977. It reopened in 1981, and since then a yearly TAC is determined based on ICES advice. Opposite is a Time series of Spawning stock biomass of North Sea herring (solid line) and total biomass (dotted line) (Source: ICES 2008b).

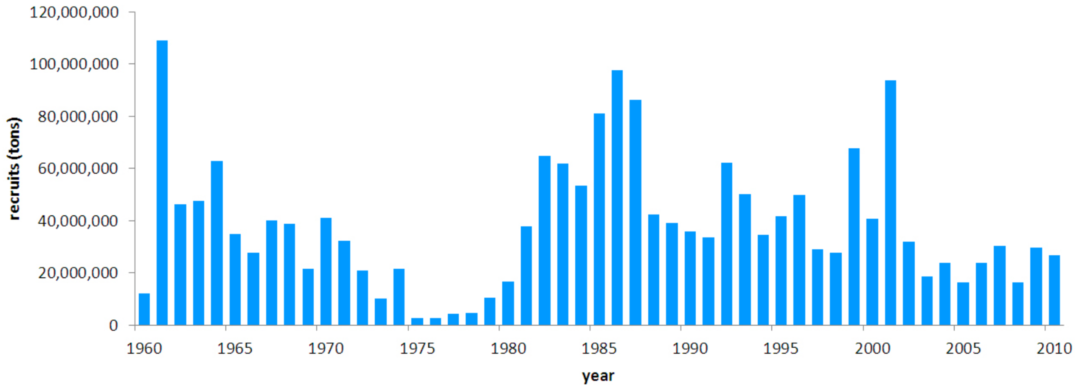




Herring landings 2000 to 2004 redrawn from WGECO 2006 database collated and provided by the STECF subgroup STGST- Cod Recovery Plan (Source: STECF, 2005).

Low recruitment

Recruitment of North Sea herring was below average in the period 2002-2006 (see graph below) and the estimates of the 2008 assessment indicate a very small year class in 2007.



Time series of Recruitment of North Sea herring (Source: ICES, 2008b).

Economic

The EU as a whole is a net-exporter of herring, which is a relatively cheap product (AER 2008). However, the low value per weight is counteracted by the large amounts landed. The Dutch herring-processing industry consists of approximately 15 companies with an industry turnover of €115 million. The industry turnover has remained virtually the same since 2000, but it fell in real terms due to general inflation over this period (14%) (Productschap vis, 2008).

Marine Stewardship Council

A large number of the companies fishing for North Sea Herring have been given the Marine Stewardship Council (MSC) certificate. The MSC certification process recognizes and rewards willingness to fish sustainably and certified fisheries are subject to a rigorous assessment against standardised principles and criteria. It is however a commercial initiative and benefits certified fisheries through higher prices and a larger market.

Management

A clear management plan is defined for North Sea herring, which is agreed upon by most of the scientific, governmental and fisheries community. The plan, agreed between the EU and Norway, was adopted in December 1997 and last amended in November 2007. It states that effort should be made to maintain the spawning stock biomass (SSB) of North Sea Autumn Spawning herring above 800,000 tonnes. If SSB is above 1.5 million tonnes, the TAC will be based on a fishing mortality of 0.25 for adult and 0.05 for juvenile herring. If SSB falls below 1.5 million, the fishing mortality will have to be linearly reduced. As long as SSB is above 800,000 tonnes, a TAC deviation of more than 15% between two subsequent years should be avoided, however, the TAC might be reduced by more than 15% if the parties consider this appropriate.

