Distribution of fish species for the generic Appropriate Assessment for the construction of offshore wind farms

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Summary

The Dutch government aims at the production of 450 MW of electricity by offshore wind farms by 2010 and 6000 MW by 2020. Possibly the construction, exploitation and dismantlement of the wind farms will influence fish in the North Sea, which are protected under the European Habitat Directive or are considered as prey for other Habitat Directive species such as marine mammals. Deltares will use this study as input for the generic 'Appropriate Assessment' (environmental impact study) for the building of offshore wind farms, as required by the Habitat Directive.

In this study we have provided an overview of relevant information for a number of important fish species in the North Sea in relation to coastal Natura 2000 areas and future wind farms: herring, plaice, twaite shad, allis shad, Atlantic salmon, sea lamprey and river lamprey. For each species maps have been made that show general distribution patterns of eggs or larvae, juveniles and adults, based on survey data on a large scale over the last decade. It was not possible to provide very detailed data of fish abundance for the areas where the wind farms are planned, since such data are not available. Only for salmon an estimate of the natural mortality is provided. For the other species the natural or background mortality could not be determined due to effects of fisheries and/or a lack of knowledge. Finally, a short overview is given of the impact of other human activities on fish. In general it is thought that the construction and usage of wind farms will not have significant effects on the fish populations on a North Sea scale. The effects on fish larvae are not considered in this report however, and are estimated in a parallel study by Deltares.

1. Introduction

1.1 Background of the current study

The Dutch government aims at the production of 6000 MW of electricity by offshore wind farms by 2020. The wind farms will be built in the Dutch Economic Exclusive Zone (EEZ) outside the 12 nm zone and north of the Euro-Meuse channel (Figure 1). Deltares has been asked by Rijkswaterstaat, the manager of the Dutch territorial waters (the qualified authority), to produce a 'generic appropriate assessment', as is obliged under the Habitat Directive (92/93/EEC). This assessment is restricted to the effects of the construction, the exploitation and dismantlement of offshore wind farms in the North Sea on the conservation status of protected species, such as fish that are mentioned in the Habitat Directive Annex II. The focus of the assessment is on the effects of underwater noise produced by the aforementioned activities. Deltares will produce a generic Appropriate Assessment based on distributional data and literature studies on fish distribution done by IMARES in combination with studies and data on underwater noise and effects on fish by other parties.

1.2 Conservation objectives for Dutch Marine Natura 2000 areas

The above mentioned generic Appropriate Assessment for the construction and exploitation of wind farms is required since these activities may have indirect effects on the ecosystem in Natura 2000 areas in the North Sea and coastal zones. The Netherlands have formulated conservation objectives for the Natura 2000 network consisting of 162 terrestrial, fresh water and marine areas in the Netherlands (LNV 2006). For the marine areas the main conservation objectives can be summarized as follows:

<u>Open water:</u>

- Sandbanks: For the marine open waters the aim is to conserve the sandbanks (habitat 1110b) and several bird species that rely on fish and benthos as a food source. Furthermore, in this habitat fish populations should have a more natural population structure.
- Marine mammals: The quality of marine mammal biotopes should be improved.
- Intertidal sandbanks and biogenic reefs: In the Wadden Sea, biogenic structures (mussel beds) should be developed in the intertidal sandbank habitat (1110a). Furthermore, the function of the Wadden Sea as a biotope for the eider and the common scoter should be conserved as well as the function of the area as a nursery area (kinderkamer) for fish.
- Fish eating birds: The function of the marine open waters as a feeding area for fish eating birds should be conserved, notably for black necked grebe, great crested grebe and red-brested merganser.

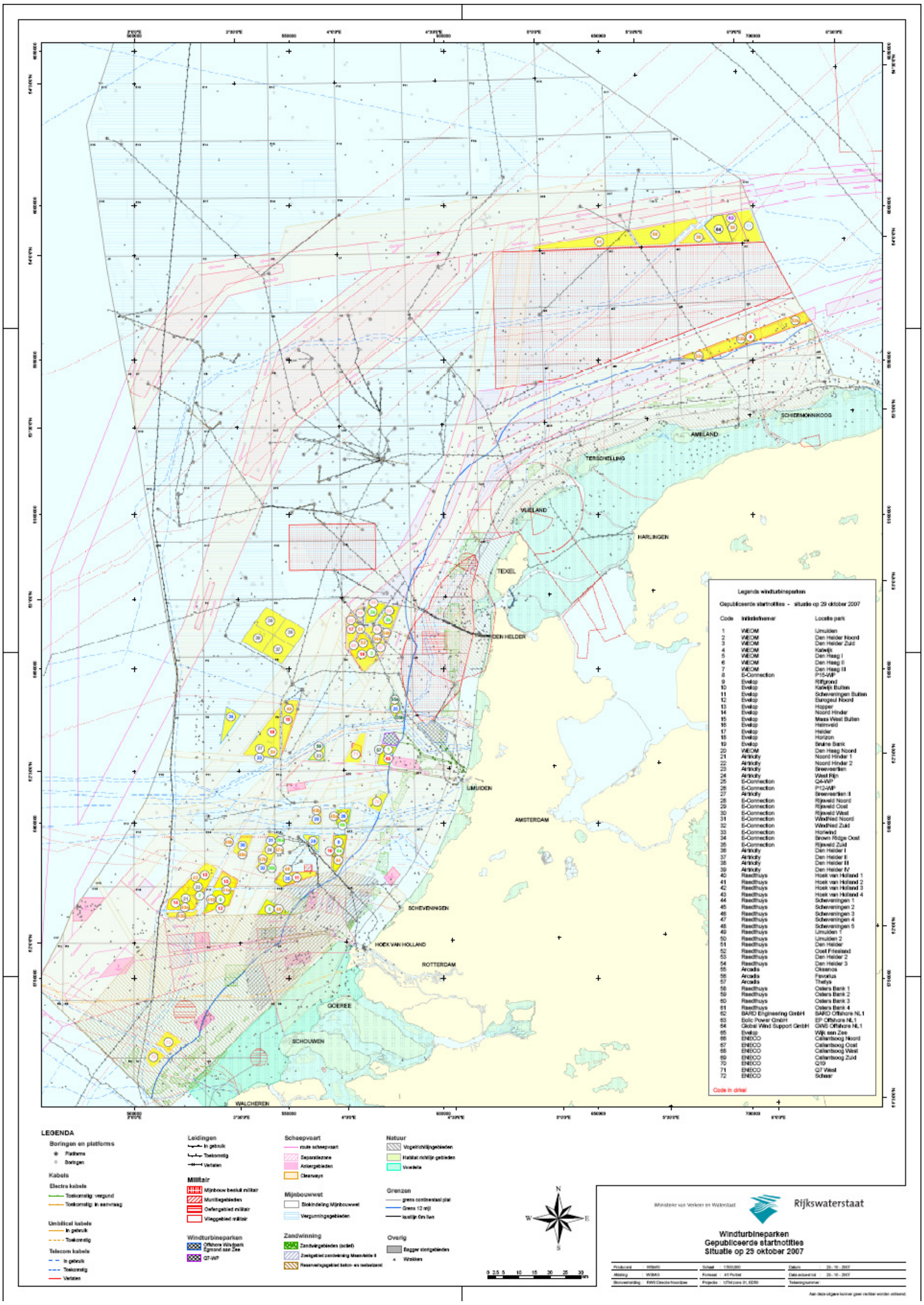


Figure 1. Possible locations for wind farms on the Dutch EEZ, indicated by the yellow areas (source: Rijkwaterstaat).

Fresh water/seawater transitions:

- Estuaries: The quality of the Westerschelde estuary should be improved and the quality of the Eems-Dollard estuary should be maintained.
- Recovery of the Haringvliet: in the Haringvliet area more impact of salt water is desired to improve the quality of the area for migratory fish species (salmon, allis shad, twaite shad, sea lamprey).
- Recovery of the fresh water/salt water transitions: in the Wadden Sea recovery of the fresh water / salt water transitions is important for migratory fish (river lamprey).
- Twaite shad: The hinterland for twaite shad (fint) should be improved by conserving the connection with the Elbe river and the Eems river.

The conservation objectives for the other parts of the marine waters such as tidal flats, sandbanks and beaches, salt marches and brackish vegetations are less relevant and will not be treated in this study, but can be found in the 'Doelendocument' (LNV 2006).

When activities, such as building wind farms, possibly have a direct or indirect influence on the Natura 2000 areas and the above mentioned conservation goals, they should be studied in an 'Appropriate Assessment'. The outcome of the study may have consequences for the project concerned. More information on the procedures can be found in the Doelendocument (LNV 2006) and associated documents. More information on the Natura 2000 areas in the Netherlands can be found on the website of the Ministry of Agriculture, Nature and Food Quality (www.minlnv.nl).

1.3 Conservation objectives for the German Wadden Sea

For the German part of the Wadden Sea the following area specific objectives were officially formulated in 2007 (http://www.umwelt.schleswig-holstein.de/servlet/is/77788/2007-04-23_Amtsblatt_VSG_NP.pdf).

The general aim for the German Wadden Sea is to conserve:

- The natural geomorphologic dynamics
- The natural hydrophysical and hydrochemical status and processes
- The natural state of the sediment and currents in the coastal area
- The complex biotopes such as structure and function of the habitats present (for details see the above mentioned link)
- The highest possible water quality

The conservation objectives for the Habitat Directive Annex II species (priority species) are in short:

Allis shad, twaite shad:
Conservation of:

- The tidal influence
- The natural dynamics of the coastal sea and tidal inlets
- A barrier-free area between the sea and the lower parts of the rivers
- A stable population

Grey seal, harbour seal
Conservation of:

- A viable population and a natural reproductive capacity including the survival of pups
- A natural dynamical environment with bays and sandbanks
- The concentration of toxic substances should be minimized
- Quit resting places, and very quit places to give birth
- Areas with a low impact of noise
- A species rich fauna (fish, shrimp, bivalves, crabs, etc.) that serves as a basis for food

Harbour porpoise
Conservation of:

- A viable population should be conserved with a natural reproductive capacity and natural survival of young animals.

- Natural coastal waters with emphasis on the productive shallow water zones up to 20 m depth
- Their food source, especially herring, mackerel, cod, whiting and gobies.
- Low disturbance areas with little underwater noise for calving and nursing

Furthermore

- The load of toxic substances in coastal waters should be as low as possible.
- Collisions with ships should be avoided
- Fisheries that are dangerous to whales/dolphins should be avoided.

Bottlenose dolphin (Annex IV, important species, but not priority species)
Conservation of:

- Natural coastal waters of the North Sea
- Areas with little underwater noise
- Fish stocks that serve as food
- The load of toxic substances in coastal waters should be minimized
- Avoidance of collisions with ships
- Avoidance of fisheries that are dangerous to dolphins/whales

This overview is not complete due to the short time frame that was available for the study. However, more information on the Natura 2000 areas in Germany can be found on the websites: http://www.natura2000-sh.de/ and www.bfn.de. The other German Natura 2000 sites and UK sites are not treated in this chapter. For UK the most informative site is http://www.jncc.gov.uk/.

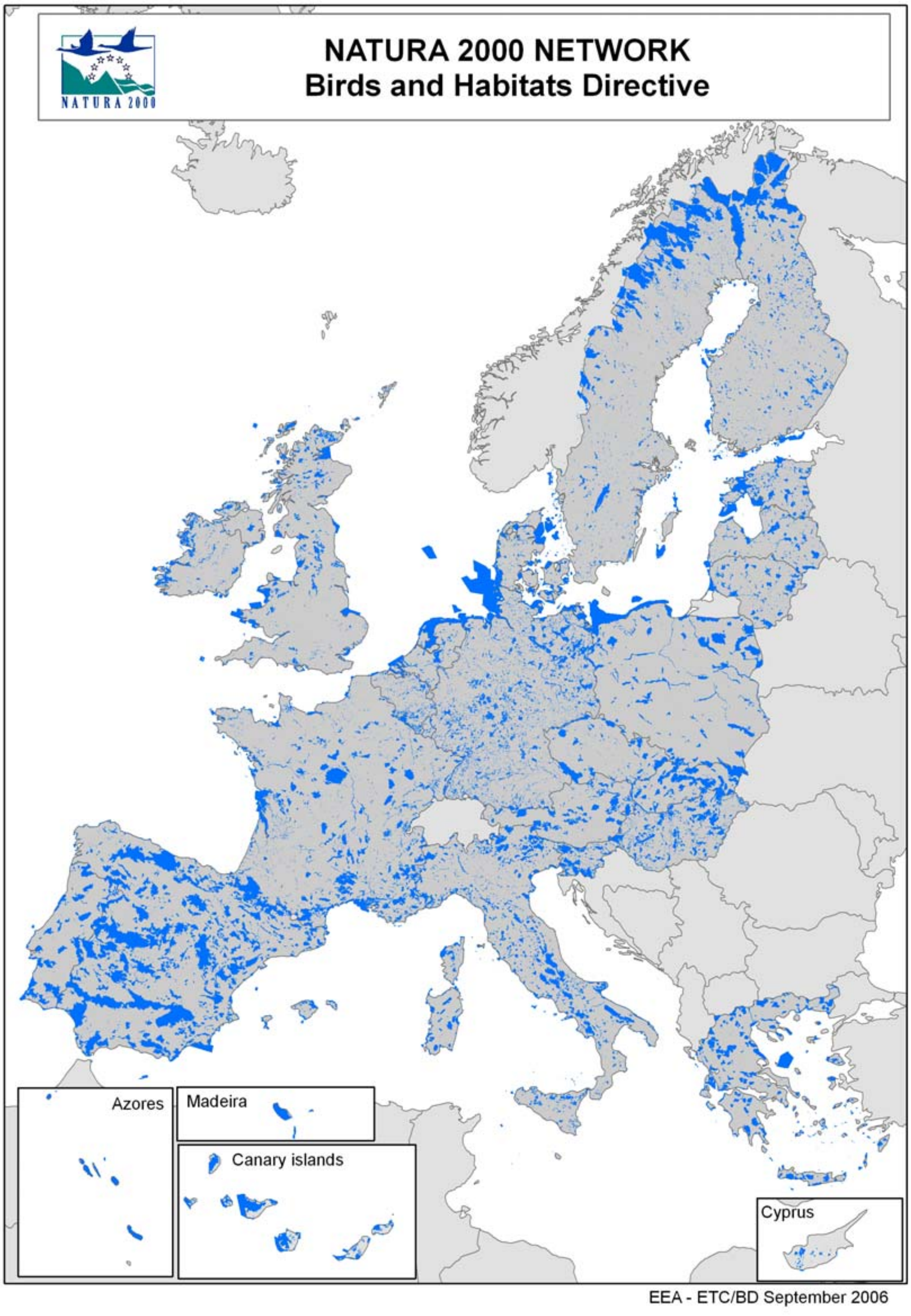


Figure 2. Natura 2000 areas in Europe, September 2006. In the North Sea no additional off-shore areas have been added so far (source: http://biodiversity.eionet.europa.eu/activities/Natura_2000/n2k_0608_300dpi.jpg).

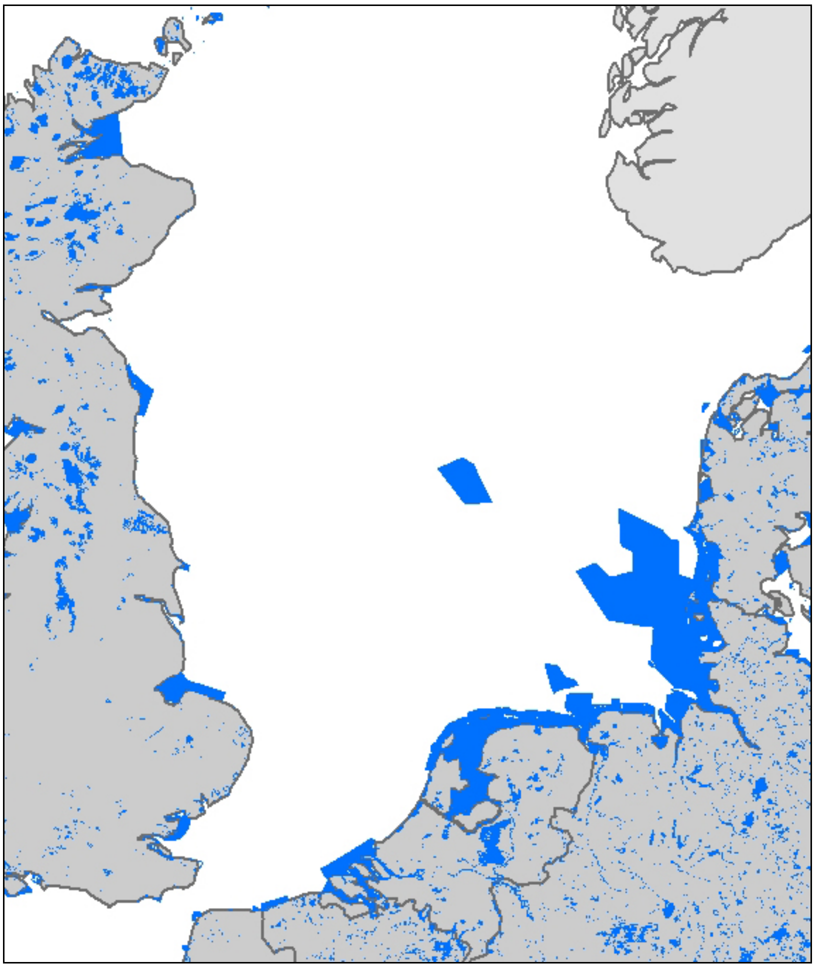


Figure 3. Detail of Figure 2: Natura 2000 areas in the North Sea. In the North Sea no additional off-shore areas have been added so far (source: http://biodiversity.eionet.europa.eu/activities/Natura_2000/n2k_0608_300dpi.jpg).

