Distribution of marine mammals in the North Sea for the generic appropriate assessment of future offshore wind farms

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Contents

Summary

In this report the current knowledge on abundance and spatial use of the North Sea by marine mammals is presented. 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 marine mammals in the North Sea, which are protected under the European Habitat Directive. Deltares will use this study as input for the generic 'Appropriate Assessment' (environmental impact study), as required by the Habitat Directive.

This report shows that large numbers of marine mammals are present in the southern North Sea. The identification of critical habitats for marine mammals is complex and not yet possible for lack of data. An overview of the available data is given in Table 1.

Table 1. Overview of the available data on marine mammals in Dutch waters deemed necessary for an appropriate assessment of the effects of off shore wind farms.

	Harbour seal	Grey seal	Harbour porpoise	Bottlenose dolphin	White-beaked dolphin	Minke whale
Population size						
	good index	good index, lacking information on exchange with other colonies	lacks systematic surveys	only incidental data	only incidental data	only incidental data
Resting						
on land	Good :summer, some: winter	Some: summer, some: winter	-	-	-	-
at sea	maybe by analysis of existing data	more tagging needed	analysis of current data & more to data be collected	currently no data	currently no data	currently no data
Reproduction						
on land	good	Some: number of pups uncertain	-	-	-	-
at sea	currently no data	currently no data	currently no data	currently no data	currently no data	currently no data
Foraging						
	maybe by analysis of existing data	maybe by analysis of existing data	currently no data	currently no data	currently no data	currently no data
Migration						
	maybe by analysis of existing data	limited data available	currently no data	currently no data	currently no data	currently no data
Adequate knowledge for appropriate assessment of wind farms locations at sea						
	NO	**NO**	**NO**	**NO**	**NO**	**NO**
Amelioration of the knowledge gap in the short term						
	2008, first comprehensive model, including habitat and behaviour	2009, first tentative full model, not enough data?	3 suveys in 2008 along the North Sea coasts up to Texel	no funding	no funding	no funding

Most progress has been made in the studies of harbour seals. Here, telemetry studies are very useful to study individual habitat preference and the data can be used for model input. Results of a first model study comprising all tagged seals is expected by the end of 2008 or early 2009. It is expected that additional studies will be needed before a complete model can be drawn. For grey seals, less data are available and the regular exchange between the Dutch and British coasts complicates the matter. In both pinnipeds fundamental understanding of individual variation will be needed to estimate true effects of habitat changes on the populations.
The harbour porpoise is the most abundant species, but since no systematic counts are done, relatively little is known about this species in the southern North Sea. Regular, standardized and dedicated surveys in order to define and maybe explain temporal changes in density are still lacking for harbour porpoise and other cetacean species. As a result, abundance and distribution data for all species in the NCP is insufficient to assign importance of specific areas to marine mammals.

1 Introduction

1.1 Background of the current study

The Dutch government has formulated the ambition to increase the generation of renewable energy, among others by increased exploitation of offshore wind farms in the North Sea. The short term objective is to reach a commitment for wind farms with a total power of 450 MW by the year 2010. The longer term objective is the extension of offshore wind farms to a level of 6000 MW by 2020. The wind farms will be built outside the 12 nm zone and north of the Euro-Meuse channel. Deltares has been asked by Rijkswaterstaat, the managing authority of the Dutch territorial waters to produce a generic 'appropriate assessment', as is obliged under the Habitat Directive (92/93/EEC). This assessment is confined 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 marine mammals 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.
In this report IMARES summarises all relevant data available on the distribution and abundance of marine mammals. Deltares will use this report in combination with studies and data on underwater noise and effects on mammals by other parties to produce a generic appropriate assessment.

1.2 Offshore wind farms and marine mammals in an European context

Offshore wind farms have in recent times been constructed in shallow waters across Northern Europe, from the Irish Sea eastwards across the southern North Sea to the Baltic. New proposals are currently made for the development of farms in eastern Scotland, France, the Iberian Peninsula, but also in the southern North Sea in Germany, Belgium and the Netherlands. Adequate long term monitoring data on the distribution and abundance of marine mammals lack in most of the concerned areas. In general, the industry has moved faster than researchers could develop proper procedures to survey for affected populations or monitor impacts. As a result, inadequate assessments have been performed that in addition are difficult to compare between countries. Therefore it is necessary that standards are developed and that adequate baseline studies are performed (Evans 2007). Methods that are commonly used nowadays should be intercalibrated. To date, only a few detailed studies on the impacts of offshore windmills on marine mammals have been done, mainly around the Danish wind farms of Nysted (Baltic) and Horns Reef (Wadden Sea) (Evans 2007). One could question whether and to what extent results from local studies are applicable elsewhere.

1.3 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 marine mammals that are protected under the Habitat Directive Annex II: common seal (*Phoca vitulina*), grey seal (*Halichoerus grypus*), harbour porpoise (*Phocoena phocoena*), bottlenose dolphin (*Tursiops truncatus*) . In addition, white beaked dolphin (*Lagenorhynchus albirostris*) and minke whale (*Baleanoptera acutorostrata*) are treated (Annex IV).

The existing knowledge on marine mammals in the (Dutch) North Sea is briefly presented in this report. The report could seem incomplete simply because data on the behaviour, distribution and population size of most marine mammals species is often incomplete or absent. We also attempt to define the important gaps in the information, preventing adequate assessment of the area.

The report is structured as follows: 1) current methods used in the assessment of distribution and abundance in marine mammal research in the North Sea are presented, 2) fact sheets per species, with information on population size, important areas (reproduction, foraging, migration and resting) including maps of the species 3) an overview of knowledge gaps will be given and plans for future research.

2 Methods in marine mammal research in the North Sea

2.1 Seal distribution

2.1.1 Seal counts

Seals regularly haulout on sandbanks in estuaries and along the Dutch coasts. On land, the animals are much more visible and conspicuous than in the water. Inevitably, the monitoring of the population development concentrates on counting the seals on land.

In order to produce an index for population growth, seals are counted in the period where numbers are most predictable from year to year. In most areas seals are therefore counted during the annual moult. In this period seals display a higher necessity to haulout. Reproduction is monitored during the pupping season, when most mothers and pups haul out frequently or when possible even continuously, to suckle. The annual cycle in haulout for harbour seals is demonstrated for harbour seals in Figure 1.

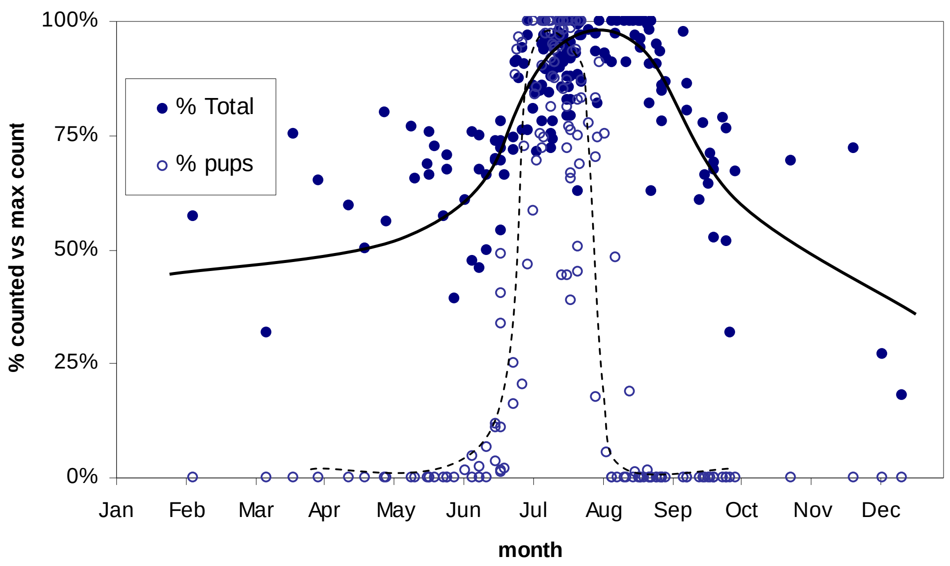


Figure 1. Percentage harbour seals (both total numbers and pups) counted in the Wadden Sea on the haulout sites compared to the maximum counted that year. Data collected during 1974-1992, IMARES.

The present monitoring scheme for harbour seals in the Wadden Sea consist of three surveys in the whelping period (June-July) and two in the moult period (August). Similarly, whelping and moult of the grey seals are monitored in December-January (pupping) and March- April (moult). Animals are counted around midday at low tide throughout the entire Wadden Sea. The trajectory follows all known haulout sites, regular scans for new sites are made including boat observations.
The total count only represents a fragment of the entire population, as at least part of the population is in the water at that time. For the Dutch Wadden Sea a correction factor for the amount of animals not seen during the flights was determined to be 1.47 (Ries et al. 1998, Reijnders et al. 1997). This is very similar to many authors like Huber et al. (2001) who estimated a correction of 1.53 for harbour seals on the west coast of the USA during pupping. In other areas, depending on survey method, but also on environmental factors such as tidal regime, the correction could be as low as 1.16 (Simpkins et al. 2003) or as high as 1.74 for the moult census surveys (Withrow & Loughlin 1995).


Figure 2. Aerial seal counting and recording in the Dutch Wadden Sea.

In addition to the seasonal variation in haulout behaviour due to moult and reproduction, variation on shorter time scales exist. Several studies show that haulout behaviour is strongly related to the tidal cycle, time of day and local weather conditions (Ries et al. 1998, Terhune 1985, Watts 1992 , Heide-Jorgensen & Härkönen 1992, Thompson et al. 2005).

2.1.2 Telemetry

Though a relatively precise estimate of the population size can be obtained in aerial surveys, little information is available on the spatial distribution in their aquatic environment. Like most marine mammals, seals are cryptic and difficult to spot in the water. Acoustic detection methods cannot be used, since these animals are practically silent underwater, as opposed to cetaceans. Instead, recent development in wildlife telemetry devices attached to the fur of the animal, have facilitated the collection of detailed information on individual behaviour and how animals use their environment.

Data used to model seal distribution in this rapport is collected using Argos- satellite tags (developed by 'Wildlife Telemetry' and SMRU). These so-called Satellite (Relay) Data Loggers first collect dive information, summarizes this and finally transmit this data (called uplinks) when the animal is at the surface. The satellites receiving these uplinks are in a polar orbit and determine the position of the tag using the observed Doppler-shift. The reliability of the localisation of the tag (and the seal) is dependent of the number of uplinks received within one satellite pass. The Argos service also provides for each location estimate a measure of location quality (LQ). The qualitiy can vary considerably; from a few hundred meters (LQ=3) to several kilometres (LQ=B).