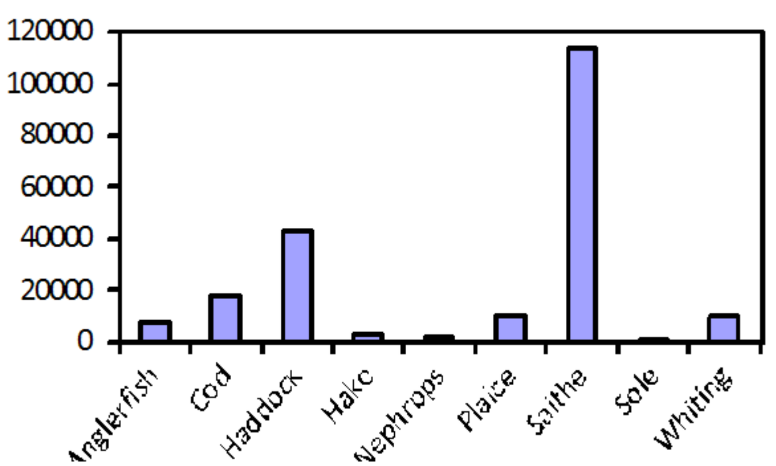
Mixed white fish demersal trawling

Mixed white fish demersal trawling

The whitefish demersal trawl fleet utilise otter trawls to target demersal species including:

- Saithe (*Pollachius virens)*
- Haddock (*Melanogrammus aeglefinus*)
- Cod (*Gadus morhua*) (left)
- Anglerfish (*Lophius* species)
- Whiting (*Merlangius merlangus*)
- Plaice (*Pleuronectes platessa*)

Haddock and whiting are predominantly taken by the UK otter trawl fleet whilst saithe is mainly caught by the Norwegian fleet. There is no single nation that dominates the cod catch.