2 Assignment

To compose the generic Appropriate Assessment, Deltares has asked IMARES to provide an overview of the current knowledge on the spatial and temporal use of the North Sea by a number of fish that are protected under the Habitat Directive (Annex II) (allis shad, twaite shad, Atlantic salmon, sea lamprey and river lamprey) and of two common species: herring and plaice that serve as an important food source for e.g. marine mammals, which are also protected under the Habitat Directive. These two species were chosen by Deltares and IMARES for two reasons: herring is very sensitive to sound (e.g. Enger 1967) while plaice is not (e.g. Chapman & Sand 1974), making them a sensible selection for this study. Furthermore, a pragmatic reason underlies the choice of plaice and herring in this study: for these 2 species a larval transport model has been developed during the Maasvlakte-II studies (Bolle et al. 2005) which will be re-used for the generic Appropriate Assessment by Deltares. Studying more than two species was not feasible given the short time frame in which the study had to be performed, although the sand eel for example is probably a very important prey as well.

In this report we provide a brief overview of existing and lacking knowledge on the above mentioned fish species in the North Sea. We also attempt to define the important gaps in the information.

3 Survey methods of fish populations

3.1 Monitoring of fish in marine areas

3.1.1 Survey information

The data used are derived from four surveys: the International Bottom Trawl Survey (IBTS), the Demersal Fish Survey (DFS), the International Herring Larvae Survey (IHLS), and the Plaice and Cod Egg Survey (PLACES). The first three surveys are executed annually, the latter only once. Note that all surveys differ in their design, and that they only supply relative data (not absolute) on the spatial and temporal state of fish populations.

<u>IBTS - International Bottom Trawl Survey</u>
The International Bottom Trawl Survey is organised under the auspices of ICES, to map the distribution of fish populations in the North Sea, Skagerrak and Kattegat and to estimate the recruitment of several roundfish species. The surveys are conducted annually during the first quarter (February) since 1965. From 1991 to 1995 surveys have been carried out on a quarterly basis, herewith providing a full description of the seasonal distribution of the stocks sampled. The following years (1996 - present), the majority of participating countries has only carried out surveys twice a year: a first quarter survey (February) and a third quarter survey (August). Stratification of the survey grid is based on ICES statistical rectangles (one degree longitude x 0.5 degree latitude). Each rectangle is usually fished by two different countries, so that at least two hauls are made per rectangle.

The sampling method consists of 30 minute hauls with fishing speed of 4 knots using a GOV trawl net during daytime. A GOV is a bottom trawl net with a vertical opening of 5 m, a horizontal opening of 20 m and a door spread (between the boards) of 70-120 m. After sorting the catch into species, a length distribution is obtained. Where the numbers of individuals are too large for them all to be measured, a representative sub-sample is selected of at least 50 fish. The otoliths are removed from target species and stored for age determinations in the laboratory. Catch data together with specific information like haul position, survey area etc. are reported to the ICES DATRAS database annually. The data are combined from all surveys and expressed as number per hour per haul. For further information we refer to the IBTS-manual (Van Damme et al. 2005, Anonymus 2006).

<u>DFS - Demersal Fish Survey</u>
The Demersal Fish Survey (DFS) is an inshore survey, carried out by the Netherlands since 1969. This survey covers coastal and estuarine areas from the south of the Netherlands to Esbjerg in Denmark, including the Wadden Sea and Eems-Dollard estuary and the Wester- and Oosterschelde. In this report only data for the Dutch Natura 2000 sites are shown.

For this DFS survey a 3 m (estuaries) or 6 m (coastal seas) beam trawl is used. The survey was originally designed to monitor the abundance of 0 and 1-group plaice and sole. It is carried out once a year in September–October and sampling is stratified by geographical area and depth (5 m depth classes). Trawling details such as position, date, time and depth are recorded for each haul. The catches are sorted on board. For each haul, catch numbers and length frequency distributions of all fish species are recorded. In case of large catch numbers a random sub-sample consisting of at least 50 individuals is measured. Furthermore a length-stratified sample is taken by area to establish age-length-keys. The catch, trawl and age data (expressed as numbers per hour) are stored in the IMARES database “FRISBE”, and available for analysis and calculation of abundance indices. For further information we refer to the DFS-manual (Van Damme et al. 2005).

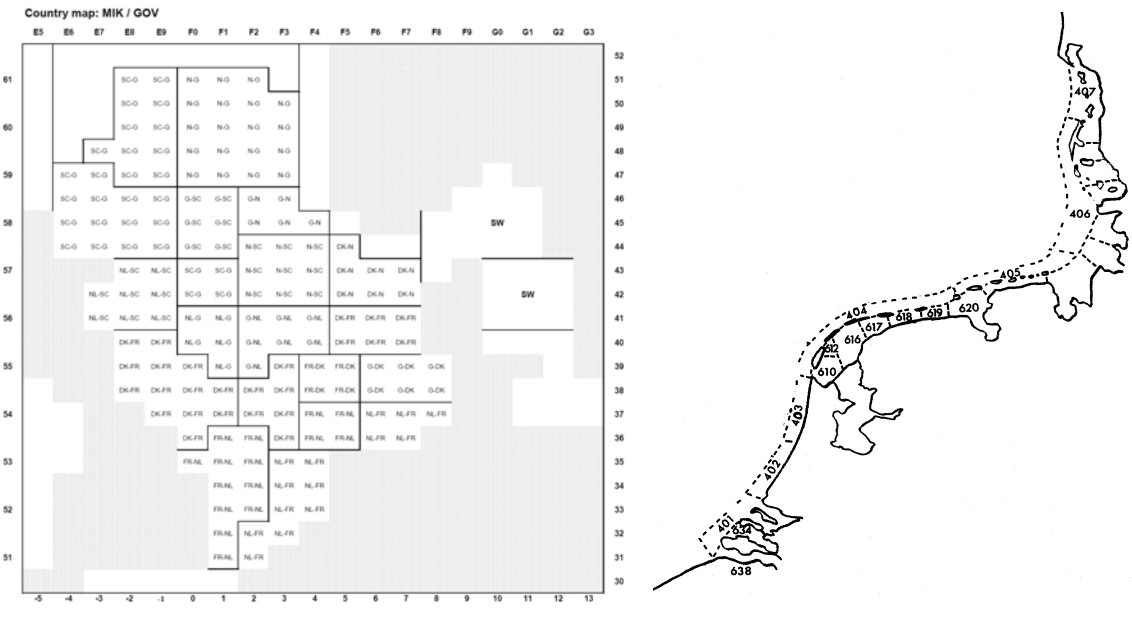


Figure 4. Survey-grid of the international 1st quarter North Sea IBTS (left) and the geographical areas covered by the Dutch DFS (right).

IHLS International Herring Larval Surveys
The international herring larval surveys in the North Sea and adjacent areas are in operation since 1967 and coordinated by ICES. The main purpose of this programme is to provide quantitative estimates of herring larval abundance, which are used as a relative index of changes of the herring spawning stock biomass in the assessment.

The larvae surveys are carried out in specific time periods and areas, following the autumn and winter spawning activity of herring from north to south, thereby covering the Orkney/Shetland area, the Buchan region, the Central North Sea and the Southern North Sea. Catch data together with specific information like haul position, survey area etc. are reported to the ICES International Herring Larvae database annually. The database contains information about the surveys conducted since 1972. The IHLS manual describes most aspects of the methods used in the surveys (Anonymous 2008).

PLACES - Plaice and Cod Egg Survey
In 2004, ichthyoplankton surveys covering the whole North Sea were conducted to comprehensively assess the spawning areas of cod and plaice. The survey itself was titled PLACES (Plaice and Cod Egg Survey). Several research institutes from England, the Netherlands, Germany, Denmark, and Norway participated in PLACES. Subsamples of eggs that were “cod-like” in appearance were presorted from samples at sea and preserved in ethanol for analysis using species-specific genetic probes. The remainder of each sample was preserved in formalin, and the ichthyoplankton was identified later, using traditional visual methods. A full account of the material and methods used, plus initial results of the distributions of cod and plaice spawning, can be found in Fox et al. (2005). The ICES Cooperative Research Report No 285 presents the distributions and abundances of eggs and larvae of among other species plaice identified from the survey series (Taylor et al. 2007).

3.1.2 Data aggregation

Juveniles/adults
Distribution maps are mainly based on data from the IBTS and made for two time periods, 1991-1996 and 1997-2006 (see Table 1). The resolution of the maps is 1/9 ICES rectangle (20° longitude by 10° latitude; ≈ 10*10 nautical miles). In combination with a time period of several years, such a resolution guarantees a good coverage of the stations fished. During the early ‘90s the IBTS was carried out in all 4 quarters, which provides information

on seasonality of the whereabouts of fish in the North Sea. The period 1997-2006 represents the current distribution of the fish, but data are only available for the 1st and 3rd quarters. Note that the Natura 2000 areas are only sampled during the 3rd quarter, and moreover by a survey (DFS) that differs from the one covering the North Sea (IBTS). The sampling method in the Natura 2000 areas is consequently different from the one in the North Sea, therefore a straightforward comparison with the North Sea catches is not possible.

For the abundant species (herring and plaice), the survey catches are presented as average catch in numbers per hour. A distinction has been made between juveniles and adults, in which juveniles are defined as all individuals smaller than 24 cm for herring and smaller than 33 cm for plaice, following the separation used in the Atlas of North Sea Fishes (Knijn et al. 1993).

For the Habitat Directive species, the catches are shown as presence/absence, because catches are very small. Since the determination of some of these rare species is often not reliable during research surveys (Daan 2001, Ter Hofstede & Daan 2006), salmon ('zalm') and trout ('forel') were grouped at the genus level *Salmo* spec, and twaite shad ('fint') and allis shad ('elft') as *Alosa* spec, following Ter Hofstede and Daan (in prep). It is relevant to bear in mind that probably most of the *Salmo* spec are trout and most of the *Alosa* spec are twait shad.

Eggs/larvae

The catch data of herring larvae were treated likewise the data on juveniles/adults (see above). This means that the average distributions for the period 1997-2006 were calculated by quarter with a resolution of 1/9 ICES rectangle (20° longitude by 10° latitude; ≈ 10*10 nautical miles). The only difference is that following the design of the survey, the catches are presented as average catch in numbers per m^2 instead of per hour (see Table 1).

Also the catches of plaice eggs are expressed as numbers per m^2, however since the PLACES survey was a one-off event, actual catches per station are presented in stead of the average per 1/9 ICES-rectangle.

Table 1. Overview of data used for the creation of distribution maps.

Species	**Life stage**	**Data**	**Area**	**Quarter**	**Period**	**Survey**	**Source**
Herring Plaice	adult, juvenile	mean catch per hour	North Sea	1,3	1991-1996 1997-2006	IBTS	DATRAS
				2,4	1991-1996		
			Natura 2000	3	1991-1996 1997-2006	DFS	IMARES
Herring	larvae	Mean catch per m^2	North Sea	1,3,4	1997-2006	IHLS	ICES- IHLS
Plaice	eggs	Catch per m^2	North Sea	1	2004	PLACES	ICES
Salmo spec *Alosa* spec Sea lamprey	all	Presence/ absence	North Sea	1,3	1991-1996 1997-2006	IBTS	DATRAS
				2,4	1991-1996		
			Natura 2000	3	1991-1996 1997-2006	DFS	IMARES

3.2 Monitoring of diadromous fish species

3.2.1 Monitoring programmes:

There are two types of monitoring programmes in the larger freshwater water bodies in the Netherlands: 1) the so-called passive monitoring with fyke nets, and 2) active monitoring with gears such as trawl nets and electro fishing. In this report an overview is given of all programmes that are carried out by IMARES and a fyke net programme by NIOZ at one location in the Wadden Sea.

1) The passive monitoring programmes used for this study (Figure 5) are:

<u>FGRF</u> (fyke net monitoring rivers): fyke net registrations on 29 locations in the large rivers in which all fish species, except the common occurring fish species Roach, Bream, Perch, Pikeperch, Ruffe are registered during April to November. In addition, at two sites in the coastal zone near the mouth of the Haringvliet, a year-round monitoring with 4 fyke nets at each location occurs. This monitoring programme (MWTL; Monitoring Waterstaatkundige Toestand des Lands) is executed in cooperation with commercial fishers and runs parallel to their commercial conduct of business which is addressed to the catch of eel. The monitoring started in 1992 (Wiegerinck et al. 2008).

<u>FGRZ</u> (Salmon fyke net monitoring): this type of monitoring is done by commercial fishers at 4 locations: River Meuse near Lith, river Waal near Woudrichem, the River Lek near Hagestein and the IJssel/Nederrijn. In addition to Salmon and Sea Trout also other caught migratory fish are registered (Wiegerinck et al. 2008).

<u>Diadromous Fish monitoring</u> in the Wadden Sea in the scouring basin near Kornwerderzand: in this fyke net monitoring the entire spectrum of fish species is registered and is executed by hired commercial fishers since 2000. In 2001 the program has been standardized (Tulp et al. 2007).

<u>FYMZ</u> (rare fish monitoring Lake IJssel): this program has been executed since 1994 by selected commercial fishers. The program had not been executed in 2004 due to a lack of financial resources. Since 2001 the fishers also register their effort in numbers of fyke nets per day per period per location (Leijzer et al. 2007)

<u>MVII</u>: monitoring in the Maasvlakte 2. This program started in the fall of 2004. Temporarily, the catches are registered with 4 fyke nets near the present Maasvlakte (Tulp et al. 2006).

<u>NIOZ</u>: fyke net monitoring. Catches of one fyke are monitored by NIOZ at 't Horntje at Texel since 1960 during spring and autumn (Philippart et al. 1996).

These 'passive' monitoring programmes are, given their large fishing effort and covering different seasons throughout the year, especially suited to determine rare fishes or species that are only present temporarily. Both apply to the diadromous species treated in this study. However, because these intensive programmes are mostly not carried out by researchers but by commercial fishers in addition to a commercial fishery, variation and precision of the data is usually higher than in more standardized monitoring programmes.