The inaccurate estimates of the true location of the animal may lead to imprecise maps of their spatial distribution. Furthermore, if the animal is close to shore, the Argos location estimates are more likely to fall on land and are consequently removed. This may bias our estimated distribution even further. To reduce these errors, a filter was developed. It uses the speed of the animal, position of land and the location quality (LQ), to obtain the most accurate estimates of the actual position of the animal.

Amelioration of these tags using GPS location devices and relaying the data through the mobile phone network generates the possibility of collecting data with much higher resolution both in space, as in time. The latter is related to the fact that the transmitting of data is not dependant of the coincidence of a satellite being overhead when data is transmitted.

2.1.3 Modelling seal distribution

De telemetry data described in the previous section provides a very detailed picture of the behaviour as well as the spatial distribution of seals. However relatively few individuals (~ 1% of the population) have been equipped with transmitters. Furthermore, the seals are captured from a few haulout sites only. For that reason, the telemetry locations alone will not provide a representative depiction of the distribution of the entire population. Fortunately, we do know the numbers of seals at the different haulout sites throughout the Wadden Sea, which can than be used (in combination with the telemetry data) to provide better distribution maps. In total three methods have been developed in the past.

1. Distribution estimates based on averaged distance from the haulout (Brasseur et al. 2004b)
The distribution model presented in Brasseur et al (2004b) was based on combining aerial survey data with data from seals equipped with a satellite transmitter.
For the seven seals deployed in this study a frequency distribution of the distance to haulout was made. Interval size used was 2 km. The frequency distributions were averaged, creating an average distance distribution (Figure 3). For every haul out site the frequency distribution was used to estimate the seal's distribution in each 2 km^2 grid cell, which was then multiplied by the number of seals observed on the haulout site. The abundance estimates for each grid cell obtained for each haul out were summed over all haulout sites, to estimate the total offshore distribution of the entire population.

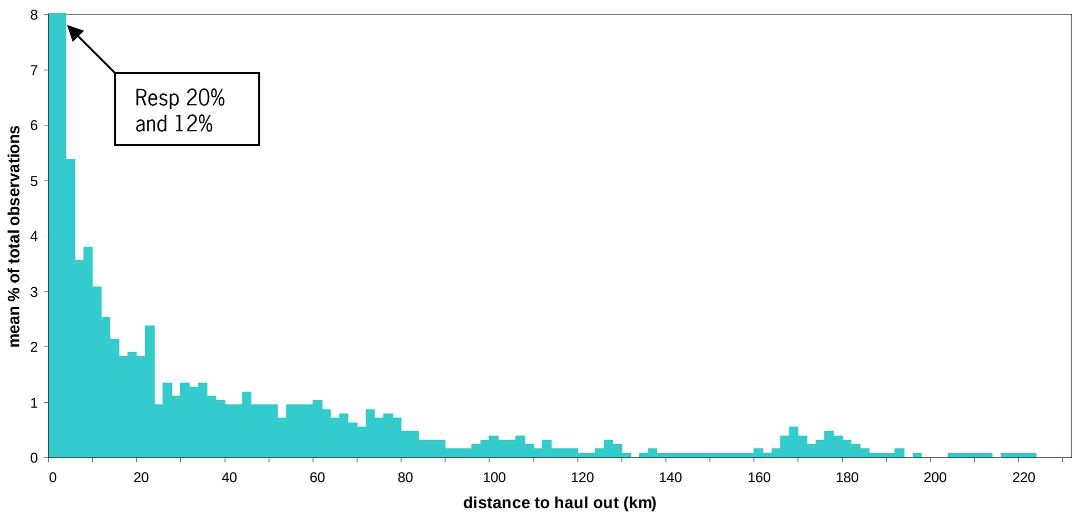


Figure 3. Frequency distribution of the average distance to haul out site of seven harbour seals, in 2 km intervals (Brasseur et al. 2004b). Note that bars in the left were cut off.

2. Model-supervised Kernel Smoothing (Matthiopoulos 2003)
For those regions of the Wadden Sea in which a large number of seals was equipped with satellite telemetry devices, an accurate map of their spatial distribution can be generated using those telemetry locations. For other regions, with little or no telemetry data, the information on the distribution as a function of the distance to the haulout can be used (see section 1. above and Brasseur et al. 2004b). As an intermediate solution model-supervised smoothing can be used. This method calculates the density of animals in each grid cell in space as a weighted average of the density of telemetry locations in vicinity of that grid cell and the prediction made by a simple distance model.

3. Modelling habitat preference
The spatial distribution of animals will be determined by local environmental conditions, such as food availability, but also abiotic conditions such as temperature, depth and sediment type. Quantifying the relation between seal distribution and local environmental conditions can be a useful tool to predict the distribution of animals at places where no or few individuals where equipped with telemetry devices (Aarts et al. 2008). In a recent study

(Brasseur et al. in prep.) investigated the effect of distance to the haulout, depth and silt-content on the distribution of tagged harbour seals. This model and information on the number of seals at the haulout sites, was then used to predict the distribution of the entire Wadden Sea population.

2.2 Cetacean distribution

2.2.1 TPOD monitoring

The TPOD is a passive acoustic device to monitor echolocation behaviour of harbour porpoises. It registers the time of occurrence and length of click events that feature a frequency spectrum matching criteria of harbour porpoise echolocation clicks (Tregenza 1998). To filter out other high frequency sounds in the sea (e.g. ship sonar, cavitation) the data is analyzed with special software to detect porpoise click trains.
TPODs provide high resolution information on temporal click activity in the area around the device. One of its main advantages is the continuous collection of data, thus providing information during times when visual observations are not possible, e.g. at night or during bad weather periods. The results can also be linked to oceanographic variables such as tidal state. Aside from the number of TPODS used, the spatial coverage is dependent on the version of the TPOD used and probably also the location of deployment. For the Baltic sea the acoustic detection range was determined to lie between 250 and 470m (Verfuß et al. 2004). At the moment data collected with TPODs can not be translated into density data (e.g. animals per km²), but some studies are underway to attempt this (Tougaard et al. 2008).

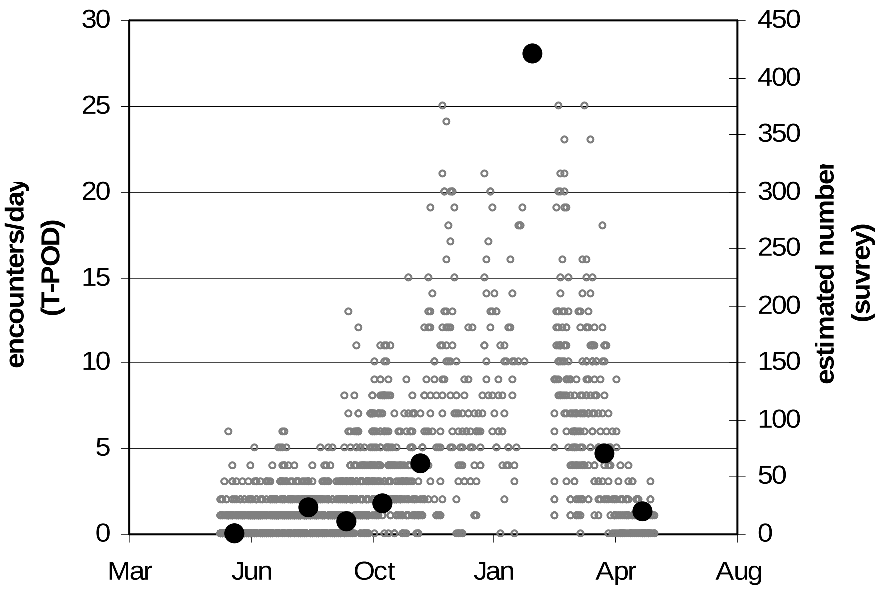


Figure 4. Comparison of the encounter rate provided by the 8 T-PODS (grey circles) and the number of porpoises provided by the ship-based surveys (black dots). The data show the local increase in porpoise occurrence during the winter months. Figure taken from Brasseur et al. 2004a. Data collected during the baseline studies prior to the building phase in the study area of the Offshore wind park Egmond aan Zee (OWEZ).

2.2.2 Line transect sampling

The idea behind line transect sampling is to estimate the density of the target species in strips sampled by surveying along a series of transects, and to extrapolate this density to the entire survey area. The calculated number is therefore an estimate of abundance in a defined area at a particular time. In a strip transect it is assumed that all animals are detected within a given distance from the survey platform. The only way to determine if this is a valid assumption is to measure the distance to each individual observed. This can than be used to estimate the effective width of the strip that has been searched.

The basic requirement for a line transect survey is that it provides representative coverage of the study area because, typically, estimated density in the sample strip is extrapolated simply by multiplying sample density (number of animals/km^2) by study area. Common designs are sets of equally spaced parallel lines, perpendicular to the coast, or a regular zigzag pattern, starting from a random point along one edge of the survey area.

The probability of detection of a school of cetaceans from the survey ship or aircraft depends on many things including the ability and experience of the observers, the height and characteristics of the survey platform, the weather, school size, and the behaviour of the animals. It is important to record this information either in association with a sighting or with the survey effort so the effects of some or all of these variables on detection probability can be investigated.

Standard line transect sampling assumes that all targets present on the transect line will be detected with certainty (see above). This is clearly not the case with cetaceans, with the result that estimates of abundance calculated in this way will be biased downwards by an unknown amount. The accepted way to take this into account on shipboard surveys is to use data collected from two observation platforms on the same vessel, which is only possible on larger survey ships. For aerial surveys working with two platforms is more difficult. One method is the racetrack method in which one part of the trackline is covered twice to estimate the proportion of animals missed on the trackline (Hiby & Lovell 1998, Hiby 1999).

2.2.3 RIKZ aerial surveys

Approximately every 2 months, aerial surveys are conducted in the NCP. Although the survey is originally intended for birds, marine mammals were also consistently recorded from 1991 onwards. For a detailed description see Berrevoets & Arts (2001) and Arts & Berrevoets (2005). This data source can provide information on trends in relative abundance (both within and between years) and relative changes in their spatial distribution. Currently, the data cannot be used to estimate absolute abundance because the sighting probability (*i.e.* given the animal is present, what is the chance of detecting it) cannot be correctly quantified (see also the 'future work' section).

The pre-processed RIKZ data (Arts & Berrevoets 2005, Berrevoets et al. 2005) consist of harbour porpoise counts per unit area along the transect lines parallel to the coast. Observations are made under different weather conditions. For example sea state can have a strong influence on the detection probability. Unfortunately, *in situ* measurements of weather conditions were not available, so instead daily wind speed data from the military airport 'De Kooy' were used to investigate its effect on the harbour porpoise detection probability.