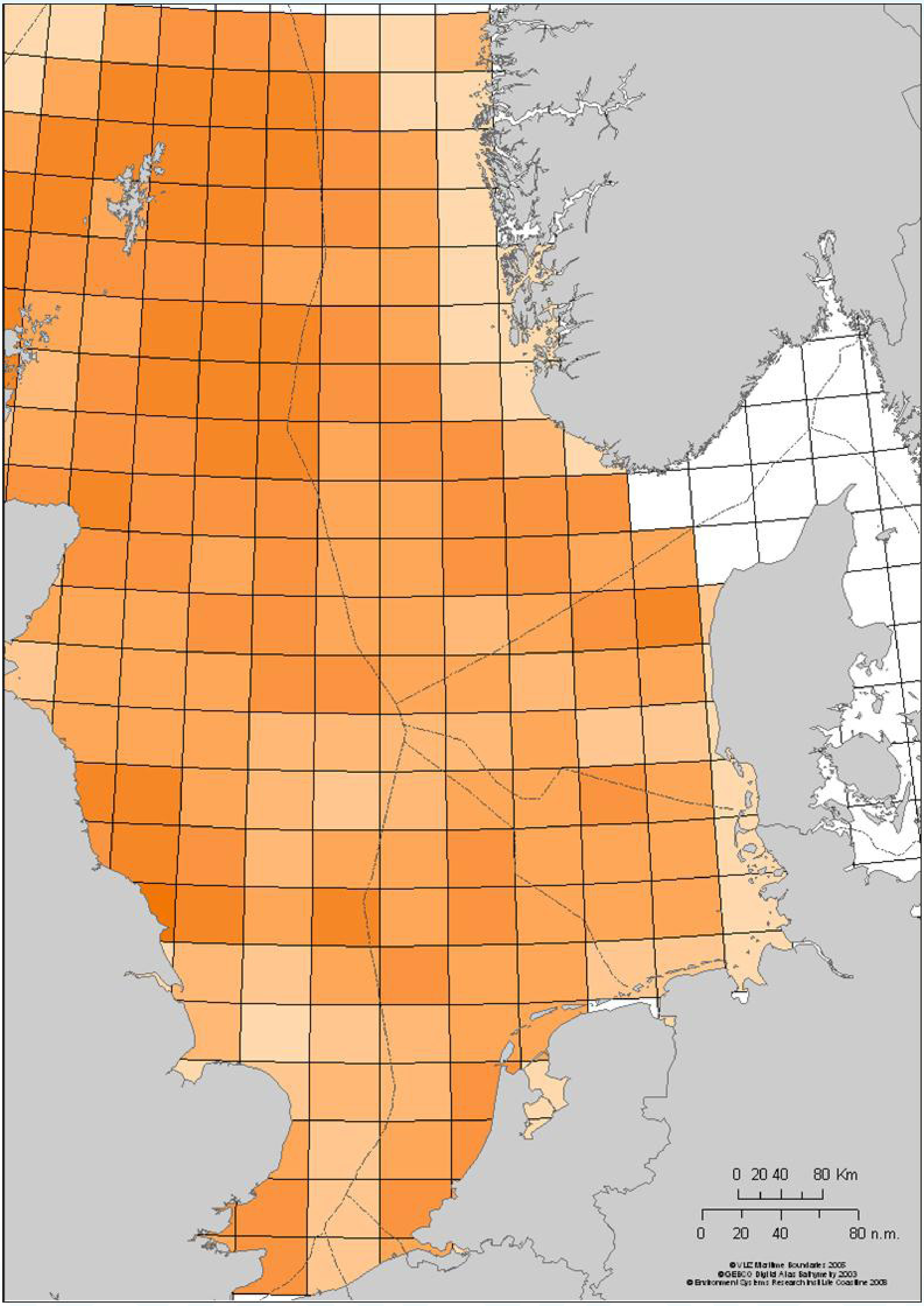


2007 catches (tonnes) of the main species by all otter trawls >100mm mesh for the North Sea, eastern Channel and Skagerrak (ICES areas IIIA, IV and VIId) (Source: STCEF)

Two fleets operate in the North Sea otter trawl fishery, the large mesh (>100mm) and small mesh fleets (<100mm). The large mesh fleets target whitefish, the small mesh fleet target *Nephrops* but will also take whitefish as bycatch. The whitefish trawl fishery in the North Sea mainly uses otter trawls with a mesh size of >100mm. Otter trawls are large, roughly cone shaped nets with 'otter boards' attached at the mouth of the net to keep it open it is pulled through the water. Weighted bobbins along the footrope keep the bottom of the mouth in contact with the sea floor and floats along the headrope hold to the top of the mouth open. Rockhopper trawls are specially adapted to work on rough ground.

Distribution of the fishery

The map opposite shows the distribution of otter trawl effort targeting whitefish for the years 1997 to 2004. The majority of fishing activity occurs the northern North Sea. The fishery with a mesh size of ≥120 mm is dominated by the UK, Danish and German vessels. Smaller segments of the fishery are a 70-79 mm French whiting fishery in the Eastern Channel, extending into the southern North Sea and a 90-99 mm Danish and Swedish fishery centred in the Skagerrak, extending into the eastern North Sea.



Average Otter trawl effort on mixed white demersal fish for 1997-2004 based on International data collated within an EU-project (Greenstreet *et. al.*, 2007).

Impacts on the benthos

Dermersal fish are those that live near the sea floor. Commercial fisheries use otter trawls to capture these species as this technique is quicker and more efficient than other fishing techniques such as long line fishing. However, using trawls to capture demersal fish can have devastating effects on the benthic environment. The nets are designed to drag along the sea floor to ensure maximum catch per trawling effort. The net (and the rollers attached to it to allow easier movement along the sea bed) can damage habitats and cause long term disturbances within the entire ecosystem (right). Benthic organisms can be physically damaged by the nets, either killing them or incapacitating them which leaves them vulnerable to predators.

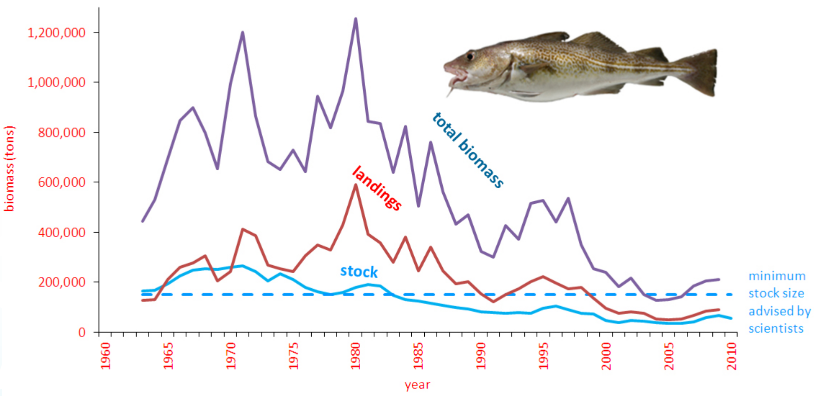
A trawled seabed can be left desolate if the habitat and organisms living there are sensitive to disturbance.