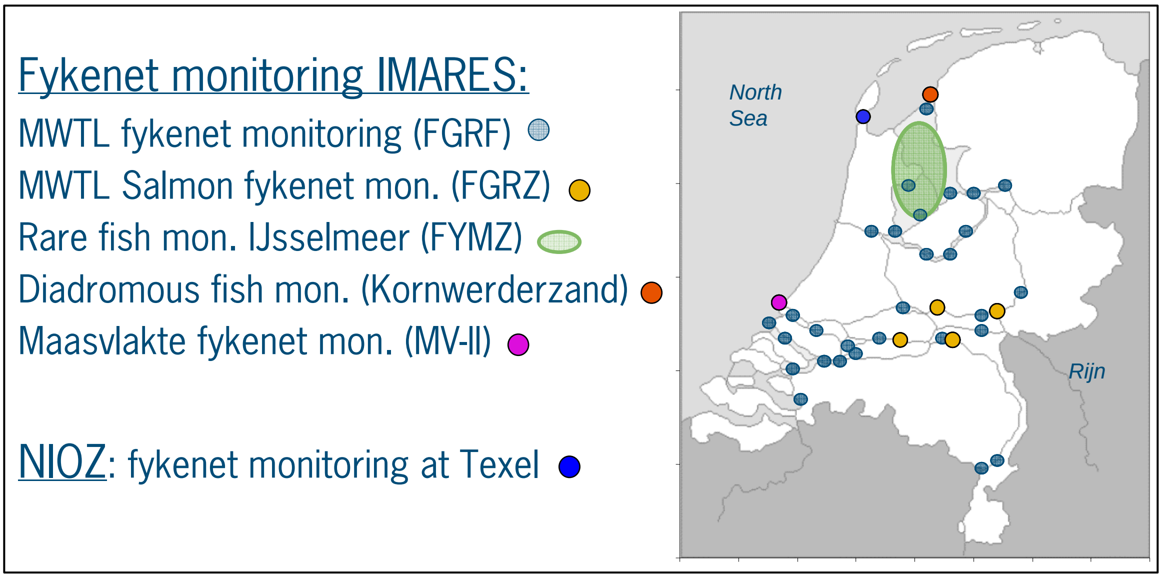


Figure 5. Overview of locations of the different passive monitoring programmes used for this study. MWTL = Monitoring Waterstaatkundige Toestand des Lands. FGRF = fyke net monitoring rivers; FGRZ = salmon fyke net monitoring; FYMZ = rare fish monitoring Lake IJssel; MVII = Maasvlakte II; NIOZ = Royal Netherlands Institute for Sea Research.

2) The active monitoring used for this study were:

MWTL fish monitoring in large rivers with the research vessel "Schollevaar". In this monitoring the open waters are sampled with a 3m beam trawl. Riverbanks are sampled with an electro landing net. 11 core areas are yearly sampled this way, partly in spring and partly during autumn. this monitoring started in 1992 and since 1997 the program has been executed as in its present form (Patberg et al. 2006)

MWTL fish monitoring Lake IJsselmeer, Lake Markermeer and Lake Ketelmeer with research vessel "the Stern". In this program the open waters are sampled using an (electro-) trawl net. This monitoring program started in its present form since 1989 (Jansen et al. 2007b).

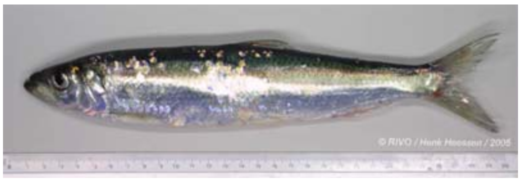
The diadromous fish species studied in this report were nearly absent in the active monitoring programmes performed by IMARES. Only adult river lamprey was caught on some occasions in the Rhine near Nijmegen and in the lower section of the Rhine. The other species appeared to be too rare to occur in the active monitoring programmes.

Other research programmes with data on diadromous fish species:

In addition to the above long-term monitoring programmes, also other datasets on the occurrence and migratory behaviour of diadromous species are present: 1) monitoring fish passage through fishways (Winter 2007), 2) tagging experiments with sea lamprey in the Lek/Nederrijn branch of the Rhine (Winter 2007), and 3) telemetry experiments with sea lamprey (in the lek-Nederrijn) and Atlantic salmon in the lower reaches of the Rhine and Meuse (Bij de Vaate & Breukelaar 2001, Jurjens 2006, Jansen et al. 2008). For further details on these studies see the referenced reports. These studies mainly focus on the behaviour, timing and local abundance of adult diadromous fish in the rivers during their upstream migration. Based on this information, a rough estimate of total numbers of adult fish using Dutch rivers is given in Jansen et al (2007a, 2008).

4 Herring - *Clupea harengus*

4.1 Population size



Herring is numerically one of the most important pelagic species in several North Atlantic ecosystems and intensive exploitation goes back several centuries. Stocks have fluctuated enormously in the past to both natural variations in the environment and human exploitation. Over the last 60 years, the North Sea herring has undergone huge changes. Following a period of heavy overexploitation, the stock of North Sea herring collapsed in the mid-1970s. After the fishery was stopped almost completely, the herring stock increased to above the precautionary level of 1.3 million tonnes and is now considered to have full reproduction capacity (Heessen et al. 2005).

4.2 Important areas

Herring is widely distributed in the Northwest and Northeast Atlantic. Within the Northeast Atlantic, they are distributed from the northern Bay of Biscay to Greenland, and east into the Barents Sea (Whitehead et al. 1986). This report focuses only on North Sea herring.

4.2.1 Reproduction areas

Herring are demersal spawners that need specific gravely substrates to spawn. Eggs are laid in dense layers on coarse sand, gravel, shells and small stones. 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 (Heessen et al. 2005). Larvae are pelagic and metamorphosis takes place after 2-7 months depending on spawning time.

The fish congregate on traditional spawning grounds, many of which are on shoals and banks and in relatively shallow water, approximately 15-40 m deep. North Sea herring has various spring and autumn spawning sub-populations, each with specific spawning sites.

Spawning of the main North Sea herring population begins in the north of the North Sea in September and then progresses southwards with time, ceasing in January in the eastern English Channel (Boeke 1906, Cushing & Burd 1957, Zijlstra 1969, Burd & Howlett 1974). Smaller coastal populations tend to spawn in spring (Redeke & Van Breemen 1907, De Groot 1980, Fox 2001, Roel et al. 2004).

The number of spawning sites varies with stock size (Burd 1985, Corten 1999, 2001a) with a decline in spawning sites at lower biomass of North Sea herring. Due to the phenotypic differences exhibited by herring associated with each spawning site or spawning season (Cushing 1958, Baxter 1959, Baxter 1963, Almatar & Bailey 1989, Hulme 1995), the fecundity and egg size and obviously the associated sea temperatures result in larvae with different characteristics and energetic requirements (Sinclair & Tremblay 1984, Heath et al. 1997). These differences are called meristic characteristics and are indicative of temperature at spawning time and are not indicators of different races of herring.

There are three major populations of autumn spawners (Figure 6), which mix on the feeding grounds for the majority of the year, but then migrate to specific grounds to spawn (Daan et al. 1990):

a) Buchan/Shetland herring spawn off the northeast Scottish and Shetland coasts during August to September.
b) Banks or Dogger herring spawn in the central North Sea off the northeast English coast during August to October.

c) Southern Bight/Downs herring spawn in the Southern Bight of the North Sea and English Channel during November to January.

These three autumn spawners represent the bulk of the North Sea herring stock, but some spawning also occurs in spring (e.g. the Skagerrak spring spawners that are related to the Western Baltic stock and Thames Estuary stocks).

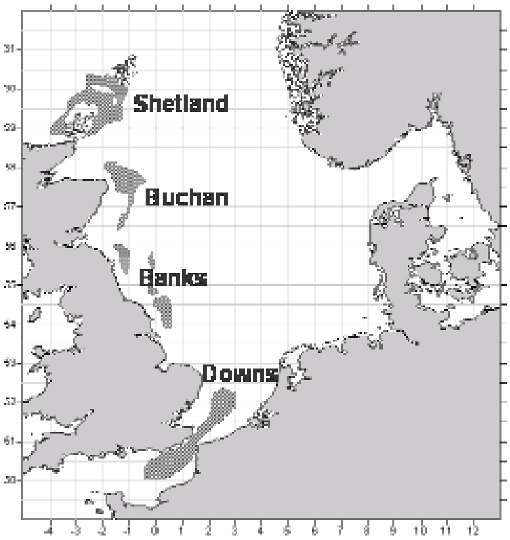


Figure 6. Herring *Clupea harengus.* Spawning grounds of North Sea herring, based on the catches during ICES herring larvae surveys in the period 1996-2003 (from Dickey-Collas 2004).

Figure 7. Herring larva *Clupea harengus*. Photo: Van Damme/Tribuhl, Wageningen IMARES

Habitat characteristics: Herring deposit their egg masses on gravel-type habitats, and geographically the spawning grounds tend to be well-defined, although the intensity of spawning varies and over time some areas may be deserted and new ones be occupied. The habitats of juveniles and adults are primarily pelagic, and many hydrographical features (e.g. temperature, depth of the thermocline, degree of mixing, proximity of frontal systems), as well as abundance and composition of the zooplankton on which they feed affect the distribution (Maravelias 1997, 2001).

4.2.2 Foraging areas

Herring form large shoals, with diurnal vertical migration patterns through the water column. During the day, herring shoals tend to remain close to the sea bottom or in deep water to a depth of 200 m, and they move towards the surface at dusk and disperse over a wider area during the night. These diurnal vertical movements may be related to the availability of prey items, or to the stage in their maturation cycle (Harden-Jones 1968).

Throughout the year, herring displays no pattern in seasonal distribution. Juveniles always tend to occur in shallower water in the eastern North Sea (German Bight), quite separate from the adults, whom are distributed in the northwest.

4.2.3 Migration routes

Herring larvae are transported by passive drift from the spawning grounds eastward to the nursery areas. The German Bight and the Dutch coastal zone are the main nursery areas for herring in the southern North Sea and larvae from both the northern and southern spawning components of North Sea herring enter the area in spring. The IBTS data indicate that the German Bight is the most important nursery area for herring (Figure 8, Figure 9)

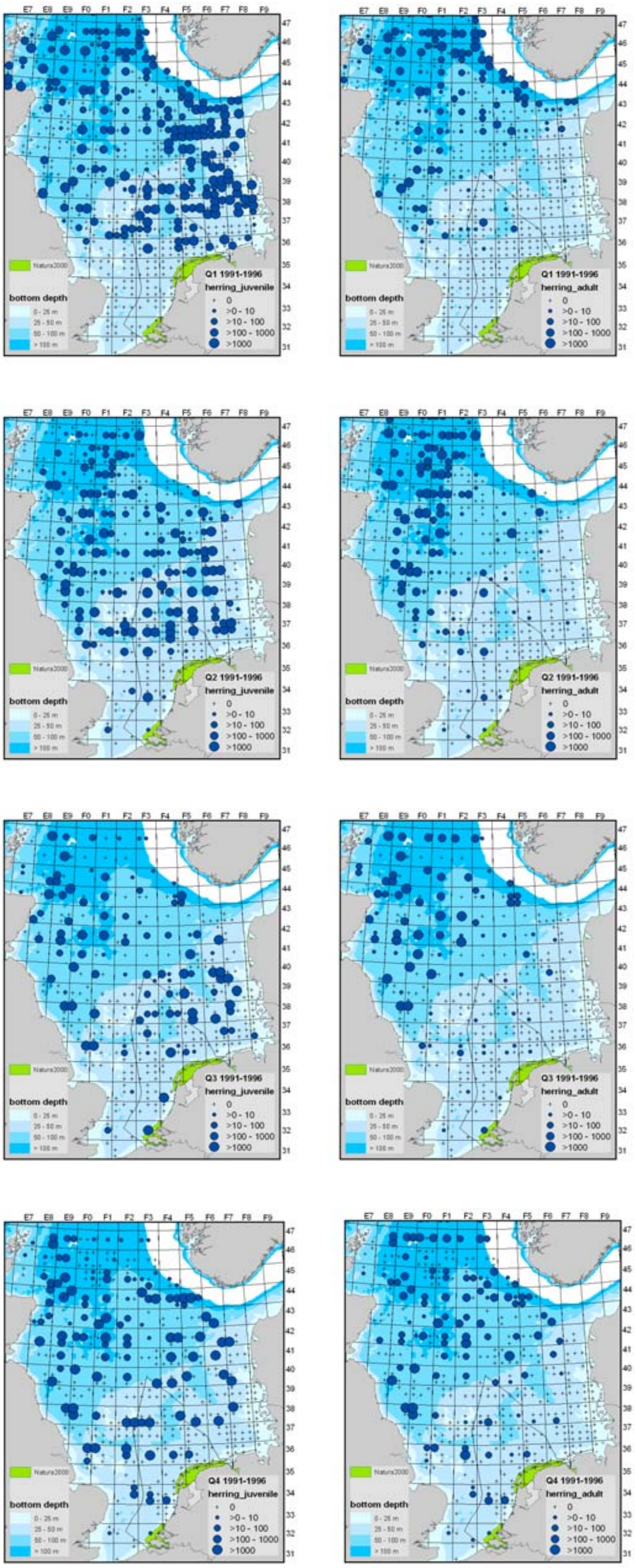
After spending their first few years in coastal nurseries, two-year-old herring move offshore into deeper waters (MacKenzie 1985), eventually joining the adult population in the feeding and spawning migrations to the western areas of the North Sea. These migration patterns, developed as juveniles, are generally regarded as being relatively constant over periods of several years despite environmental variation (Corten 2001b).

4.3 Function of Natura 2000 areas and the effect of wind farms

It is clear from Figure 9 that juvenile herring is rather abundant in the Dutch Natura 2000 areas during the 3rd quarter, though adult herring are practically not caught. However, compared to the German Bight, the Dutch Natura 2000 areas are of minor importance to herring as nurseries.

Herring larvae migrate from the spawning grounds (Figure 6, Figure 10) along the Dutch coast to the nursery areas (Figure 8), and on their way they will pass by or through the future wind farms. From an investigation of the possible effects of the Maasvlakte 2 land reclamation project on the transport of herring larvae in the southern North Sea it was concluded that changes in water movements due to the presence of the Maasvlakte 2 area would not have a direct effect on the recruitment or the abundance of herring in the Wadden Sea, nor would the disturbance and the expected increase of turbidity during the construction phase have an effect on the transport of larvae (Bolle et al., 2005). Based on these conclusions, we would not expect a significant effect on the migration of herring larvae due to the (construction of) wind farms either (Dickey-Collas, pers. com.).

Juvenile	Adult	1991-1996



Quarter 1
IBTS

Quarter 2
IBTS

Quarter 3
IBTS

Quarter 4
IBTS

Figure 8. Herring *Clupea harengus*. Distribution of juvenile (left) and adult (right) herring in the North Sea during 1st, 2nd 3rd and 4th quarter in the period 1991-1996. Data are derived from the IBTS. No data = no sampling. + = 0.

Juvenile	Adult	1997-2006
		Quarter 3, only IBTS
		Quarter 3, IBTS and DFS

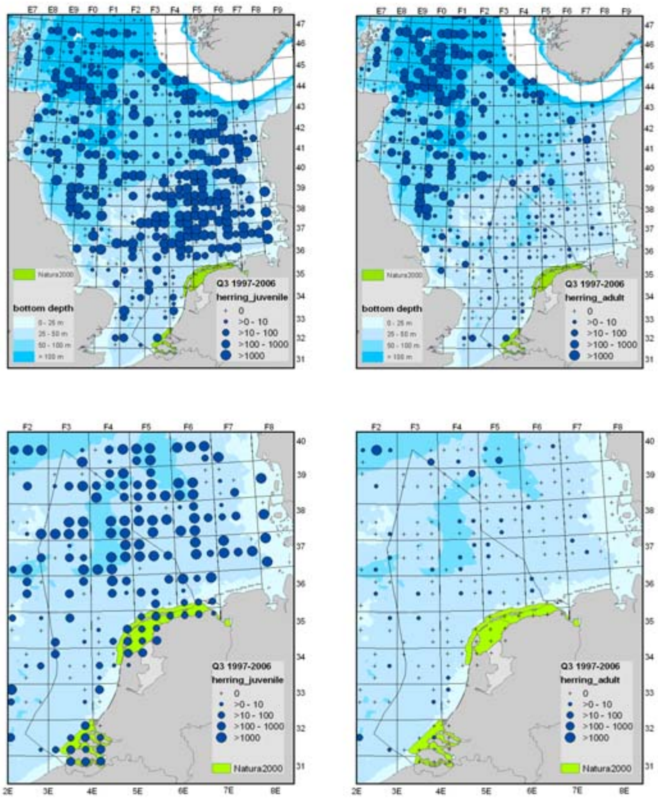


Figure 9. Herring *Clupea harengus*. Distribution of juvenile (left) and adult (right) herring in the North Sea during the 3rd quarter in the period 1997-2006. Note that the data for the Natura 2000 areas are derived from the DFS, and for the North Sea from the IBTS. Both data series can not be compared, as described in the methods section of this report. No data means not sampled.