To produce maps covering the entire NCP, it is essential to also estimate the relative abundance between transect lines. To do so, one could use interpolation or extensions thereof. Alternatively, the survey data can be used to investigate the preference of harbour porpoises for environmental conditions. For Figure 16 a combination of these two methods was used. More specifically, a Generalized Additive Model (Wood 2006) is used to model the harbour porpoise densities as a function of a smooth of distance to land, silt-content, depth, maximum daily wind-speed, year and a smooth interaction between latitude and longitude. Next predictions were made for each 1 x 1 km cell in space for wind speeds at 1 Bft, assuming that under those conditions all harbour porpoises at the surface were indeed detected. Next, using telemetry data from Danish waters, these estimates were corrected for the time spent at the surface.

Figure 20 deals with temporal trends in abundance, but the harbour porpoise distribution is assumed not to change between seasons and years. This assumption is evidently incorrect. Further work is currently in progress to relax these assumptions and improve the estimated distributions.

2.2.4 Non-dedicated sightings: European Sea Birds at Sea (ESAS), counts from the coast, stranding data

Often, seabird surveys also yield information on marine mammals and the most systematic record of this was discussed above (RIKZ-data). In other frameworks, marine mammal sightings are also recorded. This information can be divided into three different types: (1) Sightings from ship-based surveys (ESAS); (2) Shore-based sightings during bird migration observations and (3) Strandings. In some cases these data sets are the only and best available and can be used in marine mammal studies.

3 Harbour seal (*Phoca vitulina*)

3.1 Population size

In the North Sea the harbour seals consist of several populations, which are more or less closed. In 2007 ICES reported a number of over 45,000 animals in the North Sea area. In 2007, for the population in the Wadden Sea, ranging from Texel in the Netherlands to the Danish Esbjerg, a maximum of 17,605 seals were counted during the moulting season. These represented an estimated population size of almost 26,000 seals. In the Dutch Wadden Sea alone 4159 harbour seals were counted, leading to an estimate of over 6000 harbour seals (Trilateral Seal Expert Group 2008) In addition, a small colony of 148 harbour seals is counted in the southern Netherlands or Delta Area in the summer (Strucker et al. 2007). The Harbour seal population in the North Sea was reduced by almost 50% in both1988 and 2002 due to a virus epizootic, but recovered relatively well afterwards.

3.2 Important areas

P. vitulina is one of the most widely distributed pinnipeds over both longitudinal and latitudinal range; it has a practically circumpolar distribution and can be found between 30°N and 80°N. Three subspecies occur in the North Atlantic. *P. v. mellonae* occurs endemically in lakes in eastern Canada, *P.v. concolor* can be found along the eastern coasts of the Northern American continent, and *P.v. vitulina* is the only subspecies that occurs along the European coasts.
In the North East Atlantic, harbour seals are distributed around the British Isles and Ireland, in the Kattegat/Skagerrak, the south-western Baltic Sea, the Wadden Sea and along the North Sea from Denmark, to Brittany. The most northerly distribution is along relatively warm Svalbard. They also occur in the waters of Iceland, along the coasts of Norway and at the north coast of Russia.
Within the southern North Sea area, the harbour seal *P.v. vitulina* occurs in four more or less distinct areas. Though some exchange is recorded, these groups have been considered to form four different populations. These are: the Wadden Sea population ranging from Esbjerg in Denmark to Den Helder in the Netherlands, the southern Dutch and Belgian population, the Wash population in Great Britain and the population in the Baie de Somme, France (De Jong et al. 1997b). However, there are several indications that there is a regular exchange between the different colonies (i.e. Brasseur & Reijnders 2001).
Seals typically divide their time over a terrestrial phase and an aquatic phase. During the terrestrial phase animals lay on the haulout sites, more frequently when moulting or in the breeding period, but also outside these periods, albeit to a lesser extent. As described in the methods, population estimates are based on counts made when seals are hauled out. Figure 5 shows how the seals are distributed during the pupping and moulting surveys in the Wadden Sea. The actual function of hauling out is multiple: including rest, skin maintenance and predator evasion. Typically, the harbour seal does not show marked differences between seasons in its spatial distribution and seem to show fidelity to haul out areas (Härkönen 1987). They may use several haulout sites (Thompson & Miller 1990, Reijnders 1992, Brasseur et al. 1996, Thompson et al. 1996, Brasseur et al. 2004b). Some young seals can disperse over larger distances shortly after weaning (Thompson et al. 1994, Ries et al. 1999). Especially movements of this group are thought to account for most of the exchange between populations.
For a larger part of time, approximately 80%, the seals spend their time at sea. In the sea the animals forage, mate, travel and even sleep occasionally.

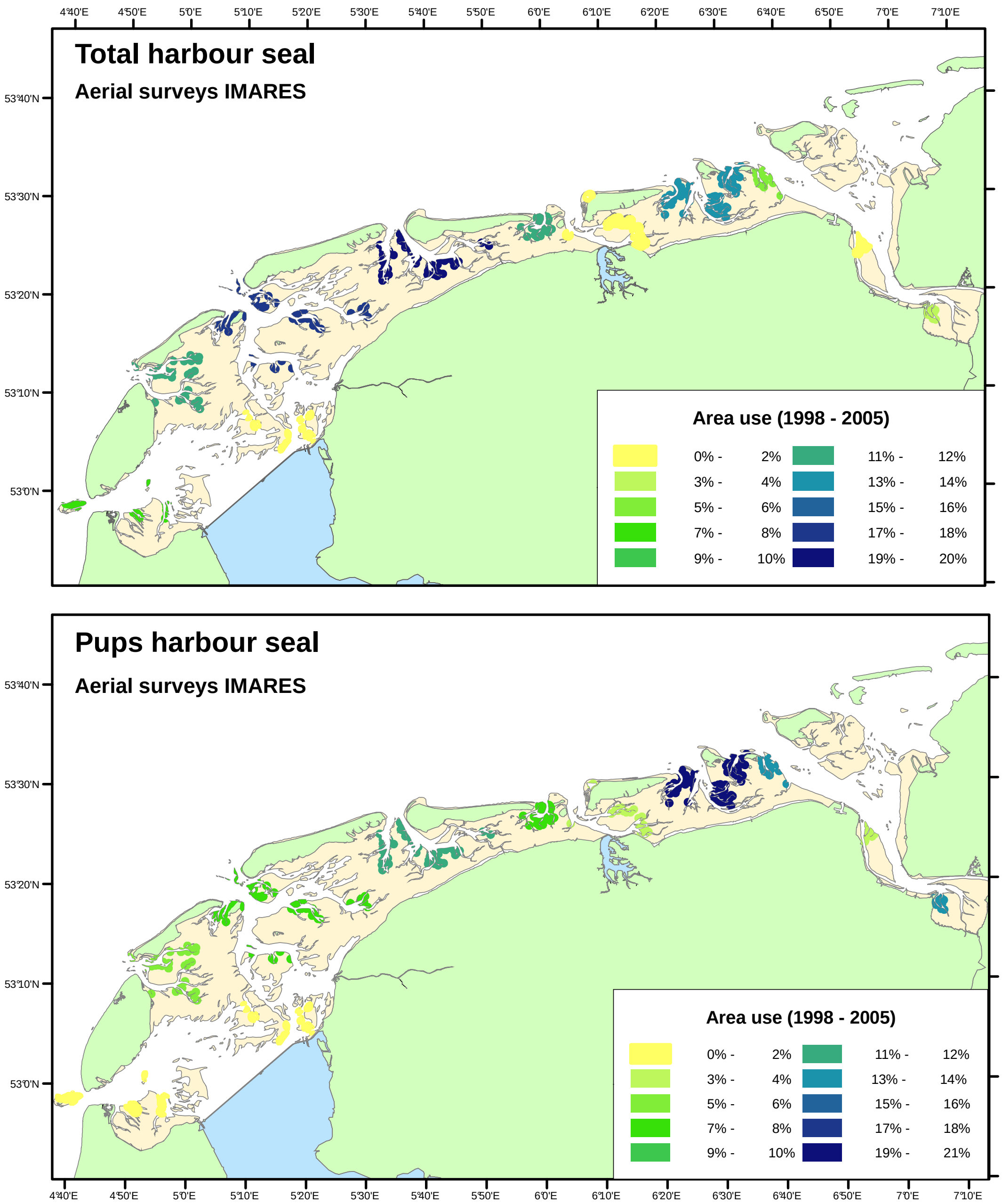


Figure 5. Average relative distribution of the total harbour seal numbers (top) and of pups (bottom) in the Dutch Wadden Sea. Individual haulout sites were buffered to account for changes in the exact position of the seals on the sandbank. Colours indicate the relative distribution of the harbour seals in the Dutch Wadden Sea over the different water-shed areas (Dankers et al. 2007). Changes in haulout locations have somewhat, been accounted for, because natural processes such as storms can markedly change the morphology of sandbanks, thus the seals use of it.

3.2.1 Reproduction areas

Pupping peaks in the second half of June but can occur from May to July (Härkönen & Heide-Jørgensen 1990, Reijnders 1992, Gjertz & Borset 1992). A single pup is born weighing about 10 kg and measuring about 80cm. Pups are born ashore but can swim almost within minutes of being born. Suckling can only take place on land, therefore, in areas where the seals can only haulout on tidal flats, disturbance can influence pup survival by limiting the amount of time the pup can suckle (P.J.H. Reijnders unpubl.data). Lactation lasts for 3 to 4 weeks, with pups reaching a weaning weight of about 24 kg (Härkönen & Heide-Jørgensen 1990, Reijnders 1992). During the lactation period seals spread out over a large number of haulout sites. Observations of single mother-pup pairs are frequent; whilst in other periods animals seem to form larger groups. There is some indication that mothers with young pups then avoid disturbance as much as possible.
Harbour seals show a lactational oestrous, so mating occurs at the end of or just after the lactation (Reijnders 1990). Harbour seals are assumed to mate in the water. They seem to be serially polygynous, as males are recorded to remain in shallow waters and display both visually and vocally during the mating period (Sullivan 1981, Godsell 1988, Thompson 1988, Boness et al. 1995). Aquatic mating areas are assumed to lie in the vicinity of the breeding sites, but this behaviour and where it takes place, is still poorly understood.

3.2.2 Foraging areas

Recently, a project on the feeding ecology of seals has been carried out in the Netherlands (Brasseur et al. 2004b, Brasseur et al. in prep.). The study shows that harbour seals feed on a large variety of mostly demersal fish, dominated by various species of flatfish. Efforts have been made to identify specific feeding grounds but this has been hampered by the large individual variation in behaviour displayed by the animals. In a new study, modelling of large numbers of tagged seals, combining both information on distribution and diving behaviour obtained through telemetry, will give more insight in the seals' choice for specific feeding grounds.
In general, one might state that seals could feed throughout their distribution range in the Dutch waters. For example water depth does not act as a limiting factor, as most areas are shallower than 50m, whilst harbour seals have demonstrated dives beyond 150m (Frost et al. 2001). Further research on the diving behaviour in relation to oceanographic, geomorphological and biological features could give insight in possible specific feeding grounds.