Cod Recovery Plan

North Sea cod stock has been declining since the early 1970s (see below) and since the mid 1980s the cod stock has been below the precautionary limit set by scientists. Below this limit it is expected that the North Sea cod stock suffers from reduced reproductive output. The stock dropped to such a low level official ICES advice in 2001 was for there to be no catch of cod the following year. The Cod Recovery Plan was developed in response to the declining cod stocks and was introduced in 2002. The Cod Recovery Plan has been modified since its initial inception and a 'new' version was introduced from 1st January 2009.

The Cod Recovery Plan for the North Sea cod stock covers the greater North Sea, eastern Channel and Skagerrak (ICES areas IIIa, IV and VIId). The objective of the Cod Recovery Plan is for the North Sea cod spawning stock to reach the precautionary limit of 150,000 tonnes. The Cod Recovery Plan regulates total effort, days at sea and the gears used. Additional days at sea can be gained by engaging in cod avoidance activities, this includes gear modifications and avoiding areas with high concentrations of young cod.

Fishing mortality applied to cod has been declining since the introduction of the plan, and there are increasing numbers of juvenile cod, however the increase in juveniles has yet to show up in the adult numbers.



Spawning stock size and fishing mortality applied to North Sea cod. (Source: ICES catch statistics database).

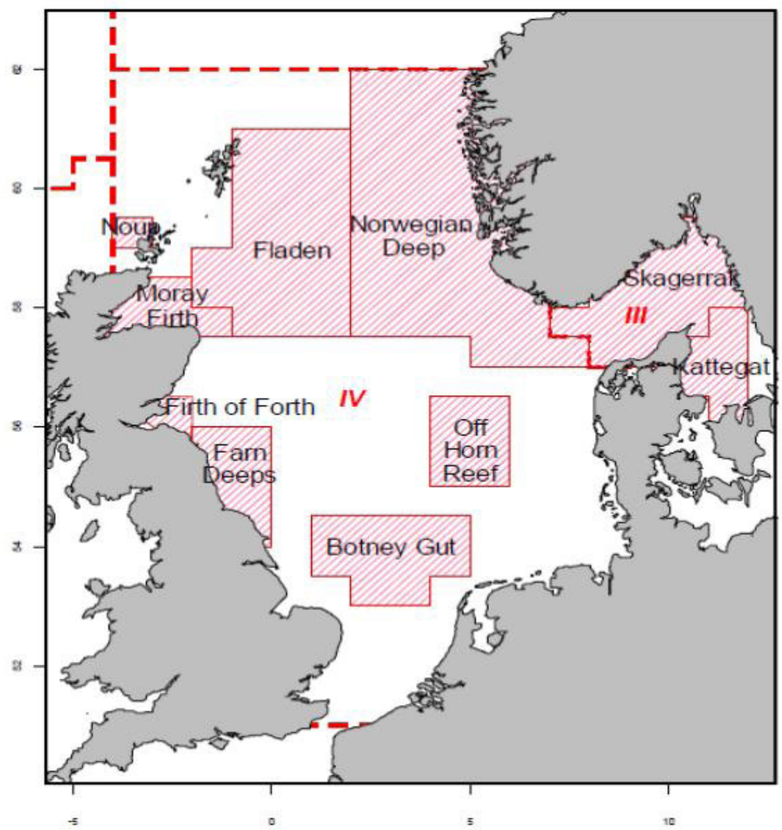
Nephrops/ Prawn Fishing

Nephrops/Prawn Fishing

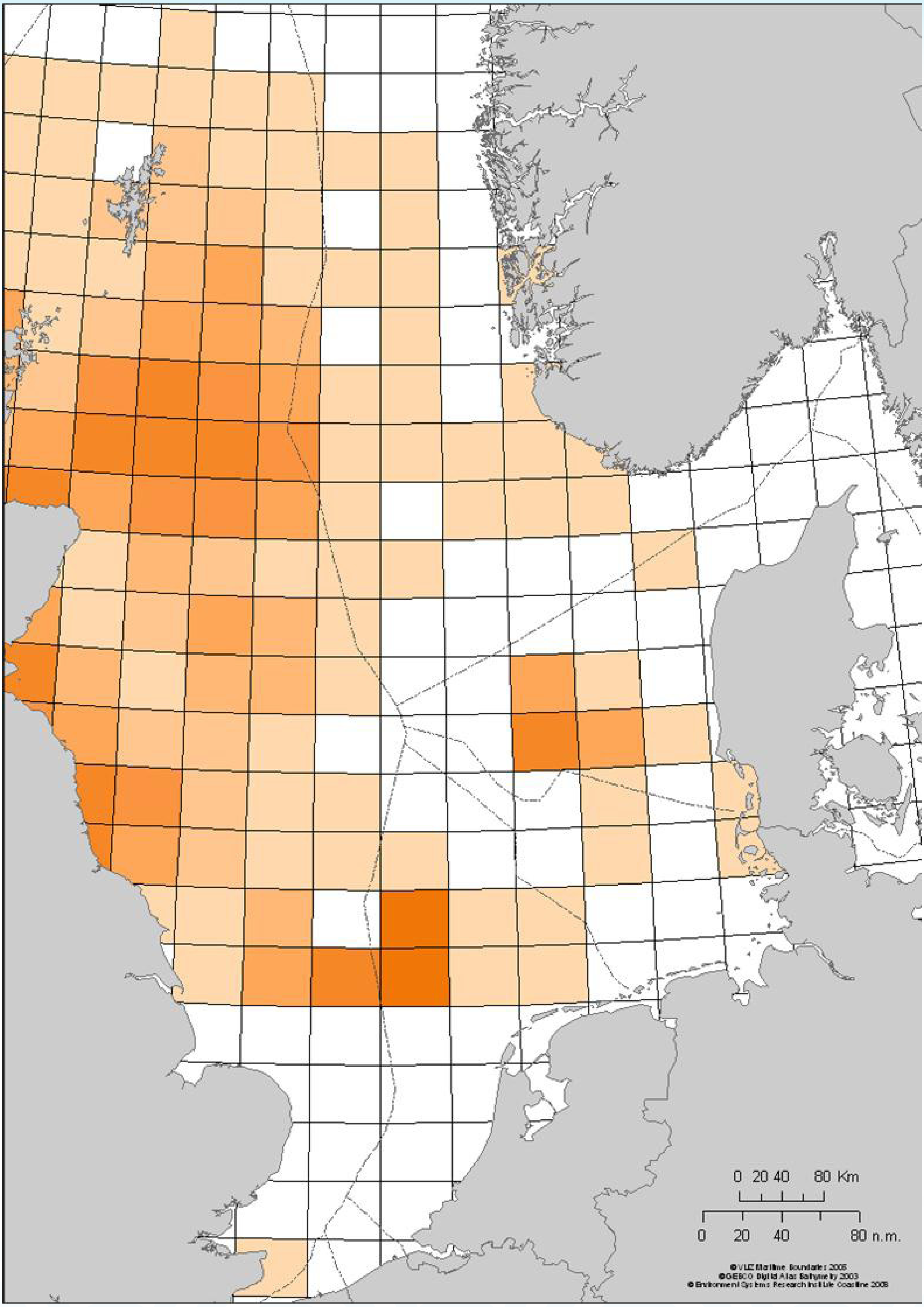
The main target species is *Nephrops* (*Nephrops norvegicus*). Minimum landing size varies depending on the area they are caught.

The *Nephrops* fishery mainly utilises demersal trawls with a mesh size of 70-99mm, although other mesh sizes are also used and different rules apply to different net constructions in different economic zones. Otter trawl effort on *Nephrops* is concentrated in the northern North Sea off the coast of Scotland (map opposite). The concentration of fishing effort for *Nephrops* is due to the patchy distribution of these species.