Herring larvae 1997-2006

Quarter 1	Quarter 3	Quarter 4

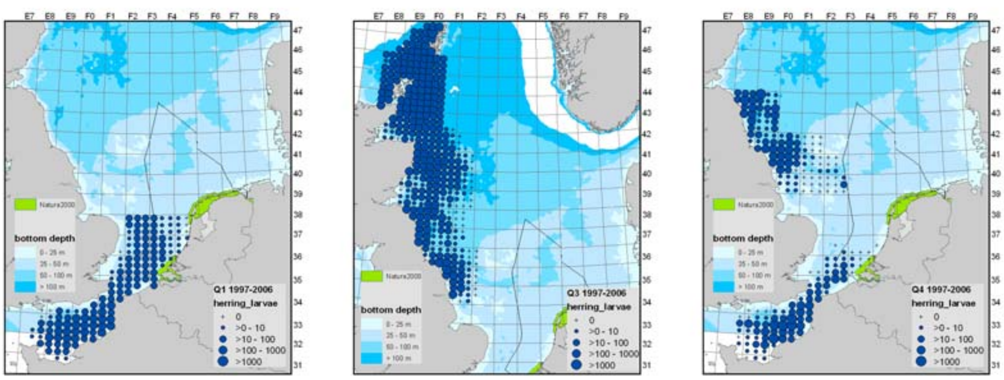


Figure 10. Herring *Clupea harengus*. Distribution of herring larvae in the North Sea during 1st, 3rd and 4th quarter in the period 1997-2006. Data are derived from the IHLS. Areas with no data are probably less important and are therefore not sampled due to a restricted budget for the sampling programme.

5 Plaice - *Pleuronectes platessa*

5.1 Population size

Plaice is an important species in European waters that has been exploited for centuries. It is also one of the best studied species in the North Sea. The size of the spawning stock of plaice in the North Sea varied around 300,000 t between 1957 and 1989. It then declined sharply to just above the limit reference point (B_{lim} = 160,000 t). The stock was considered to be at risk because of reduced reproductive capacity (Heessen et al. 2005). The last 10 years, the spawning stock fluctuated around 220,000 t. Currently the stock is estimated to be at full reproductive capacity again (ICES assessment 2008).

5.2 Important areas

Plaice may be found from the western Mediterranean Sea, along the coast of Europe as far north as the White Sea and Iceland. Occasionally they occur off Greenland (Whitehead et al. 1986). This report focuses only on plaice in the North Sea.

5.2.1 Reproduction areas

Plaice spawn over most of the offshore and deeper parts of the southern North Sea and off the east coast of Britain from Flamborough Head to the Moray Firth, from where the pelagic eggs and larvae are transported effectively to the coastal nurseries. Centres of high egg production are the eastern Channel and the Southern Bight, while egg production around the Dogger Bank and in the German Bight is more diffuse (see Figure 11) (Harding et al. 1978, Heessen & Rijnsdorp 1989, Taylor et al. 2007). Peak spawning time shifts from early January in the eastern Channel to mid-February in the German Bight and off Flamborough (Rijnsdorp 1989).

Tagging experiments have shown strong fidelity behaviour, individual fish returning to the same spawning and feeding areas, where they had been before (Hunter et al. 2003).

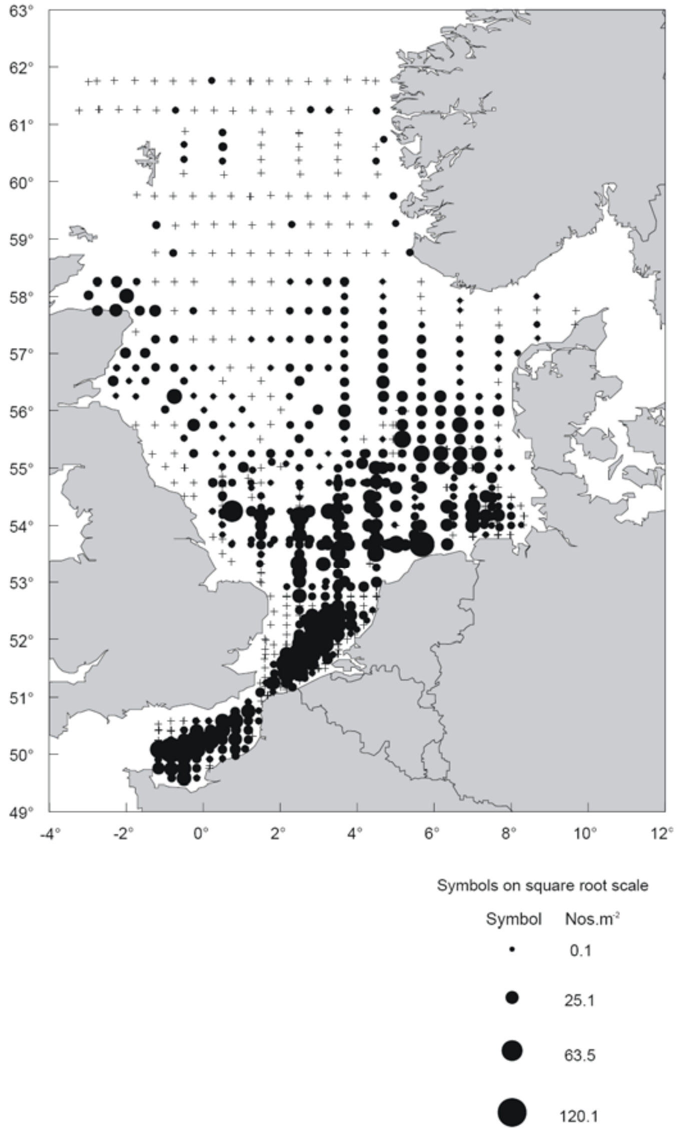


Figure 11. Plaice Pleuronectes platessa . Composite map of distribution of plaice eggs in the North Sea during 1st quarter in 2004 (number/m^2). Data are derived from the project PLACES. (+)= 0; No data = not sampled. More details on the sampling programme can be found in Taylor et al. 2007.

5.2.2 Foraging areas

Juveniles are found in shallow coastal waters and outer estuaries. As they grow older they gradually move into deeper water. In recent years, there have been changes in the distribution of juvenile plaice, and juveniles now seem to occur in deeper waters than before (Van Keeken et al. 2007).

Coastal and inshore waters of the North Sea represent essential nursery areas, with the Wadden Sea being the most important one (Kuipers 1977). Sediment characteristics are thought to be of importance during larval settlement and positive relationships have been found between grain size and plaice densities (Zijlstra et al. 1982). For example in the Wadden Sea, protected muddy areas are less populated by plaice than more exposed sandy flats (Berghahn 1986). The preference for sandy sediments remains during the entire lifespan, although older age groups may be found on coarser sand.

One-year-old plaice show a strictly coastal distribution while the older age classes gradually disperse further offshore, away from the nursery areas (Rijnsdorp 1989, Rijnsdorp & Beek 1991). Nursery grounds for plaice tend to be very shallow, 0-group even staying behind in pools on the tidal flats in estuaries during ebb.

During summer, juvenile plaice are concentrated in the Southern and German Bights, and also occur along the east coast of Britain (see Figure 12, left). Juveniles are found at lower densities in the central North Sea, and are virtually absent from the north-eastern part. Additional survey information indicates seasonal changes in distribution pattern with 0- and 1-group fish leaving the estuaries and shallow coastal zone in winter and returning in spring. Adult plaice have a broader distribution in the North Sea (see Figure 12, right).

5.2.3 Migration routes

Plaice make selective use of tidal currents in various stages of their life. Metamorphosing larvae enter estuarine nursery areas by migrating to midwater during the flood tide and settling at the bottom during ebb (Rijnsdorp et al. 1985, Van der Veer et al. 2000) juvenile plaice in the Wadden Sea move with the flood tide onto sandy flats to feed and move back to the surrounding channels on the ebb tide (Kuipers 1973). Adult plaice are also known to make use of tidal stream transport during their seasonal migrations between spawning and feeding grounds; they move downstream with the tide in mid-water, and stay on the bottom during the opposing tide, showing little or no movement (Greer Walker et al. 1979, Metcalfe & Arnold 1997).

Part of the North Sea plaice population spawns in the Channel and returns to its feeding grounds in the North Sea afterwards. Progeny of this group enters the North Sea as eggs and early larvae by passive drift (Houghton & Harding 1976). In the North Sea, spawning-feeding migrations occur along a north-south axis. The distances over which the plaice migrate increase with size.

5.3 Function of Natura 2000 areas and the effect of wind farms

Coastal and inshore waters of the North Sea are of extreme importance to the North Sea plaice stock. The most important nursery areas for North Sea plaice are the German Bight and the Wadden Sea. These nurseries contribute the majority (50-90 %) of the recruits to the North Sea plaice stock (Zijlstra 1972, Van Beek et al. 1989).

Plaice migrates from the spawning grounds into the nursery areas back to the feeding grounds, and on its way it will pass by or through the future wind farms. From an investigation into the possible effects of the Maasvlakte 2 land reclamation project on the transport of plaice larvae in the southern North Sea it was concluded that changes in water movements due to the presence of the Maasvlakte 2 area would not have a direct effect on the recruitment or the abundance of plaice in the Wadden Sea (Bolle et al. 2005). Based on these conclusions, we would not expect a significant effect of changes in water movement due the (construction of) wind farms either. However, if the construction of wind farms causes direct mortality of the larvae this may affect the proportion of larvae reaching the nursery areas. This is being examined in the modelling part of the generic Appropriate Assessment by Deltares.

For foraging plaice (juveniles and adults), it may be hypothesized that the physical presence of wind farms may slightly diminish the potential habitat, i.e. sandy bottoms in stead of concrete constructions. Furthermore, in the case the wind farms can be used as a refuge by fish predating birds such as cormorants, the predation pressure on the plaice population will increase (Rijnsdorp, pers. com.).

Also, the wind farm area will most likely be closed for fisheries. Although at first, the plaice stock may locally benefit from this exclusion of fishing pressure, a recent study showed that bottom trawling disturbance benefits the small benthic invertebrates that form the food source for plaice, and that the restriction of fishing in a certain area had a negative impact on the production of food for plaice (Hiddink et al. in press). Therefore, on the long term it is all together expected that plaice will not benefit from wind farms. However, these effects on foraging juveniles and adults are local effects and it is unlikely that these small scale effects will have a mayor impact on the North Sea plaice stock or on the population numbers in the Natura 2000 areas.

Juvenile	Adult	1991-1996

Quarter 1

Quarter 2

Quarter 3

Quarter 4

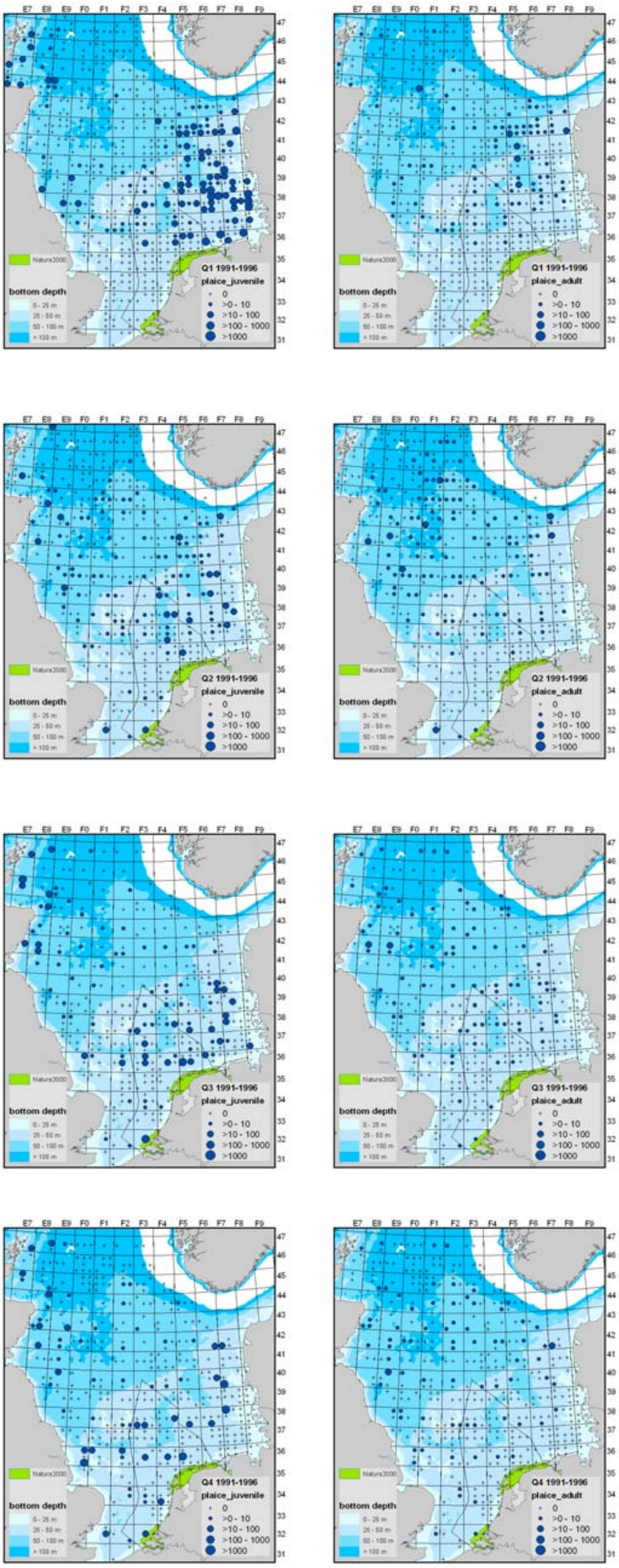
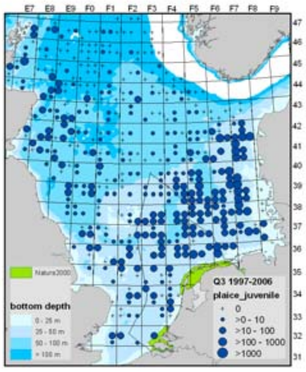
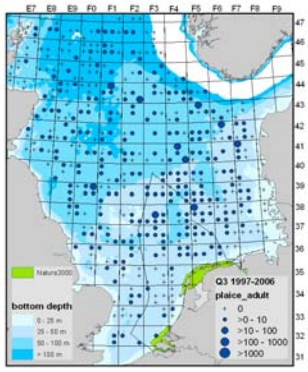


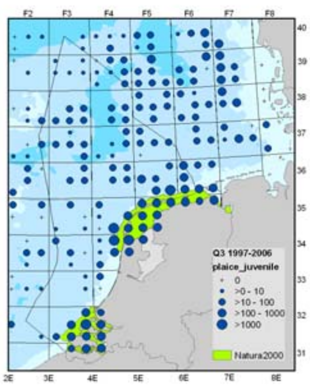
Figure 12. Plaice *Pleuronectes platessa.* Distribution of juvenile (left) and adult (right) plaice in the North Sea during 1st, 2nd 3rd and 4th quarter in the period 1991-1996. Data are derived from the IBTS.

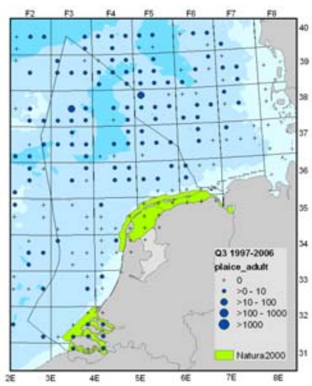
Juvenile	Adult	1997-2006





Quarter 3, IBTS



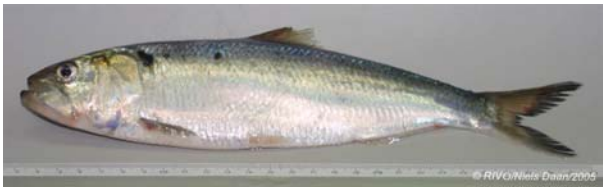


Quarter 3, IBTS and DFS

Figure 13. Plaice *Pleuronectes platessa*. Distribution of juvenile (left) and adult (right) plaice in the North Sea during 1st and 3rd quarter in the period 1997-2006, Note that the data for the Natura 2000 areas (green areas) are derived from the DFS and the data for the North Sea from the IBTS. The DFS and IBTS data can not be compared.

6 Twaite shad – *Alosa fallax*

6.1 Population size



Twaite shad *Alosa fallax* is an anadromous clupeid species. Twaite shad occurs along most of the west coast of Europe, from southern Norway to the eastern Mediterranean Sea, and in the lower reaches of large accessible rivers along these coasts (Maitland & Hatton-Ellis 2003). In the North Sea area spawning populations have been recorded in Denmark, Germany, Britain, Belgium and the Netherlands. Most populations showed a strong decline in the course of the 20th century (Aprahamian et al. 2003). The spawning populations in the lower reaches of the Rhine, Meuse and Scheldt rapidly declined after the 1940s and presumably became extinct in the 1970s (De Groot 2002). The main causes for these declines where the deterioration of water quality, overfishing (only after the extinction of salmon, houting and allis shad the river fisheries shifted more towards the commercial less interesting twaite shad, De Groot 2002), habitat loss and migratory barriers. In the Netherlands, the poor water quality and overfishing lead to a serious decline (and presumably the extinction of twaite shad in the Scheldt, Maes 2001), where after the completion of the Delta works (inducing migration barriers and loss of intertidal habitats) caused the extinction of the spawning population in the lower Rhine and Meuse (De Groot 2002).