One could expect temporal variation in the necessity to feed as harbour seals seem to show seasonality in food requirement. In autumn after the reproduction and moult, both wild and captive seals display more need for food (as shown in Figure 6).

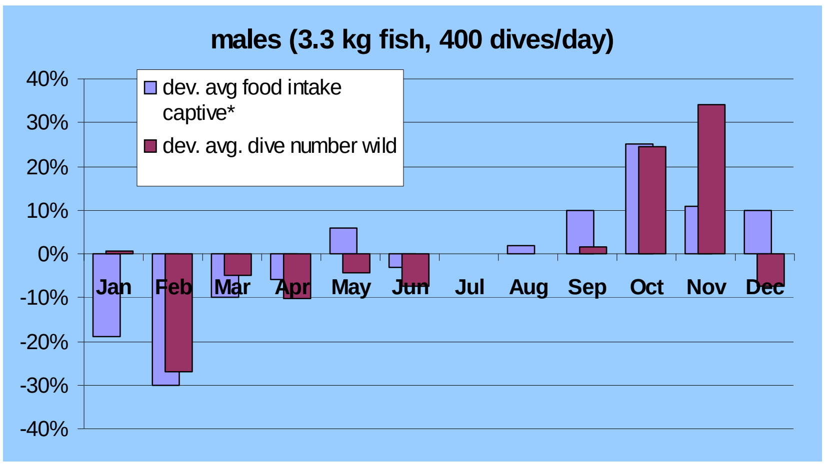


Figure 6. Comparison of seasonal variation in food intake of a male seal in captivity compared with male diving frequency in the wild. Data expressed as percentage relative to average i.e. 3.3 kg fish and 400 dives/day (Brasseur & Fedak 2003; data from Kastelein 1998, R. v.d. Zwaag pers. comm.; Brasseur & Reijnders pers. comm.).

3.2.3 Migration routes

Relatively recent satellite tracking of harbour seals in the Netherlands demonstrated that the animals can migrate over several hundreds of kilometres. Studies by IMARES (formerly IBN and Alterra) show for example that some seals tagged in the Delta area migrate to the Wadden Sea and back or even to the northern French coast (Reijnders et al. 2000, Brasseur & Reijnders 2001). Within the Wadden Sea some seals easily migrate to German or Danish waters (Brasseur et al 2004). From the all the animals tagged in the Netherlands (over 100) it is evident that individuals show marked differences in their migratory behaviour and offshore distribution.
Individual seals seem quite specific in their regular trips offshore. Some may display high fidelity to daily trips off the haul out sites and back while others tend to stay away for up to several days (Figure 7; Brasseur et al. 2007).

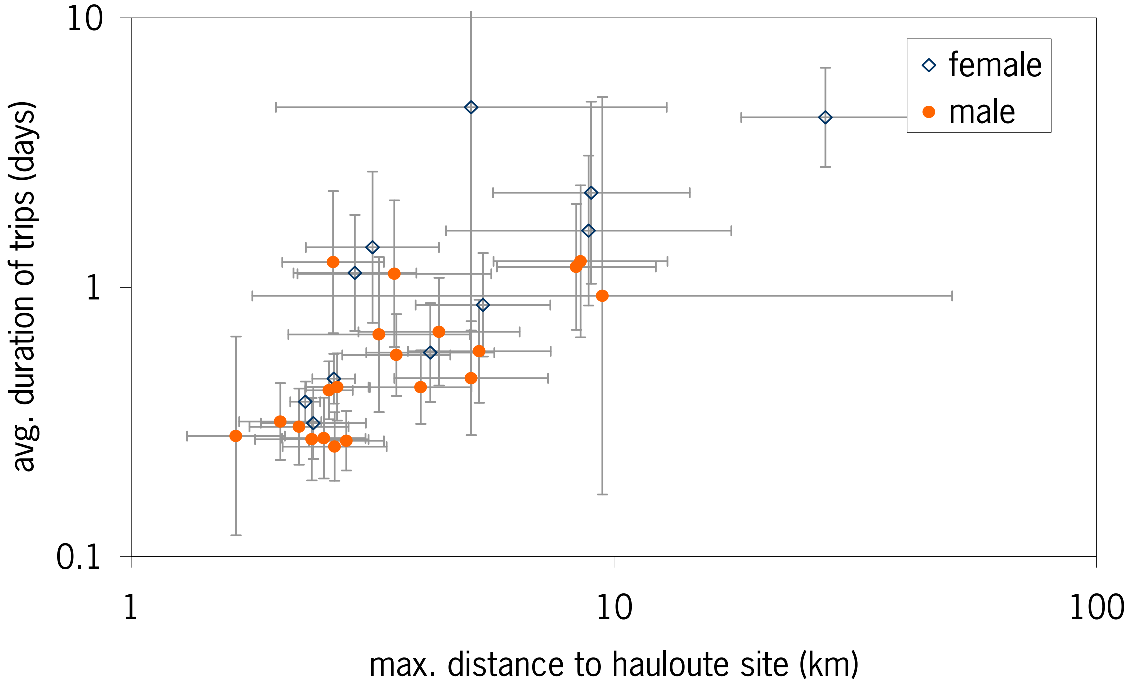


Figure 7. Relationship between trip duration and trip distance for 30 individual seals tracked between 2004 and 2007, showing how specific individual harbour seals are in their regular trips (Brasseur et al. 2007).

Despite this individual variation, there is some evidence that human disturbance such as offshore developments may have an impact on their migration: in the Delta area seal numbers are low and births do not make up for the mortality. Stabilisation or growth of the seal colonies in that area can only be sustained if enough seals can migrate from the Wadden Sea or other areas. The few animals recorded to make these long trips seem to travel parallel to the coast, within some tens of kilometres off the shore (Figure 8).

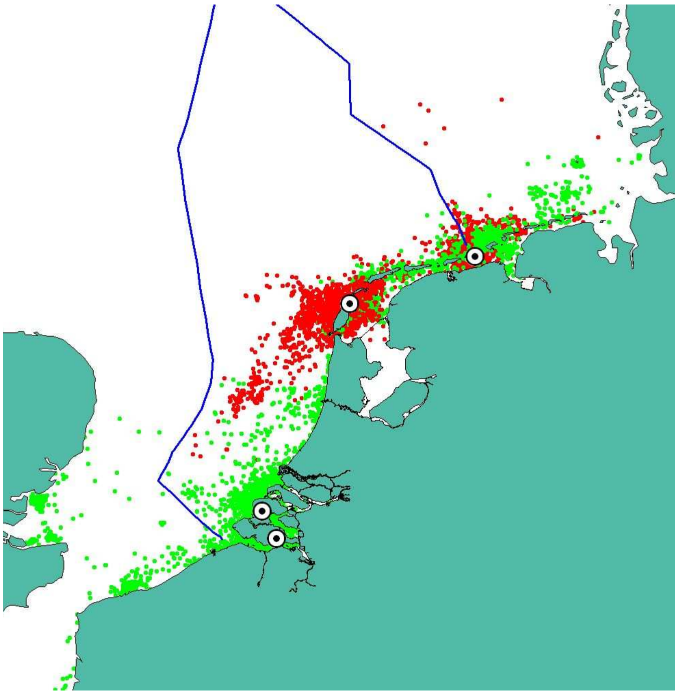


Figure 8. Unfiltered locations from harbour seal telemetry data collected between 1997-2006. The locations observed are very dependant of the location the animals were tagged, the number of animals tagged and the methods used (see 2.1.2). Tagging locations are indicated in white; seal locations in green (animals tagged in the southern Netherlands) and red (animals in the Wadden Sea); blue line indicates NCP contours.

3.2.4 Distribution maps

Ideally, a distribution map should include the various areas used by the animals differentiating in behaviour such as foraging, resting, migration routes. In lack of the possibility to differentiate for the various functions at this stage, several maps describing the general distribution of harbour seals have been drawn. A first map showing the estimated distribution, based on averaged distance from haulout sites is demonstrated in Figure 9 (Brasseur et al. 2004b). Using data from more tagged seals and applying Model-supervised Kernel Smoothing (Matthiopoulos 2003) a second distribution map was drawn (Figure 10). Expectedly, the two maps show reasonable overlap as both methods are based on the distance to haul outs and numbers of seals counted on these haul outs. In these two methods possible preference for a certain habitat type is not taken into consideration. In a first attempt, to do so the distribution of harbour seals is predicted using information on sediment type, depth and distance to the haulout site (Figure 11). By the end of 2008, beginning 2009, IMARES expects to have finalised a more extended model based on habitat preference. In addition to distance to the haul out and geo-morphological features also human activity and possibly factors such as the presence of thermal fronts will be included. Figure 10 is still a simplification because it does not incorporate the importance of different areas in terms of foraging behaviour, it merely quantifies general use. It was compiled using relative few environmental variables (only depth and sediment type) and lacks for example seasonality and yea to year variation which may play an important role as well.

Incidental sightings from boats were recorded in the ESAS data base (Figure 12). Though overlap is seen, with the models (Figure 9, Figure 10, Figure 11) it is clear that only seals relatively close to shore were observed. Possibly, this is an observer effect, where the observers capable of spotting seals travelled close to shore. Another explanation is that the seals display a different behaviour near the coast, making the animals more visible.