Nephrops are limited to muddy habitats due to their burying behaviour. (see below). This therefore defines the distribution of the species (see map below). This behaviour can also affect the sex-ratio of catches; the proportion of females in the catch is lower when they are carrying eggs, because they are less active and more often hide in burrows. Due to the distribution and life history of this species, stocks are assessed as eight separate functional units.



Muddy sites in the North Sea where *Nephrops* are found.



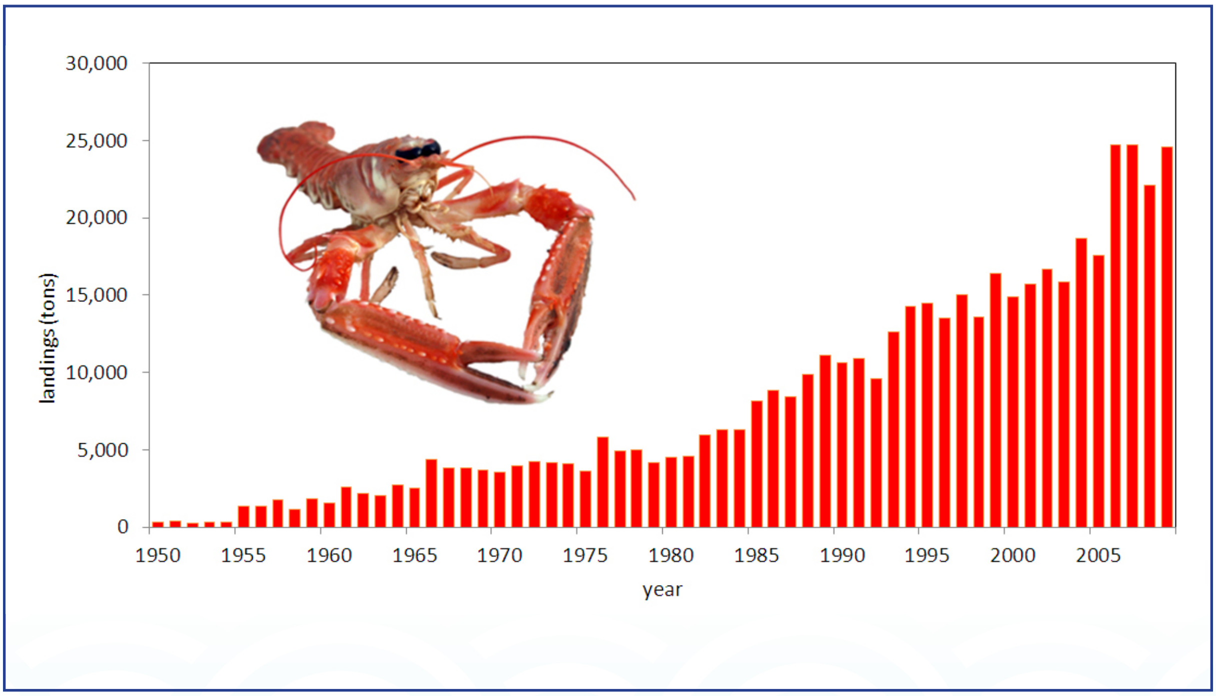
Average Otter trawl effort on *Nephrops* for 1997-2004 based on International data collated within an EU-project (Source: Greenstreet *et. al.*, 2007).

Discards

Trawling for *Nephrops* results in bycatch and discards of other species, including cod, haddock, and whiting. The energy available from discards could potentially provide scavengers on fishing grounds with 37% of their energetic requirements. This is probably sufficient to allow larger populations of these scavengers to exist than would otherwise be possible (Catchpole *et. al.*, 2006). Initiatives are in place to reduce bycatch and discards, such as including the use of 110 mm square mesh panels in 80 mm gear to allow small fish to escape.