The largest remaining spawning population in the North Sea is present in the lower reaches of the Elbe in Germany (Thiel et al. 1996, Thiel & Backhausen 2006). At present, in the Netherlands only occasional spawning is indicated: in some years in the Eems-estuary (Kleef & Jager 2002, Jager & Kleef 2003) and some records of spawning twaite shads in the Lower Rhine (e.g. for the first time since decades local fisher Klop observed typical twaite shads spawning behaviour: swimming in rapid circles at the surface the so-called 'rakken', in the Nieuwe Merwede in 2005). In the Scheldt Estuary twaite shads are increasing, though there are no indications that a spawning population is re-appearing (Maes 2001). The spawning stocks of the rivers Rhine, Meuse, Scheldt and Eems are thus either very small or still absent.

Whereas spawning is still rarely observed in the lower reaches of rivers in and near the Netherlands, twaite shad is frequently observed and caught along the entire coastal zone. The status and origin of these twaite shads is still unknown (Jansen et al. 2007a, Jansen et al. 2008).

6.2 Important areas

6.2.1 Reproduction areas

Historically the freshwater tidal zones of the Rhine, Meuse, Scheldt and Eems were important spawning areas for the twaite shad. At present, successful spawning takes place only in the Eems-estuary, but only in some years, and there are only anecdotic indications for spawning in the Rhine-Meuse delta. Although the water quality has improved, especially in the Rhine and to a lesser extent also in the Meuse and more recently in the Scheldt and a commercial fishery on twaite shad has ceased to exist, this has not lead to the return of a self-sustaining twaite shad population in the Dutch rivers. Habitat loss and migration barriers due to the many regulatory works in the lower reaches are presumably the most important remaining bottlenecks for the rehabilitation of twaite shad as a spawning population.

6.2.2 Foraging areas

Estuaries are the most important habitats for the larvae. During the first growing season the foraging areas are gradually extended to the coastal zone and twaite shads have grown to about 10-15 cm after one year (Maitland & Hatton-Ellis 2003). Juveniles and adults use a wider range of habitats from estuaries to open sea. Overall in the different surveys in the Dutch North Sea area, twaite shad is rarely occurring. Most frequently in the DFS, and especially in the Wadden Sea and Dollard-Eems estuary (Figure 17). To a lesser extent it is occasionally caught in the Voordelta area, along the Dutch coast and rarely in the more central parts of the North Sea. The same picture emerges from the German part of the North Sea (Stelzenmüller et al. 2004). Most twaite shad in the North Sea surveys concern juvenile shads. The used bottom trawls are presumably not very efficient in catching shads. Therefore, the surveys indicate a minimum appearance and the true abundance is believed to be higher, especially for the faster more pelagic larger shads. In the fyke net programmes also larger adult twaite shads are caught during the entire period April-October (Figure 14), suggesting that the coastal zone and to a lesser extent the lower reaches of the rivers are used for foraging by different age classes of twaite shad.

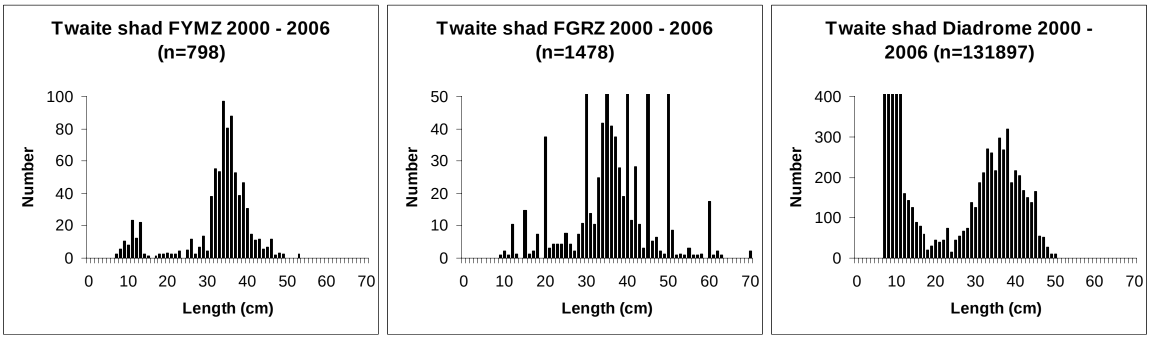


Figure 14. Length frequency distributions of twaite shads in three different fyke net monitoring programmes during 2000-2006: FYMZ (Rare fish Lake IJssel); FGRZ (monitoring rivers) and Diadromous fish programme in the Wadden Sea at Kornwerderzand (Bosveld, 2008). The few shads > 60 cm in FGRZ were presumably misidentified allis shad (*Alosa alosa*), see also discussion under allis shad.

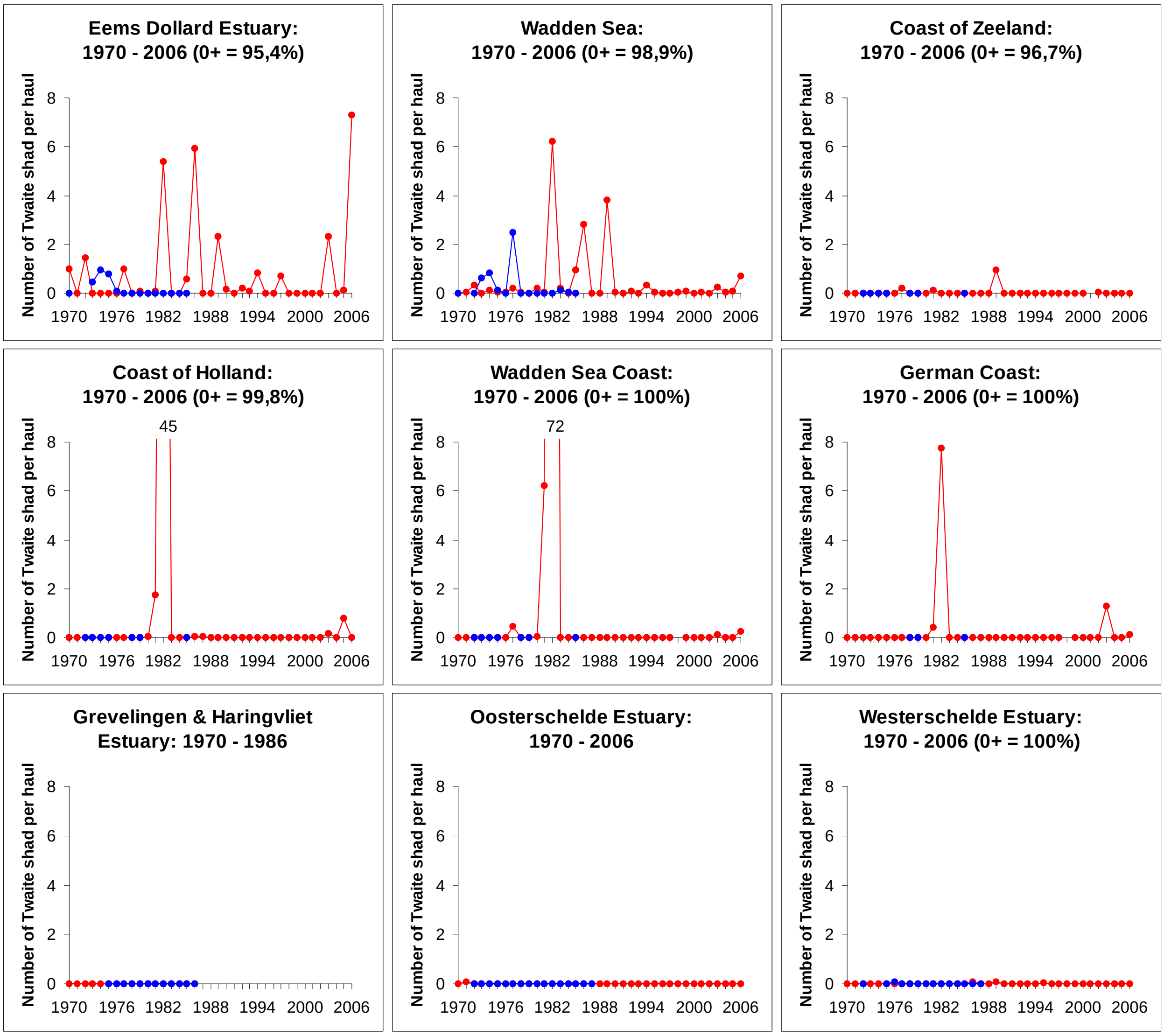


Figure 15. DFS monitoring: CPUE for Twaite shad per area (1970 – 2006). The red lines represent the autumn survey and the blue lines represent the spring survey (The German Coast represents only area 405 directly adjacent to the Netherlands) (Bosveld, 2008)

The occurrence of 0-group twaite shads in the different areas within the DFS survey during autumn (i.e. foraging areas) (Figure 15) appears to support that successful spawning occurs in some years in the Eems estuary. The occurrence in the Dutch Wadden Sea might be dispersal from the Eems estuary. Along the coast of Holland (from Hoek van Holland to Den Helder) and the North Sea Coast of the Wadden Sea only in 1982 substantial 0-group twaite shads were seen. The southern delta, Grevelingen, Oosterschelde and Westerschelde show very low numbers of twaite shad.

6.2.3 Migration routes

The semi-buoyant eggs are spent in the freshwater tidal zones of the lower reaches of rivers and develop in the estuaries. The 0-group young shads gradually disperse over a wider area along the coastal zones. Males start to mature after 3 years at a length of 25-30 cm, females do not start to mature until they are 5 years old. The adult shads migrate from marine and estuarine habitats into the lower reaches of rivers mainly during April-May for spawning. In Belgium, the Netherlands and Germany migration is usually limited to the freshwater tidal reach of rivers, although in some rivers (e.g. in Britain) twaite shads might migrate to reaches over 100 km from the river mouth (Maitland & Hatton-Ellis 2003). The adults move downstream after spawning and unlike salmon, lampreys and allis shad the majority return to spawn again in consecutive years.

The distribution of twaite shad along the German coast shows a similar pattern as along the Dutch Coast. Higher abundances were found in the direct coastal areas and lower number further off-shore (see Figure 16).

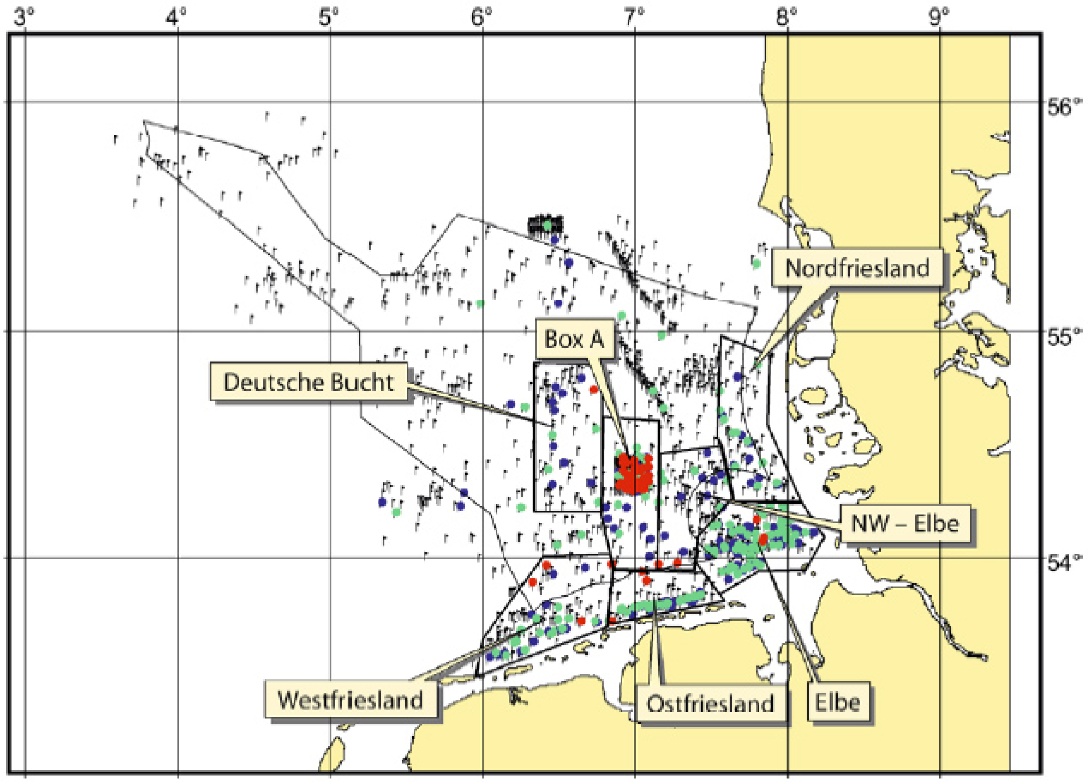


Figure 16. Distribution of all hauls and twaite shad catches from BFAFi (1978-2002) according to Klopmann et al. (2003). Flags represent individual hauls. Framed boxes: defined areas for evaluation of the spatial effort/catch proportion. Blue: first quarter, red: third quarter; green: fourth quarter. No records of twaite shads occurred in the second quarter, from Thiel & Backhausen (2006). Note that this map represents a 24 years period and that all seasons are included.

6.3 Function of Natura 2000 areas and the effect of wind farms

At present, within the Dutch marine and estuarine waters the Wadden Sea and Eems-Dollard Estuary appears to be the most important foraging area for 0-group twaite shads (Figure 14, Figure 15). Juvenile and adult twaite shads were found at all fyke net programmes along the entire coastline, mainly during summer and autumn. This indicates that the direct coastline and estuaries as used as foraging habitats, but from what spawning populations these twaite shads originate is unclear at this moment. For this, insight in individual migratory behaviour is needed using e.g. mark-recapture or telemetry experiments, and this is not an easy task with the relatively fragile twaite shads.

At present there are only indications that the Eems estuary is used for spawning in some years. For other river mouths or estuaries, the current data suggest that hardly any spawning takes place elsewhere.

On the use of more offshore habitats in the Dutch part of the North Sea little is known, since the active surveys using trawl nets are not best suited to catch pelagic twaite shads. Nor is anything known on the habitats used during wintering, because most monitoring programmes yield no data during November-March.

7 Allis shad – *Alosa alosa*

7.1 Population size

Allis shad can be found along the coasts of Western Europe from southern Iceland and Norway to Spain. They occur mainly in shallow coastal waters and estuaries, but during spawning they penetrate well upstream in the larger European rivers (Maitland & Hatton-Ellis 2003). Historically the large rivers around the North Sea contained large populations of allis shad, e.g. >100,000 allis shads were caught yearly in the lower reaches of the Rhine and Meuse around 1900 (De Groot 2002), but during the 20th century all these populations became extinct. At present the main populations occur in France and to a lesser extent Spain and Portugal (Maitland & Hatton-Ellis 2003). In the Netherlands and Belgium the allis shad became extinct in the 1930s due to water pollution, overfishing and migration barriers such as dams, sluices and weirs (De Groot 2002, Vrielynck et al. 2002). Nowadays, allis shad only sporadically occurs in the Meuse and Rhine, and it is most likely that these are strayers from other river populations. At present there are no indications that a self sustaining population is re-appearing in the rivers flowing through the Netherlands.

7.2 Important areas

7.2.1 Reproduction areas

Historically the main spawning grounds of allis shads migrating through the Netherlands were found in the German section of the Rhine in gravel beds in the mainstream. At present, only a few adult Allis shad are caught within the fyke net monitoring programmes, both in the Meuse and the Rhine. In the fish passage at Iffezheim in the Rhine in Germany, also only a few allis shads are observed passing per year (http://www.saumon-rhin.com).

7.2.2 Foraging areas

The young allis shad gradually move downstream and part of the young reach estuarine and marine habitats during the first year, the remainder during the second year. Juveniles and adult allis shads use estuaries, coastal areas and open sea for foraging (Maitland & Hatton-Ellis 2003). Only a few adult allis shad were caught in the North Sea where identification could be confirmed. Due to its high resemblance to the twaite shad, misidentification as twaite shad is very plausible, especially with the smaller individuals and in (inter)national monitoring programmes this can not be excluded (hence the maps in Figure 17). Twaite shads larger than 55 cm are very likely to be misidentified allis shads (see Figure 14). However, despite the potential underestimation of allis shad, this species is probably only very sporadically present in the North Sea nowadays.