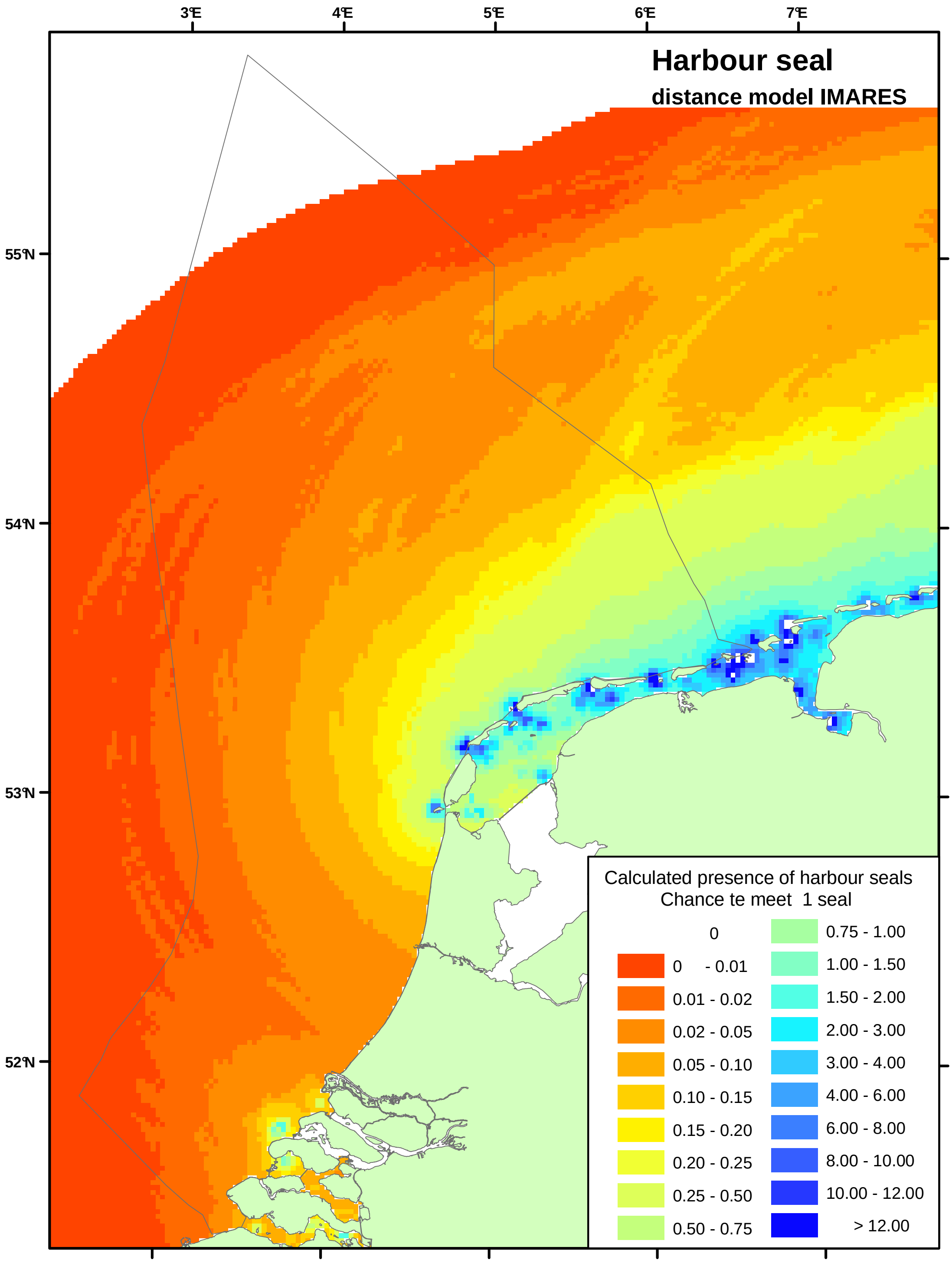


Figure 9. Estimated distribution of harbour seals in Dutch waters based on Brasseur et al (2004b). Data used to model this distribution is based on the tracked movements of seven seals, tagged near the Island of Texel. Only distance to haul out site was taken into consideration (see method section for a more detailed method). Results represent the estimated number of harbour seals per square 2 km^2.

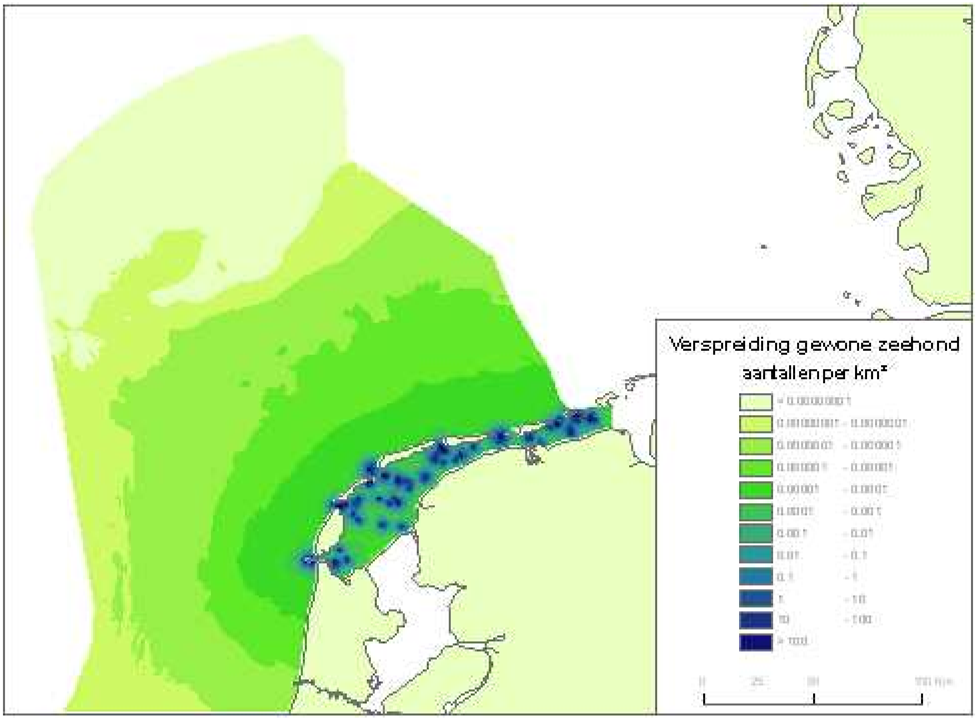


Figure 10. Example of habitat preference model based on depth and sediment type. The map shown does not take into account intra- and inter-annual variation, neither does it account for movement between haulout regions such as movement between the Wadden Sea and Delta area.

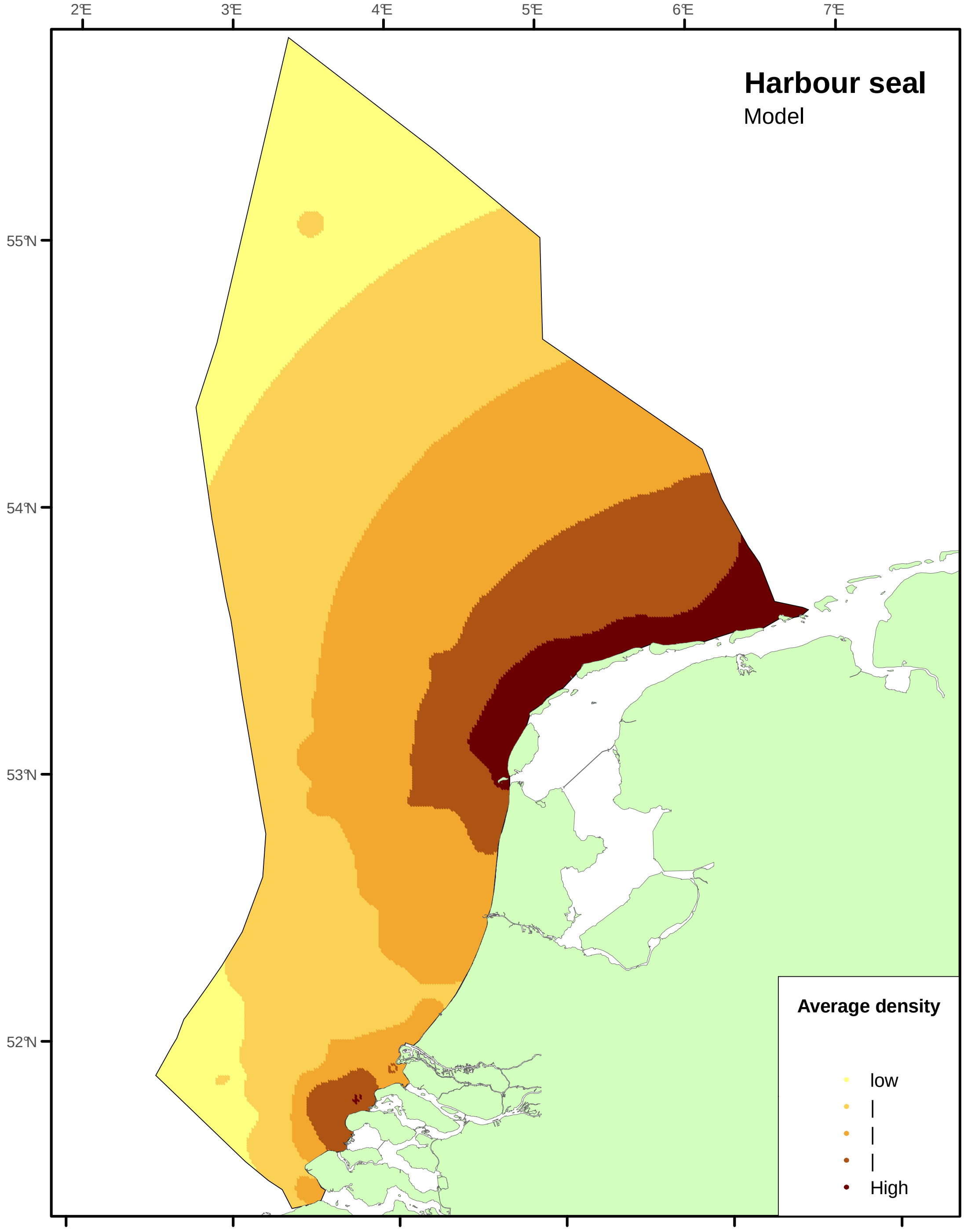


Figure 11. Modelled distribution of harbour seal using Model-supervised Kernel Smoothing (Matthiopoulos 2003). Haulout sites visited by tagged harbour seals are well estimated. However, those areas for which no or limited wildlife telemetry data is available are based on a simple distance model, which may be an insufficient representation of the actual distribution.