In the 1980s, square mesh nets that remain open during the fishing process, were recognised as being particularly useful for the escape of juvenile whiting and haddock. However, square mesh panels were not introduced into UK domestic legislation for Nephrops fisheries until a decade later, and not into EU legislation for all North Sea demersal fisheries until 2000. The proposed positioning and mesh size of the panels were not supported by the fishing industry, as they expected them to result in unacceptable losses of marketable fish. Predictions on the effect of gear-based regulations (120mm mesh size, 90mm square mesh panel and twine diameter restrictions) implemented between 2000 and 2002 in the North Sea fishery forecast considerable increases in the haddock stock and landings. The whiting stock is predicted to increase but landings to decline, while the effects on cod are marginal - principally because it still remains fully selected at a young age.

The biomass and landings of *Nephrops* has increased in recent years, the increased biomass is probably due to favourable environmental conditions for recruitment (see graph below; ICES 2011). Landings for the North Sea are shown above (ICES catch statistics database). The current levels of exploitation are considered sustainable. ICES recommends not to increase the effort and catches above the recent average (2006-2007). The stocks are managed on the level of functional units.



Glossary

Acoustic surveys Acoustic surveys use sound waves emitted from a "transducer" to estimate the density of plankton and fish shoals. The survey vessel tows the transducer under water, which is linked to an echo sounder in the vessel which records the shoals of fish as "marks" on a screen or paper trace. The density of these marks is used to calculate total biomass of a stock.

Benthic Related to the bottom of the sea or to the organisms that live on it, including the s surface sediment and the first sub-surface layers.

Biomass Measure of the quantity, usually by weight in metric tons (2,205 pounds = 1 metric ton), of a stock at a given time.

Bycatch Refers to discarded catch (see Discards) plus incidental catch not purposely targeted by fishermen.

CPUE /Catch Per Unit of Effort The catch of fish, in numbers or in weight, taken by a defined unit of fishing effort. Also called catch per effort, fishing success, or availability.

Demersal Dwelling at or near the bottom of the sea or other body of water.

Discard Discards are defined as that part of the catch returned to the sea as a result of economic, legal or other considerations.

Discard rate The percentage (or proportion) of the total catch which is discarded.

Ecosystems are composed of living animals, plants and non-living structures that exist together and 'interact' with each other. Ecosystems can be very small (the area around a boulder), they can be medium sized (the area around a coral reef) or they can be very large (the Irish Sea or even the eastern Atlantic).

Elasmobranchs Fish, such as skates, rays, sharks and dogfish, whose skeletons are cartilaginous rather than bony.

Emergency Measures Measures adopted by the EU prior to the introduction of cod and hake as part of the recovery plan.

Exploitation rate The proportion of a population at the beginning of a given time period that is caught during that time period (usually expressed on a yearly basis). For example, if 720,000 fish were caught during the year from a population of 1 million fish alive at the beginning of the year, the annual exploitation rate would be 0.72.

Fishery Group of vessel voyages targeting the same (assemblage of) species and/or stocks, using similar gear, during the same period of the year and within the same area (e.g. the Irish flatfish-directed beam trawl fishery in the Irish Sea).

Fishing Effort The total fishing gear in use for a specified period of time. When two or more kinds of gear are used, they must be adjusted to some standard type.

Fishing Mortality Deaths in a fish stock caused by fishing.

Fleet A physical group of vessels sharing similar characteristics in terms of technical features and/or major activity (e.g. the Irish beam trawler fleet < 300 hp, regardless of which species or species groups they are targeting).

Gadoids An important family of food fish, including cod, haddock, rocklings, hake, whiting, blue whiting and ling. Usually characterised by the presence of a barbel on the chin.

ICES International Council for the Exploration of the Seas

Inshore fisheries There are various definitions of inshore fisheries including those fisheries that are conducted within 12 miles of the shore, including demersal, pelagic, shellfish and sea angling fisheries.

Intertidal (zone) Coastal area that are exposed to the air at low tide and submerged at high tide.

Management Plan An agreed plan to manage a stock, with defined objectives, implementation measures, review processes and stakeholder agreement and involvement.

MPA / Marine Protected Area A conservation area in the sea usually designated for the protection and maintenance of biological diversity and natural and cultural resources.