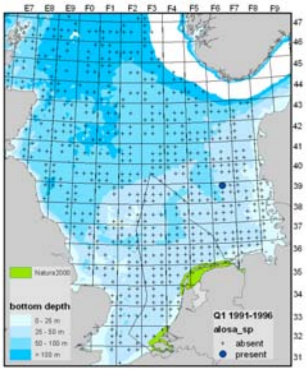
7.2.3 Migration routes

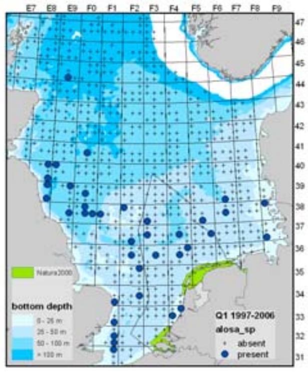
Adult allis shad migrate upstream rivers mainly in May (hence the name 'Maifisch' in Germany). In contrast to twaite shad, the vast majority of the allis shads only spawn once and then die.

7.3 Function of Natura 2000 areas and the effect of wind farms

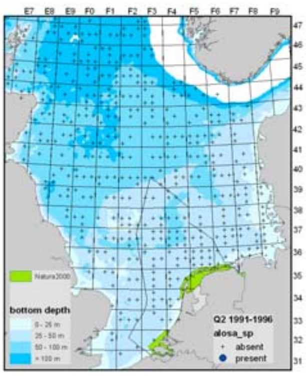
At present only strayers use any of the waters belonging to the Netherlands. There are no signs of a rehabilitation of a self-sustaining population. Therefore none of the areas currently plays a role for allis shad. In 2008, a reintroduction programme with allis shad starts in Germany within an EU-life project. This might change the status of the allis shad in the Netherlands in the near future, but only if the low rate of recolonisation is the true bottleneck at present. Whether this is the case, or that other bottlenecks still prevent a successful reappearance of allis shad is currently unknown.

1991-1996	1997-2006

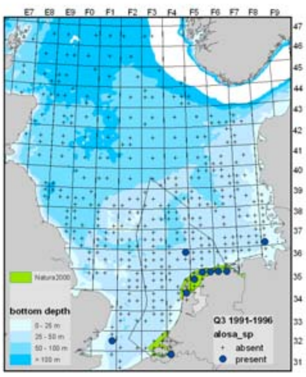


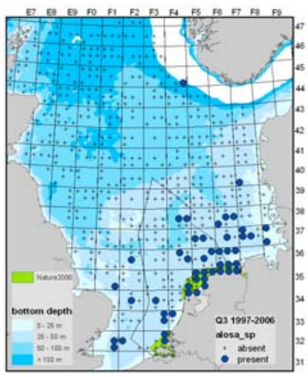


Quarter 1
IBTS data

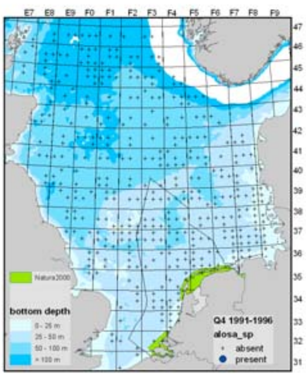


Quarter 2
IBTS data





Quarter 3
IBTS data (North Sea)
and DFS data
(Natura2000 areas)



Quarter 4
IBTS data

Figure 17. Twaite shad, allis shad *Alosa* spec. Catches of *Alosa* spec in the North Sea during 1st, 2nd 3rd and 4th quarter in the period 1991-1996 (left) and the 1st and 3rd quarter in the period 1997-2006 (right). The data are presence/absence data. Hence, IBTS and DFS data can be more or less compared. No data means not sampled.

8 Sea lamprey - *Petromyzon marinus*

8.1 Population size

Sea lamprey is distributed over both sides of the Northern Atlantic. In Europe sea lamprey is mainly found in the large rivers and adjacent seas around Portugal, Spain, France, Ireland, Britain, the Netherlands and Germany. As many other anadromous species, sea lamprey has declined strongly in the course of the 20th century, mainly due to water pollution, habitat loss and migration barriers and in addition also fishing in some countries. Little is known on historical population sizes. Homing, i.e. returning to the natal river, appears to be lacking in sea lamprey (Bergstedt & Seelye 1995). In stead, sea lamprey use the presence of pheromones excreted by larvae (so-called 'ammocoetes' that live burrowed in sediments of flowing rivers) as a cue (and 'proof' that this river is suitable for spawning and growing up of their kin) to migrate upstream rivers (Sorensen et al. 2005). Thus, unlike salmonids and shads, lampreys do not have specific 'river-populations'. Based on numbers caught in monitoring programmes and fish passages, it can be deduced that in some years an order of magnitude of 10,000 adult sea lampreys enter the Rhine catchment (Winter & Griffioen 2007, Jansen et al. 2008). Lower numbers enter the Meuse. Sea lamprey is rarely encountered in the Scheldt (Vrielynck et al. 2002).

8.2 Important areas

8.2.1 Reproduction areas

Sea lamprey use gravel beds in flowing freshwater as spawning habitats. Not much is known on the historical and present distribution and location of spawning grounds of sea lamprey in the Rhine, Meuse and Scheldt catchment areas. On the presence of sea lamprey in the Eems even less is known. Up to 200 adults pass the fishway at Iffezheim in Germany, suggesting that part of the incoming population spawns in upstream tributaries. Moreover, sea lamprey ammocoetes were found in the Roer, a tributary of the Meuse (Crombaghs et al. 2000). The sea lamprey favours gravel and fast flowing freshwater for spawning.

8.2.2 Foraging areas

Larvae disperse downstream from the spawning grounds to burrow in finer sediments in river basins and live as filter-feeders for 4-5 years before migrating to sea to live as parasites attached to larger fish and sea mammals for 2-3 years. Due to these foraging strategies, chances of detecting sea lamprey in conventional fish monitoring programmes are very low (see Figure 19). This and its presumed widely distribution and relative low abundance in foraging areas makes that the spatial occurrence during the freshwater and open sea stages is virtually unknown.

8.2.3 Migration routes

Adult sea lampreys move from the sea into rivers mainly during March-June. After spawning the adults die. The larvae disperse downstream to habitats with finer sediments within the river basin. After 4-5 years the juveniles (12-18 cm) migrate downstream to marine habitats. On the dispersal and spatial scales of movements within the marine parasitic life stages no knowledge is available.

8.3 Function of Natura 2000 areas and the effect of wind farms

The marine habitats potentially serve as a foraging habitat, but which areas and to which extent is unknown. The estuarine areas serve as corridors. The freshwater river habitats along the course of rivers serve as potential foraging habitats for the ammocoetes, but it is unknown which areas are important. This also applies to the spawning grounds, on which mostly only anecdotic information exists. Hence, the marine Natura 2000 areas potentially serve as foraging habitats and the estuarine areas as corridors, but the effect of wind farms is not clear.

Distribution along the German coast for lampreys gives a similar picture as along the Dutch coast (see Figure 18 after Thiel & Backhausen (2006)), that hardly any lampreys are caught in surveys along the coast or more offshore. The question rises whether lampreys are very rare indeed along the entire coast line of the Southern North Sea, or are they underrepresented due to the survey methods used. Our lack of insight in the behaviours and occurrence during the marine stages seriously hampers answering this question. Both options are still open.

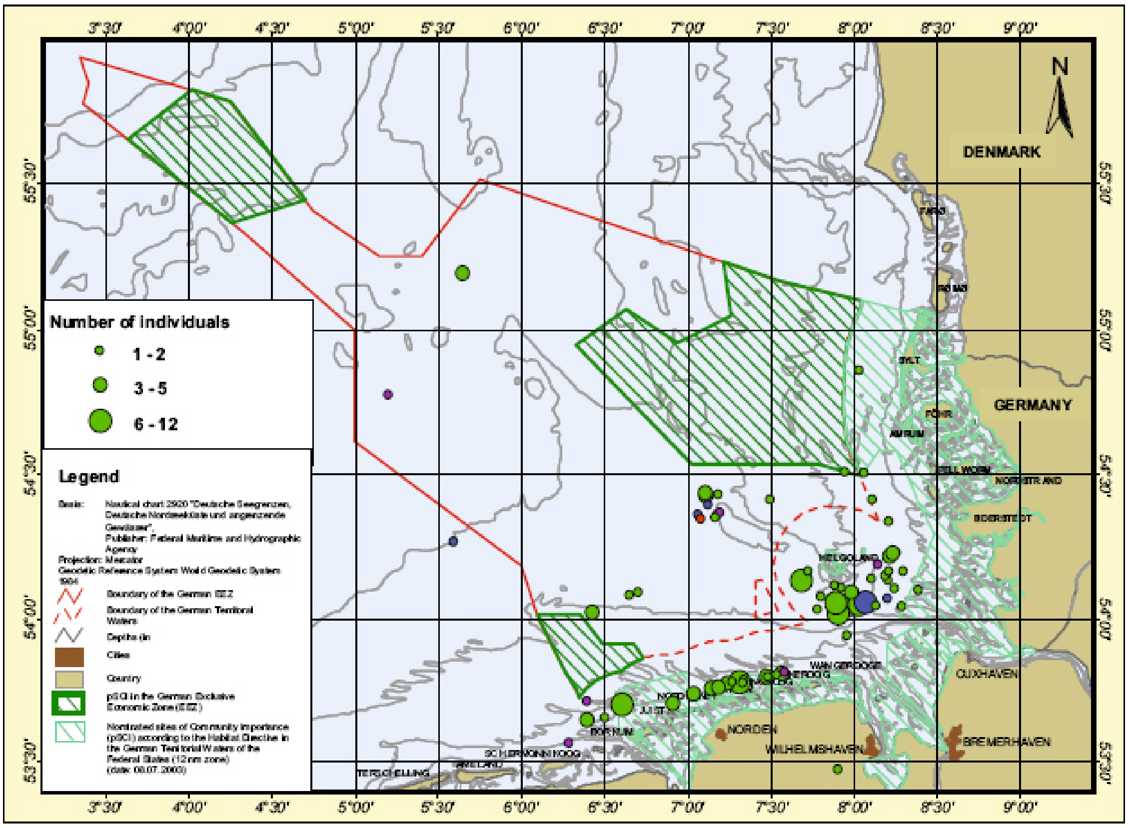
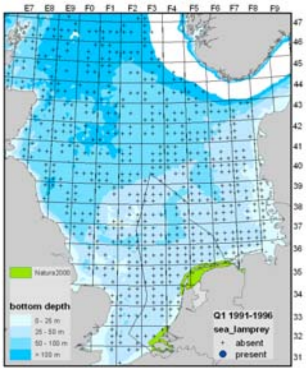
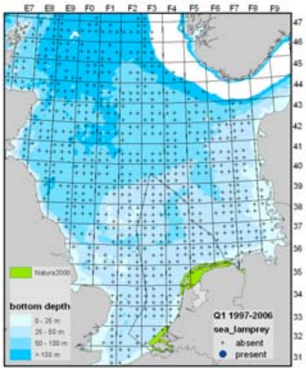


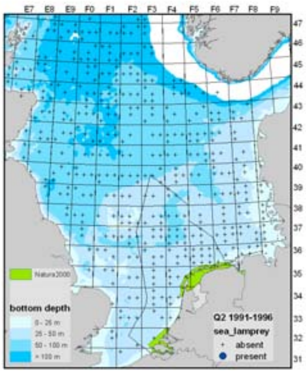
Figure 18. Distribution of lamprey catches (*L. fluviatilis* and *P. marinus*) from BFAFi in the German part of the North Sea (1978-2002) according to Klopmann et al. (2003). Purple: 1st quarter, red: 2nd quarter, blue: 3rd quarter, green 4th quarter, from Thiel & Backhausen (2006)). Note that this map represents a 24 years period and that all seasons are included.

1991-1996	1997-2006





Quarter 1
IBTS data



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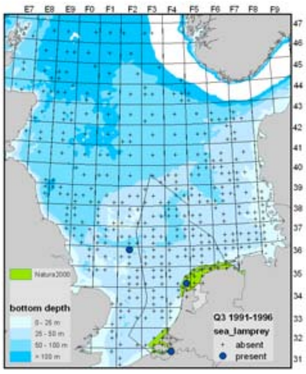
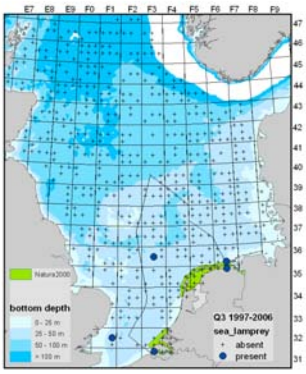
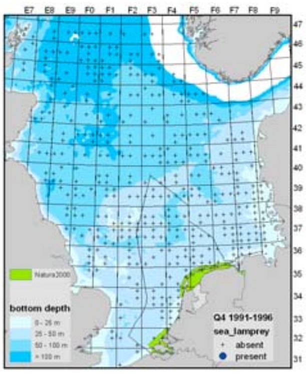




Quarter 3
IBTS data (North Sea) combined with DFS data (Dutch Natura 2000 areas)



Quarter 4
IBTS data

Figure 19. Sea lamprey *Petromyzon marinus*. Catches of sea lamprey in the North Sea during 1st, 2nd 3rd and 4th quarter in the period 1991-1996 (left) and the 1st and 3rd quarter in the period 1997-2006 (right). Dutch Natura 2000 areas are indicated in green. IBTS data are shown for all quarters, while DFS data are plotted in the 3rd quarter only in the Natura2000 sites. Data are present/absent data. Hence, IBTS and DFS data can be compared. No data means not sampled.

9 River lamprey – *Lampetra fluviatilis*

9.1 Population size

River lamprey has a more limited distribution than sea lamprey, being restricted to France, Ireland, Britain, Belgium, the Netherlands, Germany, Denmark and the Baltic. Historically the river lamprey was very abundant in the Rhine catchment area (Van den Ende 1847). At present, as deduced from monitoring data and fish passage surveys at least 100,000s of river lampreys are expected to enter the Rhine-Meuse catchment areas (Jansen et al. 2008). River lamprey increases in abundance during the last decades after a low in the 1960s and 1970s, but the present abundance is still much lower than historical levels. As described for sea lamprey, for river lamprey it is also likely that no specific river populations exist due to a lack of homing mechanisms.

9.2 Important areas

9.2.1 Reproduction areas

The river lamprey prefers gravel for spawning but other finer and coarser substrates appear to be acceptable for spawning as well. As a consequence more spawning in smaller brooks and lower reaches of rivers is observed for river lamprey in comparison to sea lamprey. But also on river lamprey much of the distribution of spawning grounds remains unknown. In the Netherlands, spawning was proven at least for the Drentsche Aa, the Roer and the Dommel (Winter & Griffioen 2007), where artificial riprap served as spawning substrate in some cases.

9.2.2 Foraging areas

The larvae (ammocoetes) disperse downstream from the spawning habitats to burrow in finer sediments (varying from sand to silt, (Winter & Griffioen 2007)). On the distribution of larvae in the river basins much remains unknown, but larvae were observed in a wide range of water bodies from small brooks, larger tributaries, to large branches of the Rhine and Meuse (Patberg et al. 2005, Winter unpublished data) and downstream to the harbours of Rotterdam (Kampen pers. comm.). After 3-4 years the juveniles (ca 12 cm) migrate to estuarine and coastal habitats. During this stage they live either as parasites on fish or actively forage on small fish like young herring and sprat. Due to their foraging strategies and slender bodies, most fish monitoring programmes are very ineffective in determining river lamprey abundance. As a consequence little is known on the relative importance of the specific foraging areas, be it freshwater, estuarine or marine.

9.2.3 Migration routes

Adult river lamprey (ranging from 30-45 cm) start migrating into rivers from November onwards and spawning usually peaks in April. Upstream migration is hampered at many locations along the Dutch coast. Only the Scheldt, Nieuwe Waterweg and Eems provide entrance to the rivers without barriers like sluices and dams. The adults die after spawning. After hatching, the larvae disperse downstream in rivers from their spawning habitats. After 3-4 years the juveniles migrate downstream to estuaries and coastal seas.