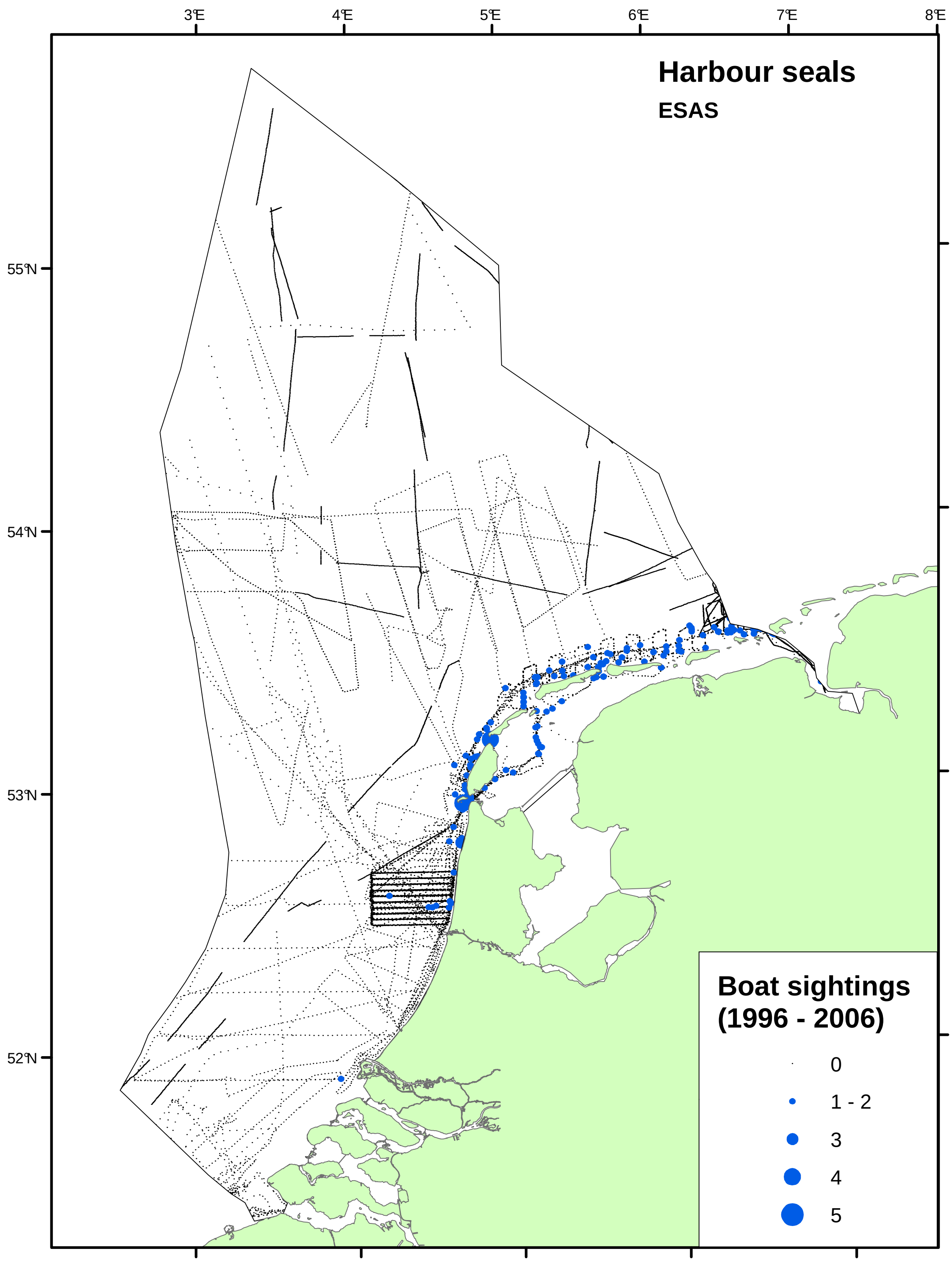


Figure 12. Boat sightings of harbour seal from the ESAS database. The data presented here were not corrected for possible differences in sighting probability between surveys, e.g. due to differences in weather. Effort and sightings are combined over a 10 year period. As mostly incidental sightings are included, effort is not equal between years and over the study area. This map provides information on seal occurrence in Dutch waters throughout the year. This map can not be used to determine high density or low density areas or for abundance estimates of seals.

4 Grey seal (*Halichoerus grypus*)

4.1 Population size

Grey seals range over the North Atlantic coast. Roughly three stocks can be identified; one in the West Atlantic, one in the Baltic and one in the East Atlantic, they are not considered different sub-species (Bonner 1989, Anderson 1990, De Jong et al. 1997a).
The number of grey seals in the Eastern Atlantic stock is dominated by the numbers that occur in the UK area. In 2006 a total population of grey seals there was estimated to be 133,000 seals (Duck & Thompson 2007).

New colonies of grey seals at the North Sea and Channel Coasts, growing since the 1990's, were most probably fed by grey seals from Britain. Seals in the Kattegat-Skagerrak are believed to come from both the Atlantic and Baltic populations. In the Kattegat-Skagerrak stable numbers of about 25 individuals have been observed since the 1970s, whereas more than 100 grey seals are found in the Southwestern Baltic. In 2007, 120 grey seals occur during moult at Helgoland, 120 in the German and over 1530 in the Dutch parts of the Wadden Sea. Along the southern Dutch and Belgian coasts small groups are regularly observed, but no colonies have yet been established. In the colonies off Brittany in France about 105 grey seals have been counted. Successful pupping has only been recorded three times in the Kattegat-Skagerrak over the past 30 years, and 2-4 pups are born annually in France and the Southwestern Baltic. The relative strongholds for breeding along the European continent are the Dutch Wadden Sea, where in 2003/2004 at least 150 pups have been recorded, Amrum in the German Wadden Sea (23 pups) and Helgoland (8 pups). The total number of grey seals counted in the Southwestern Baltic to France amounted to at least 2,000 in 2006, while about 190 pups were born in the area. As stated before grey seals in the Netherland by far outnumber grey seals in the other continental area.

4.2 Important areas

Being a relatively recent inhabitant along the Dutch coasts little is known about the distribution and variation of grey seals in the area. Most extensive knowledge is based on the yearly census. As described in Reijnders et al. (1995), regular counts of the seal colony which had settled on "de Richel" between the Dutch islands of Vlieland and Terschelling were made by boat until the end of last century. Despite the regular morphological changes the colony grew steadily to over 500 animals during the moult in March-April. From 2000 onwards also the pupping and moulting colony spread out over several sites to the west around the island of Texel. In total, 20 seals have been tracked since. The results are partially presented in Figure 14.

As boat surveys were no longer adequate to survey the larger area, numbers were most probably underestimated. Therefore, from 2001 onwards aerial surveys are conducted over the western part of the Dutch Wadden Sea. These surveys take place during pupping in December-January and moult in March-April (Figure 13).

By 2007 the maximum number of grey seals observed in the western Dutch Wadden Sea during one survey amounted to over 1500 animals. In summertime much lower numbers of seals were seen; though still concentrated around the same general area. Recently, a growing number of grey seals are seen to haulout in the southern Netherlands; over 200 animals were observed during the moult in 2006.

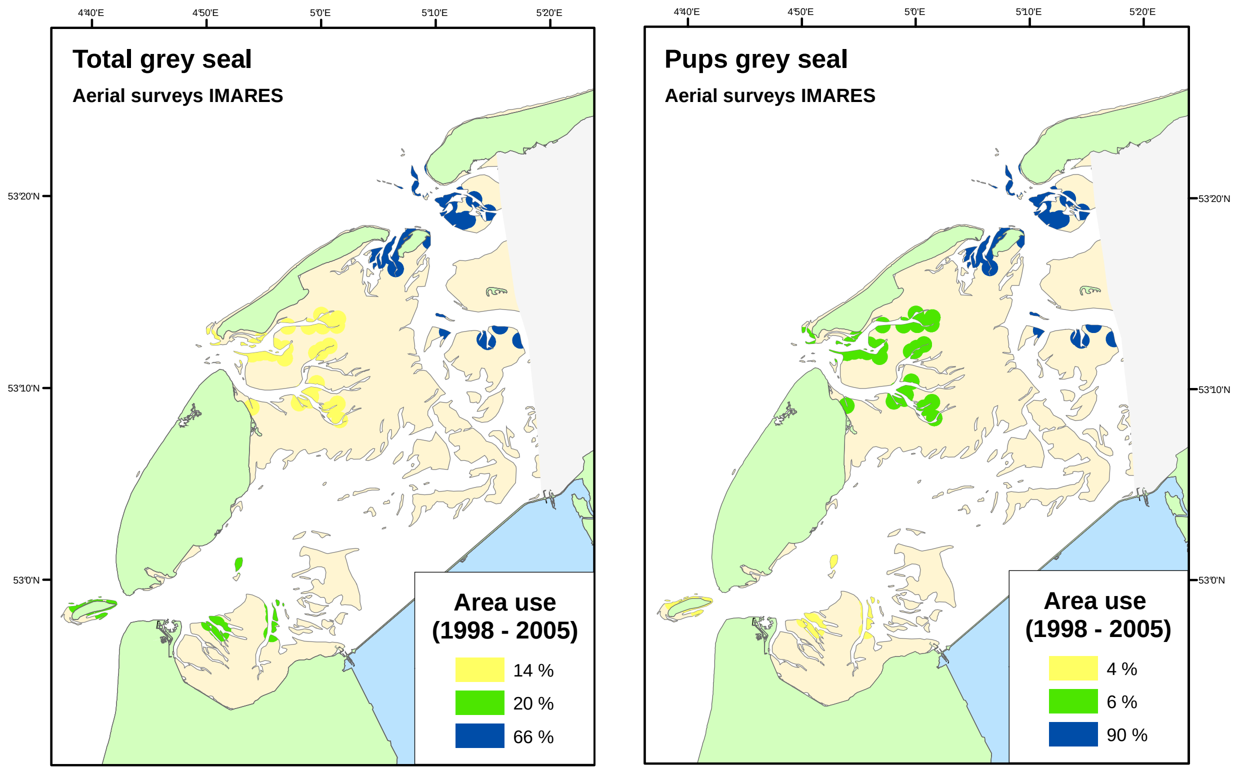


Figure 13. Relative distribution of grey seals in the Dutch Wadden Sea. Individual haulout sites were buffered to account for changes in the exact position of the seals on the sandbank. Colours indicate the relative distribution of the grey seals in the Dutch Wadden Sea over the different water-shed areas (Dankers et al 2006). Though changes in haulout locations have somewhat been accounted for, natural processes such as storms can markedly change the sandbanks, thus the seals use of it. The grey seals are continuing to colonize the Wadden Sea towards the East. These observations have not yet been included in these maps.

4.2.1 Reproduction areas

In general, females become sexually mature at 3 to 5 years of age, males at 6, although they may not be socially mature until they are 8 years of age or older. In the Baltic, maturity can be attained at 3 years for both sexes, due to the reduced population size. Gestation lasts 11 months including 3 months of delayed implantation. Females give birth on land or on ice to a single pup. The pup is suckled on shore for about 16 (west Atlantic population, Sable Island) to 18 days (UK), increasing in weight by 1.5 to 2 kg per day. Females do not necessarily feed during lactation, and either remain with their pup throughout, or occasionally make trips to sea, but it is assumed that they remain in proximity of their pupping colony. Females come into oestrus towards the end of the lactation period and are mated several times before they return to the sea. Females moult just before the time of blastocyst attachment, and males moult slightly later. Annual pregnancy rates of 83-94% have been recorded (Boyd 1988).

It is intriguing that the maximum number of pups in the Dutch Wadden Sea are observed in late December. This is relatively late compared to pupping at most colonies in the UK and early compared to the pupping in the Baltic. Also within the UK a different shift in mean pupping time can be observed: pupping starts first in Wales and mean pupping time on the east coast of Scotland is approximately one month later.

By far most pups are born on the relatively high sandflat between the Island of Terschelling and Vlieland. Dry areas are a necessity, as grey seal pups are not good swimmers until they have moulted their white coat in which they were born. However, no areas are used where the risk of flooding is entirely absent.

Some pups (1-3) are seen in the Delta area on the sandbanks of the Voordelta. However, most surveys in this region take place during the moult and reproduction should be finished by then. Correct identification of new-born pups could therefore be questioned.