Natural Mortality Deaths in a fish stock caused by predation, illness, old age, etc. (not fishing)

North Atlantic Oscillation A large scale fluctuation in atmospheric pressure between the subtropical (Azores) high and the polar (Icelandic) low.

Osmosregulation The control of the levels of water and mineral salts in the blood.

OSPAR The Oslo and Paris Commissions, which have the objective of protecting the Northeast Atlantic against pollution. Member countries range from Finland to Portugal and Iceland.

Pelagic Related to or inhabiting that region of the sea which consists of open water of any depth, independent of both the shore and the sea floor.

Quota A portion of a total allowable catch (TAC) allocated to an operating unit, such as a Vessel class or size, or a country.

Recovery Plan This is a multi-annual plan to recover seriously depleted stock. The plans generally involve agreed Harvest control rules, technical measures, effort controls and various control and enforcement measures.

Recruitment The amount of fish added to the exploitable stock each year due to growth and/or migration into the fishing area. For example, the number of fish that grow to become vulnerable to the fishing gear in one year would be the recruitment to the fishable population that year. This term is also used in referring to the number of fish from a year class reaching a certain age.

Relative Abundance An estimate of absolute abundance; usually stated as some kind of index; for example, the average catch per tow on a survey.

SACs Special Areas of Conservation are sites designated under the European Community Habitats Directive, to protect internationally important natural habitats and species.

Sample A proportion or a segment of a fish stock or other population which is removed for study, and is assumed to be representative of the whole. The greater the size of the samples, the greater the confidence that the information obtained is a true reflection of the status of a stock.

STECF The Scientific Technical and Economic Committee on Fisheries. Established by the European Commission and comprises fisheries scientists and economists from the member states. The role of STECF is to advise the European Commission on scientific, technical and economic issues related to the management of fisheries resources that are exploited worldwide by members of the European Union.

Stock A "stock" is a population of a species living in a defined geographical area with similar biological parameters (e.g. growth, size at maturity, fecundity etc.) and a shared mortality rate.

SSB / Spawning Stock Biomass The total weight of all sexually mature fish in the population. The size of SSB for a stock depends on abundance of year classes, the exploitation pattern, the rate of growth, fishing /natural mortality rates, the onset of sexual maturity and environmental conditions.

Stratified Arranged in layers or strata.

Sustainable yield The number or weight of fish in a stock that can be taken by fishing without reducing the stock biomass from year to year, assuming that environmental conditions remain the same.

TAC / Total Allowable Catch The total regulated catch from a stock in a given time period, usually a year.

Whitefish Term used to describe demersal species such as cod, plaice, ray etc.

Year class (or cohort) Fish in a stock born in the same year. For example, the 1987 year class of cod includes all cod born in 1987, which would be age 1 in 1988.

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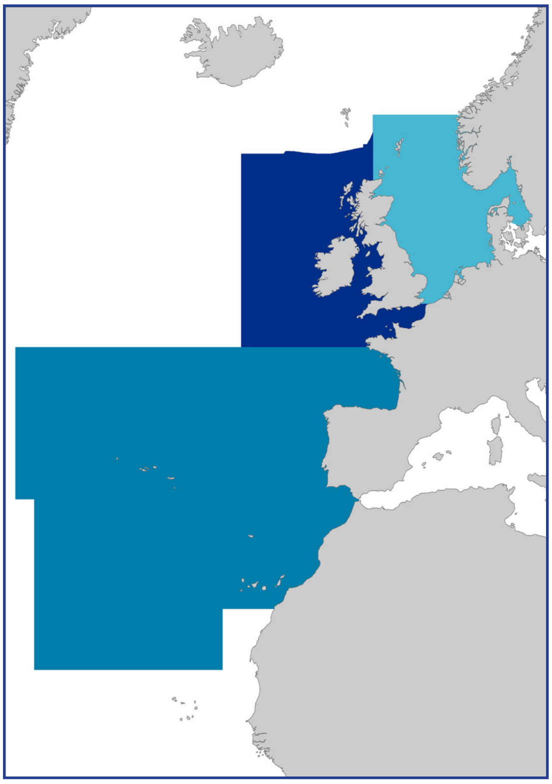

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