9.3 Function of Natura 2000 areas and the effect of wind farms

Most is known on the upstream movements of river lamprey during their spawning migrations. Relatively little is known on the distribution and relative importance of the different foraging areas in freshwater, estuaries, coastal zones and open sea. It appears, surprisingly, that a species that migrates into the Netherlands in such relative high numbers, is virtually absent in active monitoring programmes along the coast and more offshore (and this is also seen along the German coast, see Figure 18). River lamprey migrate to marine habitats at a length of about 12 cm and are very slender in form. This makes it that most mesh-sizes used in monitoring programmes presumably fail to catch them during most of the first growing season at sea. During the second growing season at sea, a fraction of them might be expected to be caught. Again, as is the case for sea lamprey, our current knowledge on the behaviour and occurrence of river lamprey during the sea stages limits us in determining whether and which estuaries, coastal zones or offshore habitats are import as foraging areas. Hence, the estuarine and marine Natura 2000 areas probably serve as feeding grounds, but their importance is not known. The effects of wind farms on this species are not clear.

10 Atlantic salmon – *Salmo salar*

10.1 Population size

Historically, the Rhine contained one of the largest populations of Atlantic salmon in Europe, as reflected by the annual catches peaking at >100,000 salmon in the late 1800s (De Groot 2002). The Meuse also contained a substantial population. The Scheldt (Vrielynck et al. 2002) and Eems are believed to have had small salmon populations at best. Due to water pollution, overfishing, habitat loss and migration barriers, Atlantic salmon became extinct in the Rhine-Meuse around the 1950s, as in many large rivers along the southern coasts of the North Sea (De Groot 2002). In the late 1980s a restocking programme started in the upstream sections of the Rhine, continuing stocking salmon at different life stages until today. It is estimated that yearly 100,000 to 250,000 juvenile salmon (so-called 'smolts') start their downstream migration to sea from the upstream parts of the Rhine catchment. The vast majority of these fish are of stocked origin (Jurjens 2006, Jansen et al. 2008). Only a small proportion (< 10 %) is from naturally hatched eggs. Yearly, an estimated 500-1000 adult Atlantic salmon migrate into the spawning areas in the River Rhine. Telemetry experiments with a limited number of Atlantic salmon (and large numbers of Sea trout as a model species) suggest that 8-16,000 adult salmon are present along the Dutch coast, but it is uncertain whether these all belong to the 'Rhine-population' (Jansen et al. 2008). More recently, a restocking programme has started in the upstream parts of the Meuse as well, but only very few returning adults are observed so far.

10.2 Important areas

10.2.1 Reproduction areas

Historically, spawning took place in upstream tributaries of the Rhine and Meuse with fast flowing water and gravel beds in Germany, Belgium, France and Swiss. At present only a limited number of tributaries and reaches are accessible for upstream migrating salmon and the quality of the spawning habitats is less than historically (Jansen et al. 2008).

10.2.2 Foraging areas

The young salmon use the spawning areas as growing habitats during 1-3 years before they start their long downstream migration to the open ocean. In the open ocean, the most important foraging areas for Atlantic salmon from Western Europe are found near Greenland, Faroer and off Norway.

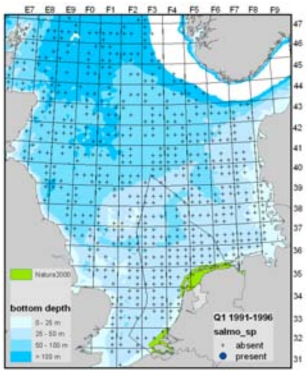
10.2.3 Migration routes

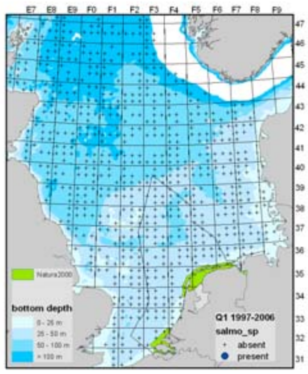
The mainstream stems of large rivers, estuaries and coastal seas are only used as corridors between their spawning sites in the upstream sections of rivers and open ocean foraging habitats. Observations of juvenile and adult salmon during their migrations through the Netherlands are most frequent in the fyke net programmes: both downstream migrating smolts as upstream migrating adults. In the active gear monitoring programmes (see Figure 20) salmon is observed only very sporadically. Atlantic salmon is often misidentified as Sea trout and caution should be taken when analyzing datasets. Sea trout is a more coastal foraging salmonid and therefore believed to be more likely encountered in coastal and open sea surveys in the North Sea than the only temporarily passing Atlantic salmon.

10.3 Function of Natura 2000 areas and the effect of wind farms

All areas along the Dutch coast, including the estuaries and all branches of the Rhine and Meuse serve as upstream and downstream corridors for the Atlantic salmon. Only the route through the Nieuwe Waterweg is open accessible to upstream migrating salmon. The Haringvliet dam is hampering adult salmon migrating upstream through the Haringvliet and Hollands Diep, whereas the Afsluitdijk sluices at Den Oever and Kornwerderzand are hampering upstream migrating salmon using the 'IJssel-route', even though telemetry has shown that part of the salmon are able to pass these sluices. The estuarine and marine Natura 2000 areas probably serve as a corridor. The effects of wind farms are not clear.

1991-1996	1997-2006





Quarter 1
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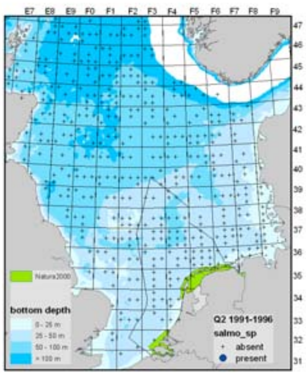

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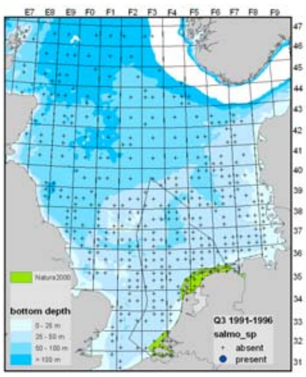
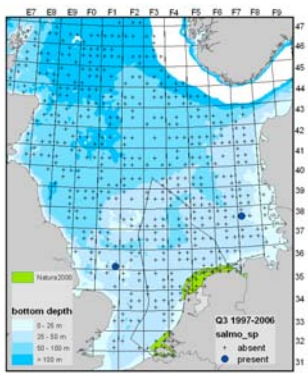
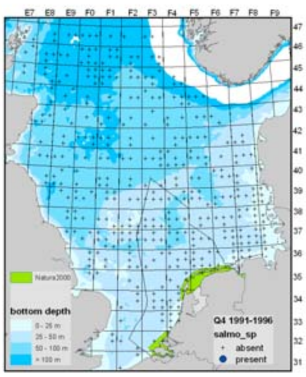
IBTS data





Quarter 3
IBTS data (North Sea) and DFS data (Natura 2000 sites)



Quarter 4
IBTS data

Figure 20. Salmonids *Salmo* spec. Catches of *Salmo* spec in the North Sea during 1st, 2nd 3rd and 4th quarter in the period 1991-1996 (left) and the 1st and 3rd quarter in the period 1997-2006 (right). Data are present /absent data. No data means not sampled.

11 Mortality

The mortality of a fish species is dependent of many factors, both anthropogenic (e.g. fisheries, pollution) and natural (e.g. predation). Commercial stocks such as herring and plaice are heavily influenced by fishing mortality, while diadromous species like salmon and lamprey encounter physical barriers during their migration in the rivers. Since the mortality of fish is affected in many ways, it can never be clearly determined, and the best scientists can do is to make a very rough estimate.

11.1 Herring

North Sea herring is one of the best studied stocks in the world. The species can attain a maximum length of 40 cm and the maximum lifespan may exceed 10 years, but most adult fish in the North Sea remain in the range of 20-30 cm and most herring are less than 7 years old. For stock assessment purposes, the international scientific community assumes a consistent natural mortality of 1.0 on 1-ringers, 0.3 for 2-ringers, 0.2 for 3-ringers and 0.1 for all older age classes, based on a Multispecies Virtual Population Analysis (MSVPA) (Anonymous 1989). The fishing mortality of herring is estimated to be higher than the natural mortality and fluctuates between 0.2 and 0.55 over the past 25 years (ICES 2007).

11.2 Plaice

The plaice stock in the North Sea has been studied extensively as well. The species can reach an age of 15 years and a size of 90-100 cm, with females generally attaining a larger size than males, although individuals larger than 40 cm are hardly caught. The natural mortality of plaice is assumed at a fixed value of 0.1 through all ages in stock assessment studies. The fishing mortality gradually increased from the 1950s until the late 1990s, from 0.2 to 0.52 (ICES 2008).

Both herring and plaice stocks are managed by defining annually a maximum fishing mortality, which can be reached by agreeing upon a Total Allowable Catch (TAC), in order to keep the stocks at a sustainable level.

11.3 Diadromous fish

On mortality rates of the diadromous fish covered in this study, very little is known. The life-spans of the different species are: Twaite shad 6-8 years (only eggs and larvae stages in tidal freshwater, rest estuarine and marine); allis shad 5-8 years (up to 1.5 year in freshwater, thereafter estuarine and marine); Atlantic salmon 4-7 years (1-3 years in freshwater, rest open ocean); sea lamprey 5-10 years (3-6 years in freshwater, thereafter 2-4 years at sea); river lamprey 5-8 (3-5 years in freshwater, 2-3 years at sea). Only for Atlantic salmon in the Rhine, a survival rate of 0.4-0.5 % from smolts that start their downstream migration from the upstream spawning habitats to adults that return to these spawning areas after the ocean phase was estimated (Jansen et al. 2008). This is considered much too low to lead to a self-sustaining population, and therefore at present the salmon relies on stocking to maintain its presence in the Rhine (see Jurjens 2006 for a detailed overview on total number of stocked salmon per life stage). The cumulative mortalities during the downstream smolt migration, open ocean foraging stages and adult migrations are too high. The underlying relative contribution of the different anthropogenic factors and natural mortalities is currently unknown. The list of candidate mortalities induced by human impact is long for diadromous species; e.g. water pollution, habitat loss, migration barriers and fisheries. Some natural mortality causes might also be influenced by human impact, e.g. an increased predation risk due to crowding and delay in front of migration barriers.

Management measures in the past have resulted in a better water quality of the rivers and estuaries. Furthermore, migration along the river branches has been improved by constructing fishways. The sluices at Haringvliet and Afsluitdijk, however, still hamper fish migration. For downstream movements the hampering is far less than for upstream movement. Future measurements as opening the sluices of Haringvliet permanently with small gaps (so-called ‘Kier-besluit’, which is scheduled to start in 2010), will enhance upstream fish migration through the Haringvliet Dam for sure for all diadromous species considered here. Whether the saline gradients in this measure will be restored sufficiently to provide the necessary habitats for successful spawning of twaite shad, remains to be seen.

12 Impact of other activities on fish

This section describes a number of projects in the North Sea that have reported effects on fish. The list of effects to be treated was made by Fred Twisk of Deltares. During the meeting of Deltares and IMARES it was decided to only mention activities that were studied in environmental impact studies or that will be new in the North Sea. These activities are listed in Table 2. In addition the effects of building of new gas installations and the effect of dismantling explosives have been described. Hence, this overview is not a complete review of all possible effects on fish in the North Sea, but only summarizes effects of a selected number of activities, as reported in the cited impact studies or in other sources.

Table 2. Activities in the North Sea and the selection for this report.

Activity	**selected**	**not selected**	**remark**
Sand extraction	x		based on report (Van Duin et al. 2007).
Maasvlakte 2	x		based on report (Heinis et al. 2007)
Musselseed fisheries Wadden Sea		x	study not finished yet. If possible, the effects on Natura 2000 populations will be considered.
Mussel seed trapping installations	x		based on report IMARES (Scholten et al. 2007)
Fisheries (professional)		x	no permit needed
Fisheries (sport)		x	no permit needed
Recreation		x	existing activity
Kierbesluit Haringvliet	x		positive effect
Sand nourishment		x	existing activity
Development in shipping		x	existing activity
Military activities		x	existing activity
Oil/gas platforms		x	based on report (NAM/Ingenieursbureau Oranjewoud B.V. 2006)
Measures in (future) MPAs		x	possibly positive effects
Dredging activities		x	permit needed, but not treated
River dams in relation to migratory fish		x	important obstacle in lifecycle migratory fish
Shell extraction		x	existing usage
Gravel extraction		x	not applicable
Dumping of ammunition		x	not applicable
Cables/pipe lines		x	existing usage

12.1 Sand extraction

In the period 2008-2012 a total of approximately 130 million m^3 of sand will be extracted from the Dutch section of the North Sea and used for nourishments of the coastline and the fore banks to protect the Dutch coast and maintain more or less the coastline of 1990. The sand extraction will take place in 17 exploitation areas along the Dutch coast between the continuous -20m depth line (NAP) and the 12 nm border. The sand will be extracted from the seabed to a depth of 2 m, or alternatively 6 m and has a grain size of preferably 250-350 μm. The total surface that will be affected is 77 km^2 (2 m depth) or 56 km^2 (6 m), being approximately 0.1 % of the Dutch section of the North Sea. The extraction areas will be situated at least 1000 m from Natura 2000 areas, (future) offshore wind farms, and platforms and 2000 m from the -20 m depth line.

In the environmental impact study (Van Duin et al. 2007) the effects of sand extraction on fish were evaluated. The main outcomes are:

12.1.1 Sand extraction of the sea floor

The effect of removing the first meters of the seafloor is that fish will loose the benthic fauna as a food source. However, since fish are mobile, they have the possibility to search for alternative food sources so that the fitness of individual fish and of populations will not be changed. Furthermore, the effects on the benthos are temporary and the benthos as a food source is not limiting.

12.1.2 Increase of silt content

There is a possible indirect effect of the increase of silt content on fish through the reduction of primary production and the reduction of visibility. The effect of the increase in silt content on the food web is calculated as follows: Assuming a conversion factor of 0.1 from one trophic level to the next, and a reduction of the primary production of 0.6 % due to the increased silt content, then there could be a reduction of 0.6 % in zooplankton and benthos biomass, and a reduction of 0.06 % in plankton eating fish and a reduction of 0.006 % in predatory fish. Even if the system is food limited, then there is probably no significant effect on fish or fish larvae. Therefore, no effects on fitness of the neither individuals nor populations are expected.

Spawning areas of fish will not be influenced by the silt plume, since they do not occur in the area where sand extraction takes place.

Fish that are visual predators can probably compensate a reduced visibility by sensing vibrations of their prey. The increase of the silt content is not thought to reduce the predation risk for fish by predatory birds or marine mammals.

Compared to the realization of the Maasvlakte 2, the reduction of chlorophyll content due to increased silt content caused by sand extraction (3.5 % reduction) is of minor importance compared to the realization of Maasvlakte 2 that will reduce chlorophyll levels with maximal 25 %.

12.1.3 Increase of sound, vibrations and movements above and under water

Sound or vibration levels may be lethal for fish; however these levels are not reached during sand extraction. Ships used for sand extraction produce about 170 dB under water. The speed of sound in the coastal zone is 1500 m/s compared to 340 m/s in the air. A storm or heavy showers may produce as much as 75 dB. In total, between 1278 and 441 dredging days per year (2008-2012) are needed to obtain the total amount of sand needed.

Fish are expected to migrate only some hundreds of meters during sand extraction operations. The disturbed area of maximal 623 km^2 is relatively small (<<1 %) compared to the Dutch section of the North Sea (57,000 km^2). This disturbance area was calculated assuming that at each sand extraction location a dredging ship would be working and that seals suffer from a ships' noise in a radius of 3150 m around the ship and that seals and fish suffer equally. Considering the mobility of fish, no fitness effects on the individual or population level are expected.

12.2 Maasvlakte 2

For the construction of Maasvlakte 2, the 2000 ha (20 km^2) extension of the port of Rotterdam, an Appropriate Assessment was written, in which the potential effects of the construction are treated (Heinis et al. 2007). For the construction of Maasvlakte 2, sand will be extracted from the North Sea. The first part of the construction, the building of the outer part and the first phase of the inner part will last from 2008-2013, next the realization of the inner area will take from 2013-2023. In the first phase, 150 million m^3 (or 150 Mm^3) of sand will be extracted each year, in the following years another 60 million m^3. The first 10 meters of the sea floor will be removed for this purpose.

12.2.1 General effects of the construction of Maasvlakte 2

The construction of Maasvlakte 2 has many effects. The significant effects are:

- Changing of the bottom topography.
- The change of the northward current along the Dutch coast. It is expected that the silt content along the coast will decrease, while closer to the sand extraction the silt content will increase.