4.2.2 Foraging areas

Generally diet overlaps largely with that of harbour seals, though there is some indication that grey seals may prefer slightly larger prey. In the UK, sandeel forms a major component of their diet. Diet studies in the Netherlands suggest that sandeel is consumed less, which may be caused by lower overall availability compared to other prey species. A recent study showed that both UK and Dutch grey seals have a preference for coarse sediment type (Aarts et al. unpublished), which happens to be the preferred burrowing habitat of sandeel (Wright et al. 2000). Depth is unlikely to play a limiting factor for their distribution, since most areas in the Dutch North Sea are extremely shallow (<50m). Compared to harbour seals, grey seals appear to forage further offshore and to make longer trips. This however is confounded by large individual variability.

In parallel to the harbour seals one could expect the feeding is most important in late spring and summer, just after breeding and moult.

4.2.3 Migration routes

As mentioned earlier, the grey seals in the Netherlands are most probably not a separate population but started an offshoot colony of the British seal population. First analysis of the results of tagging shows that the seals occasionally exchange with the British Islands. Such transitory trips can exceed 1000 km. This migration is observed using data from only few tagged individuals, which suggests that it is a more common behaviour of the population. The directional nature of those transitory trips, seems to imply that individuals have knowledge of the existence of colonies elsewhere (e.g. the UK). Juveniles however, may only discover new colonies through 'random search'. If this is the case, and if they travel independent of older individuals, possible disturbances caused by for example offshore developments, may hamper exchange rates and therefore may reduce genetic mixing in the future.

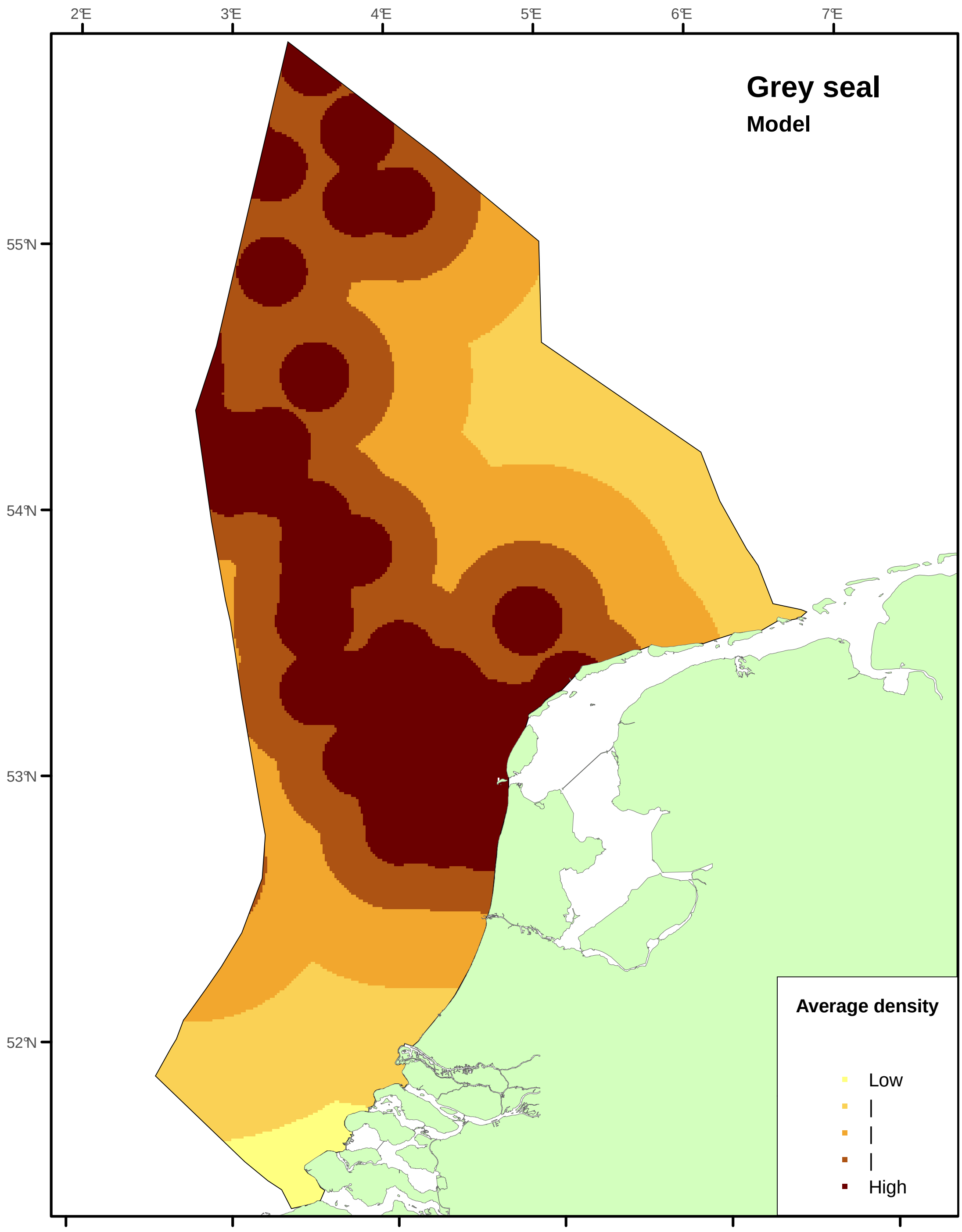


Figure 14. The estimated spatial distribution of grey seals in the North Sea using model-supervised Kernel Smoothing (Matthiopoulos 2003). Note that this map is based on telemetry data from very few individuals (six) tagged in the vicinity of Texel. Consequently, some individual trips may confound the overall picture (Lindeboom et al. 2008). For example the higher estimates of usage north-west of the Wadden Sea are only based on two individuals.

5 Harbour porpoise (*Phocoena phocoena*)

5.1 Population size

In 1994 abundance for harbour porpoises was estimated at 262,540 individuals including the whole North Sea and the Channel (Hammond et al. 2002). The Kattegat and part of the Skagerrak had an additional estimate of 36,046 harbour porpoises. During the 2005 the abundance estimate was 38,000 animals in the Northern North Sea, 59,000 animals in the Central North Sea and 134,400 animals for the Southern North Sea and the Channel. An additional 23,200 animals were estimated for the Inner Danish waters, Kattegat and Skagerrak and 128,600 animals for the western shelf waters (ICES 2008).

5.2 Important areas

The cetacean atlas (Reid et al. 2003) shows the distribution of harbour porpoises in the North Sea at the scale of 1/4 ICES rectangles. Here the highest sighting rates for harbour porpoises were found in the northern central North Sea (Figure 15). The lowest sighting rates in the North Sea were in the south-eastern part, close to the German, Dutch, and Belgian coasts and in the Channel. The atlas combines data over all seasons and over a time period from 1979 to 1998. Both the SCANS I and the SCANS II survey results have been used to spatially model the distribution of porpoises in the summer (Figure 19). The results show that the distribution of porpoises in the North Sea has changed over the last decade. Other data sources such as the strandings and sighting data from the Dutch coast confirm that over the last decade porpoise occurrence has increased (Figure 18).

5.2.1 Reproduction areas

Harbour porpoises have a gestation period of 11.5 months. Generally their mating and the birth of their young coincide in the time period from mid May to mid July. During this time it can be assumed that porpoises are particularly sensitive to disturbance. Females have an increased energy demand due to pregnancy and birth. Porpoises have a young every 1-2 years, so compared to other cetaceans their reproduction rate is quite high. Young porpoises probably are weaned at around 6 months, but are thought to stay with their mothers at least for a year.

With the current data available no reproduction (calving) areas in the southern North Sea can be defined. A future analysis of calf sightings might indicate areas of particular importance for calving.

5.2.2 Foraging areas

Generally porpoises can be considered opportunistic in their prey choice. Their diet consists of over 20 different species of fish, squid, octopus and shellfish. Due to the limited amount of information available on harbour porpoise distribution in Dutch North Sea waters no true foraging areas can be defined. However, some knowledge on distribution of prey species in the Dutch North Sea is available. One can hypothesize that those areas will be important for porpoises.

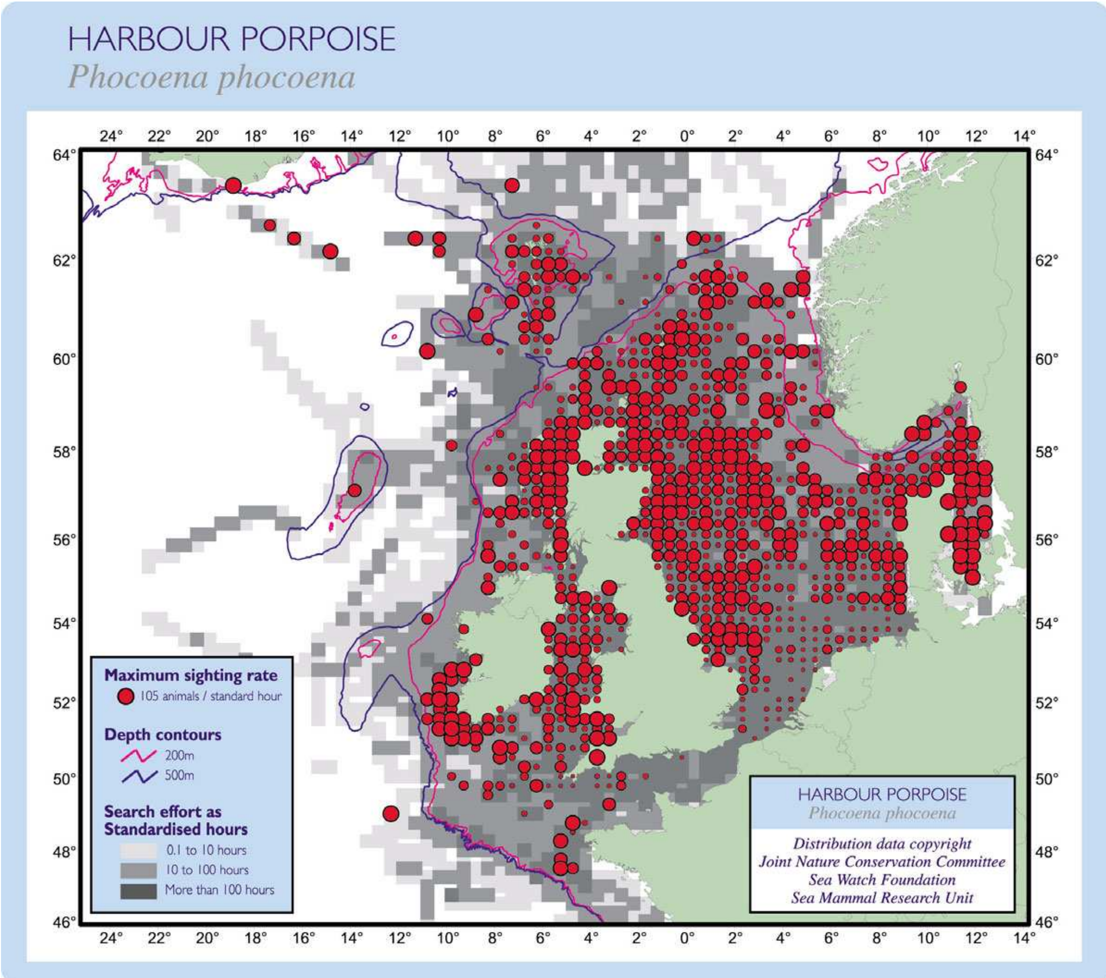


Figure 15. Distribution of harbour porpoises (Reid et al. 2003). This map is based on a combination of three different databases. The underlying effort (grey) is not equal for all areas and all seasons. This map combines data from all seasons, over a period of 10 years (1979-1998), with the most recent data 10 years old. This map should not be used as an accurate representation of current distribution patterns of harbour porpoises in the North Sea, but it can give an indication of how the general distribution of porpoises was during the period studied, taking the limitations mentioned above into account.