In contrast, there are supposedly no problems in relation to

- changes in salinity
- oxygen depletion due to stratification of the water column
- contamination of the sediment (no storage in the sediment)

12.2.2 Effects of Maasvlakte 2 on Natura 2000 Area "Voordelta"

The destruction of biotopes will have no effect on the North Sea fish populations, since the area mainly serves as a feeding ground for adult fish that have a North Sea wide distribution. No effects on the fish stocks in the North Sea are expected. Furthermore, for most of the migratory fish species (river lamprey, sea lamprey, salmon, and allis shad) the area only serves as an area to travel across. The twaite shad can use the area as a feeding ground during part of its lifecycle. The reduction of primary production due to increased silt content of the water will not lead to effects on twaite shads, since the twaite shad population is so small that the species will not be food limited. The population is more affected by size and quality of the reproduction- and nursery areas in the adjacent estuaries. Direct effects of increased silt content on the ingestion rates are not expected. Fish that are adapted to waters with reduced visibility can cope with silt contents of up to 100 mg/l. These values are only reached during heavy storms.

12.2.3 Effects of Maasvlakte 2 on Natura 2000 Area "Waddenzee"

The increase of silt content will be so small that species and habitats are not affected. Also the number of fish larvae that are transported towards the Wadden Sea will not be affected.

12.3 Kierbesluit Haringvliet

Opening the sluices of Haringvliet permanently with small gaps (so-called 'Kier-besluit') is scheduled to start in 2010 and will enhance upstream fish migration through the Haringvliet Dam for sure for all diadromous species considered here. Whether the saline gradients in this measure will be restored sufficiently to provide the necessary habitats for successful spawning of twaite shad, remains to be seen.

12.4 Mussel seed cultures

In the Netherlands the mussel fisheries are developing alternatives to obtain mussel seed, since fishing for mussel seed in The Wadden Sea is heavily discussed and currently, at least temporarily, forbidden. In a report on the effects of culturing mussel seed with nets in the Wadden Sea (Scholten et al. 2007), no effects on fish were reported. The mesh-size of the nets is too small to catch fish. And although the mussel cultures may negatively affect fish by competing for resources (plankton), the structures may give shelter to fish and the mussels themselves may serve as food.

12.5 Gas platforms

Information on the effects of new gas platforms on fish is available in the environmental impact study of the NAM (Nederlandse Aardolie Maatschappij). In this study, the impact of two new gas production platforms 25 km northwest of the islands of Vlieland and Terschelling was assessed (NAM/Ingenieursbureau Oranjewoud B.V. 2006).

- Spawning: In general, the period between January and August is the most sensitive period for fish, since in this period a number of important fish species spawns.
- Refuge: the presence of the platform, including the 500 m safety zone can be regarded as a refuge for fish, since fishing is prohibited in this area. However, the effect is considered insignificant, since the area of 78,5 ha per platform is very small compared to the whole area with similar natural values.
- Sedimentation: dumping of drillings and drilling mud, as well as the construction of pipe lines causes a higher sedimentation rate and higher content of suspended matter, which may block the well functioning of the gills of fish, depending on species and age. In general, pelagic fish are more vulnerable to this effect than demersal fish and juvenile fish are more sensitive than adult fish. However, there have been no reports of major fish mortality in studies on activities that also cause higher sedimentation rates such as sand extraction. It is thought that fish tend to avoid the turbid areas. The authors therefore conclude that the effects on adult fish are negligible. However, demersal fish eggs (e.g., eggs of herring) may suffer an increased mortality rate when covered with sediment. Pelagic eggs and larvae may be influenced by suspended matter as well. Especially when it contains toxic substances. Bentonite has a LD50 (96h) of 6000 mg/l for adult fish. However, such concentrations will only temporarily occur at the dumping site. Hence, local effects on eggs and larvae that are caused by an increased sedimentation rate and increased suspended matter content can not be excluded.
- Incidental oil spills: The effects of incidental spills of oil or oily substances may cause damage, notably to fish larvae. The toxicity of the oil varies according to the oil type, the exposure time, the fish species, the life stage and the rate of bioaccumulation. Effects on cod eggs occur at concentrations of 50-250 µg oil/l at an exposure time of 3 weeks. Effects on herring embryos occur at concentrations of 370-11900 µg/l and may vary from retarded hatching to mortality. Gadoids and flatfish are sensitive to pollution of both the water column and the sediment, while sandeel is only sensitive to pollution of the water column. NOEC (No Observed Effect Concentration) for young fish are 1 µm oil/l, for the most adult fish this value is 10 µg/l and for flatfish 25 µg/l. These values are close to the background values (1-30 mµ/l). Therefore the increase of oil concentrations due to a spill means a crossing of the NOEC values and can cause a local effect.
- Conclusion: The dumping of cuttings may have a local minor effect on the development of eggs and larvae due to increased sedimentation rates, increased suspended matter content and increased toxicity levels. Incidents such as leakage, blow outs or spills may have the same effect, but smaller. Adult fish are considered very mobile and may escape.

12.6 Explosions of ammunition

In the North Sea a lot of ammunition was dumped by allied forces in the WWII on their way back from Germany to save fuel for the airplanes. In addition, redundant ammunition was dumped at two locations 60 km west of Ijmuiden. Nowadays, fishers and other users encounter bombs in their nets. After a fatal accident in 2005 when 3 fishers were killed, fishers contact the Coastguard whenever an explosive is found, after which the Dutch Royal Navy will dismantle the bomb and let it explode. In 2006, 133 explosives were found and 128 were dismantled (Kustwacht 2007).

For dismantling bombs, no permit is required. However, in this report some information is given on the effects of the explosions to give some insight in the importance.

In general, the Navy maintains safety zones for swimmers and SCUBA divers starting from about 2 to 5,5 km around an exploding explosive (Table 5). This could indicate that this also is a dangerous zone for fish and other marine life.

Table 3 Estimated frequencies of dismantling and weights of the explosives for 2006

Type	Frequency	weight (Net Explosive Weight)
regularly reported explosives	1x per week	100 kg
explosives from fishers	1x per week	200 kg
explosives found during projects (e.g. deepening of gullies)	3 x per week (only during the project)	

For an explosion, the Navy uses safety guidelines (Kon. Marine 2005) in which the following safety distances are mentioned:

Table 4. Safe distances during under water explosions (Kon. Marine 2005)

Object	Nett Explosive Weight	Distance
Plaforms		9000 m (5 nm)
Pipelines, pumps		7200 m (4 nm)
Cables, well heads		3700 m (2 nm)
Coast	<227 kg (<500 lbs)	5500 m (3 nm)
	>227 kg (>500 lbs)	14400 m (8 nm)

Table 5. Safe distances for swimmers and SCUBA divers (Kon. Marine 2005)

Nett Explosive Weight	Distance
<225 kg	1800 m (1 nm)
….	…
>4000 kg	5500 m (3 nm)

13 Knowledge gaps

In general, the commercial species herring and plaice have been extensively studied for many years, covering all life stages of the two species. It may therefore be expected that the life history of the two species is clear-cut. However, fish live in a three-dimensional world unseen for human and the only knowledge you will get is about the catches in the nets, which immediately is the largest deficiency. One can never tell what is happening in areas or periods that cannot be covered by the scientific monitoring programmes or commercial fisheries, or with the life stages that cannot be caught due to different fishing methods. The same of course accounts for the non-commercial Habitat Directive species.

The data on fish species currently collected in the North Sea is clearly lacking coverage in seasonality and area. Shallow areas (<5 m) are hardly fished, neither are rocky bottoms, and both are known as habitat for specific fish species or life stages. Also the type of net determines the type of catch, e.g. with a pelagic net one will simply not catch any bottom-dwelling species, nor will one catch small individuals when a large mesh-size is being used. For example, fish such as river lamprey and sea lamprey have slender bodies that are not easily caught. In addition, they have parasitic life stages that are also difficult to monitor.

Furthermore, knowledge on the migration of fish species is – especially in the marine environment – mainly based on the interpretation of static distribution maps. For example, based on information about the distribution of age class x in area A and age class x+t in area B, one may easily conclude that the migration of the species is in the direction from area A to B. Although this assumption seems to be rather straightforward, whether this is all that happens within the timeframe t remains unknown.

Finally, monitoring programmes are always restricted by the available budget. A clear example is the sampling design of the International Herring Larvae Survey (IHLS) (Figure 10). The survey covers only the core of the spawning grounds but with a relatively high sampling intensity, in stead of a larger area in less detail. On the other hand, surveys that cover large areas such as the IBTS provide valuable information on a broad area (i.e. the North Sea), but become rather useless when studying a small scale area, e.g. an allocated wind farm site.

In summary, each scientific study on the behaviour of certain fish species needs its own design, depending on the desired scale, time and space.

14 Conclusions

In this study we have provided an overview of the current knowledge for a number of important fish species in the North Sea in relation to Natura 2000 areas and future wind farms. For each species, maps have been made that show general distribution patterns. However, it is not possible to come up with exact numbers and estimates that can tell which percentage of which population can be found in which area at a certain time, due to the lack of data, the usage of different stock assessment methods, and the characteristics of the fish populations themselves. The construction and wind farms will probably have local effects on the fish stocks studied. Effects of sound on fish are not subject of this study but are performed for Deltares by another party. Also, effects on larvae are studied in a parallel study performed by Deltares and can not be quantified in this study.

Herring is numerically one of the most important pelagic species in the North Atlantic ecosystems. In the North Sea, three major spawning areas can be distinguished, none of which is currently part of a Natura 2000 area. The number of spawning sites declines with lower North Sea herring biomass. Larvae are transported passively from all three spawning sites to the east and the main nursery areas are in the German bight. Adult herring tend to occur in the north-western part of the North Sea. Apart from the effects of underwater sound, which will be estimated in a study by Deltares, the building and presence of windmills will probably not affect North Sea herring. Measures such as the improvement of salt water / fresh water transitions in the Dutch Wadden Sea may enlarge the habitat for herring locally and could result locally in a larger herring population. For the North Sea herring as a whole such measures will have no effect however.

Plaice is currently considered to have full reproductive capacity and be harvested sustainably. The centres of egg production are the Channel and the eastern bight. The coastal waters and inshore waters (Wadden Sea) are of extreme importance to the North Sea plaice stock and contribute the majority (50-90 %) of the recruits to the North Sea plaice stock. The transport of larvae through the areas where wind farms will be built will probably not be affected. The effects of underwater sound are not know, however and are modelled in a study of Deltares.

Juvenile plaice are found in the German Bight and the east coast of Britain. The German offshore Natura 2000 areas could therefore be of importance to the species. Adults show seasonal migration between spawning and feeding grounds, and a strong fidelity behaviour towards these areas.

It is not expected that the building and presence of wind farms will effect the migration itself. The effects of sounds are not known, but are currently studied by Deltares. Possibly, the available habitat for plaice will be diminished by the presence of wind farms (rocky structures instead of sand), bird predation may increase and exclusion of fisheries can negatively affect prey abundance. Plaice will therefore probably not benefit from wind farms.

Twaite shad

Twaite shad is rarely observed in Dutch rivers, due to a combination of deterioration of water quality, overfishing, habitat loss and migratory barriers (Delta works). Nowadays, migratory barriers are still an important obstacle. Eggs are spent in the freshwater tidal zones and estuaries are most important for larvae. Juveniles and adult twaite shad Catches in Dutch coastal waters probably result from successful spawning in the Eems estuary, which is therefore a very important area for the Twaite shad. Building offshore wind farms may affect adult shads on their feeding grounds, but at present little is known on the use of more offshore habitats, since monitoring programmes are not best suited to catch pelagic twaite shads.

Allis shad

Historically allis shad occurred in large numbers in the rivers around the North Sea, but the populations in e.g. the Netherlands became extinct in the 1930s due to overfishing, water pollution and migration barriers such as sluices. Juvenile and adult allis shads use estuaries and open sea for foraging. Although the misidentification with a twaite shad is very plausible the species is probably only very sporadically present in the North Sea nowadays. The adults migrate upstream the rivers in May, spawn once and die. None of the Natura 2000 areas currently play an important role for allis shad.

Sea lamprey

Sea lamprey has declined strongly in the 20th century, mainly due to water pollution, habitat loss and migration barriers. Adult sea lampreys move into rivers during March-June and die after spawning. After 4-5 years in fresh water habitats, the juveniles migrate downstream to the river basin. The adults are parasitic and attach to larger fish and sea mammals for 2-3 years. The estuarine areas only serve as corridor, while the marine habitats serve as feeding grounds, but it is unknown which areas are important.

River lamprey

River lamprey increased in abundance during the last decades, but is still not back at historical levels. Spawning takes place in fresh water and the larvae remain 3-4 years in fresh waters. Then the juveniles migrate to coastal and estuarine habitats where they live as parasites on fish or actively forage on small fish. The main problem for river lamprey is upstream migration that is hampered at many locations, except for the Scheldt, Nieuwe Waterweg and Eems. Nowadays, 100 ,000s of sea lamprey are thought to enter the Rhine-Meuse catchment areas each year that are not caught in monitoring programmes.

Table 6. Overview of functions of Natura 2000 areas for the fish species treated in this report.

Area		Natura 2000 areas				
Species		Wadden Sea/Coastal sea	Delta	German Wadden Sea/ Coastal area	German offshore N2k area	English coastal N2k areas
herring	reproduction area (eggs/larvae)	-	-	-	-	-
	nursery area (juveniles)	o	o	+(?)	+	-
	foraging area (adults)	-	-	-	-	-
plaice	reproduction area (eggs/larvae)	-	-	-	o	-
	nursery area (juveniles)	+	+	+	+	-
	foraging area (adults)	-	-	-	-	-
twaite shad	reproduction area (eggs/larvae)	+ (tidal zone of Eems river)	+	+ (tidal zone of Eems river)	-	-
	nursery area (juveniles)	o	o	o	o	?
	foraging area (adults)	o	o	o	o	?
allis shad	reproduction area (eggs/larvae)	-	-	-	-	-
	nursery area (juveniles)	o	o	o	?	?
	foraging area (adults)	?	?	?	?	?
sea lamprey	reproduction area (eggs/larvae)	-	-	-	-	-
	nursery area (juveniles)	-	-	-	-	-
	foraging area (adults)	?	?	?	?	?
river lamprey	reproduction area (eggs/larvae)	-	-	-	-	-
	nursery area (juveniles)	-	-	-	-	-
	foraging area (adults)	?	?	?	?	?
salmon	reproduction area (eggs/larvae)	-	-	-	-	-
	nursery area (juveniles)	-	-	-	-	-
	foraging area (adults)	-	-	-	-	-

-=not important, o=of minor importance, +=important (for the North Sea stock) ? = unknown

Atlantic salmon
In the late 1800's large catches of salmon were reported (>100 ,000 y) for the Rhine. In the 1950's the salmon became extinct due to water pollution, overfishing, habitat loss and migration barriers. From the 1980's on large restocking programmes exist and less than 10 % of the salmon eggs is currently of natural origin. Young salmon remain 1-3 years in the spawning areas before they migrate to the open ocean. All areas along the Dutch coast serve only as corridors.

Mortality
Due to fisheries or a lack of knowledge, the natural mortality of the aforementioned fish species can not be determined. For herring and plaice estimates are made that serve for stock assessment purposes. For salmon, a survival rate of 0.4-0.5 % from smolts to adults that return to the river was estimated, while for the other species very little is known.

Impact of other activities
Sand extraction for coastal defence purposes are probably small and are not expected to have fitness effects on fish populations. The construction of Maasvlakte 2 will have no effect on North Sea fish populations since they can feed elsewhere and no effects on Habitat Directive species in the Voordelta, since the area serves as a corridor. Effects on twaite shad are not expected, since the twaite shad population is so small that it will not be food limited. The partial opening of the Haringvliet sluices will have positive effects because it enhances upstream fish migration. Mussel seed cultures probably have no negative effects on fish populations. The dumping of cuttings at gas platforms may have very local effects on eggs, but no effects on adults, since they are mobile and can escape.

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19 Quality Assurance

IMARES utilises an ISO 9001:2000 certified quality management system (certificate number: 08602-2004-AQ-ROT-RvA). This certificate is valid until 15 December 2009. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. The last certification inspection was held the 16-22 of May 2007. Furthermore, the chemical laboratory of the Environmental Division has NEN-AND-ISO/IEC 17025:2000 accreditation for test laboratories with number L097. This accreditation is valid until 27 March 2009 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation, with the last inspection being held on the 12th of June 2007.

Justification

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The scientific quality of this report has been peer reviewed by the Scientific Team of Wageningen IMARES.

Approved: F. Quirijns
Researcher

Signature:

Date: 30 July 2008

Approved: H. Lindeboom
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Signature:

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