5.2.3 Migration routes

Although porpoises in the North Sea do not seem to make long migrations, they undertake seasonal movements, probably related to food availability. Some data indicate movements from generally inshore in summer and offshore in winter, as well as sometimes north in summer and south in winter. However, in other areas porpoises are seen all year around. In the Netherlands most animals are observed during winter and early spring.
It is obvious from data collected through land based observations over the last decades that there is a seasonal change in how porpoises use the coastal waters of the Netherlands. Figure 20 and Figure 4 show an increase in sightings in early spring and fall. How the distribution of porpoises changes throughout the year in terms of offshore and inshore movements, or possibly migration on a larger scale, is open for speculation.

5.2.4 Other areas

Figure 16 gives an overview of recorded sightings in Dutch waters over the last decades. The data indicates that porpoises occur all over the Dutch waters. Clear distribution patterns and seasonal changes can not be detected with the data available.

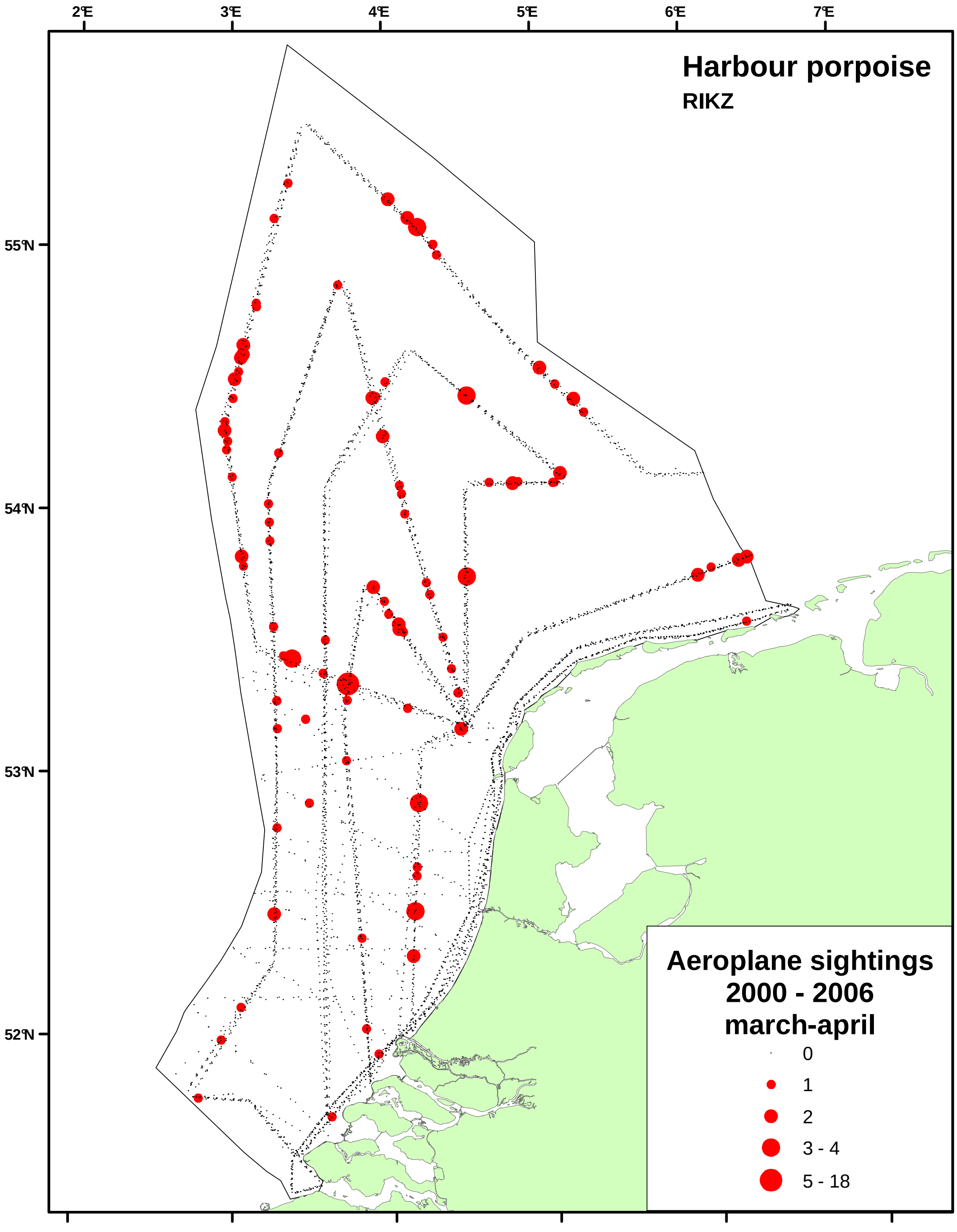


Figure 16. Sightings of porpoises during aerial surveys from RIKZ. Combined from 2000 to 2006 for the months March and April. The aerial surveys presented here were not corrected for possible differences in sighting probability between surveys. Effort and sightings are combined over a 6 year period. Effort is not equal between years and over the study area. This map provides information on harbour porpoise distribution in Dutch waters in spring (March – April). This map can not be used to determine high density or low density areas (e.g. suitable areas for offshore construction) or abundance estimates of porpoises.

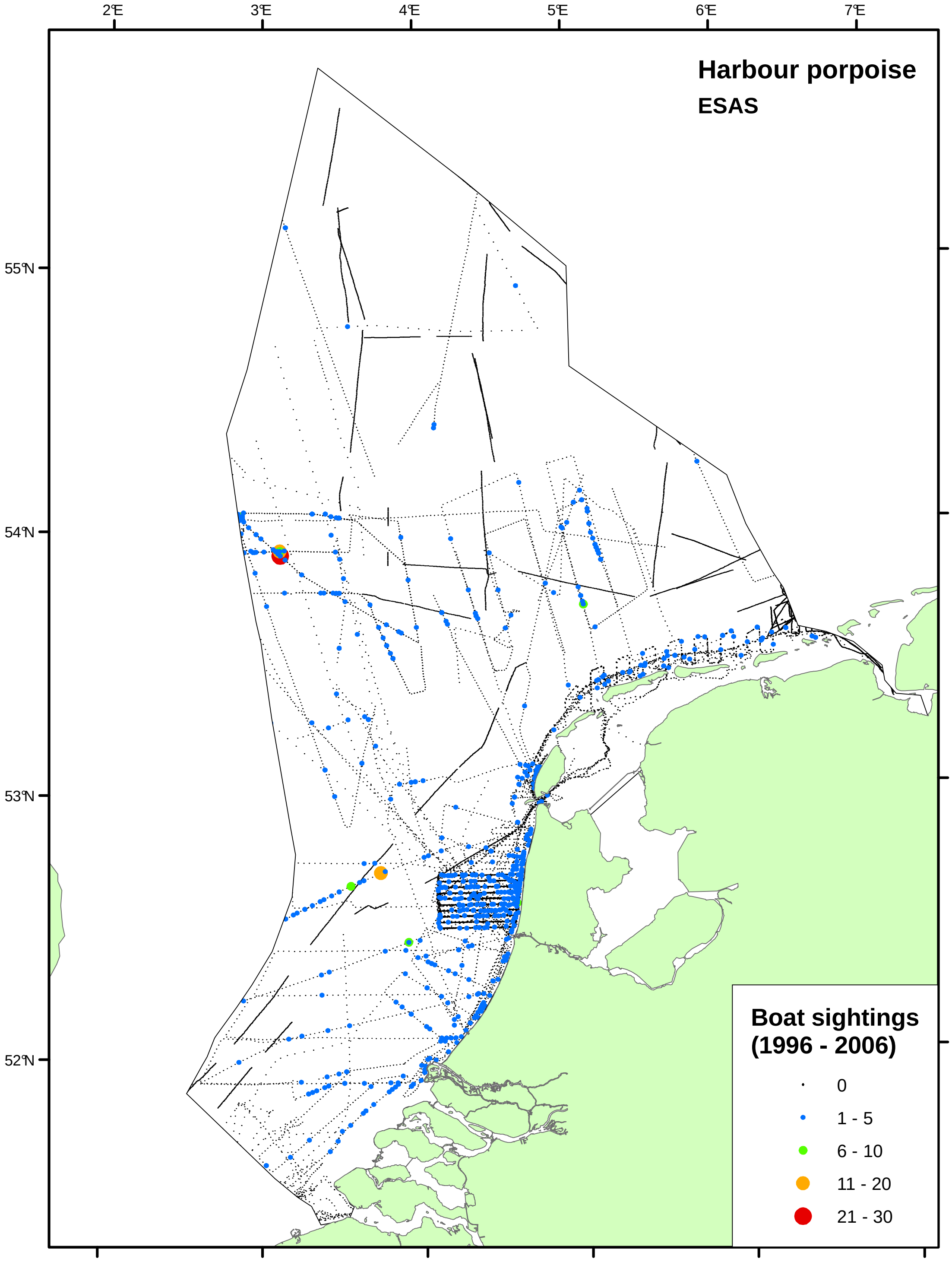


Figure 17: Boat sightings of harbour porpoises from 1996 to 2006 based on the ESAS (European Seabirds at Sea) database. The data presented here were not corrected for possible differences in sighting probability between surveys, e.g. due to differences in weather. Effort and sightings are combined over a 10 year period. Effort is not equal between years and over the study area. This map provides information on harbour porpoise occurrence in Dutch waters throughout the year. This map can not be used to determine high density or low density areas (e.g. suitable areas for offshore construction) or abundance estimates of porpoises.

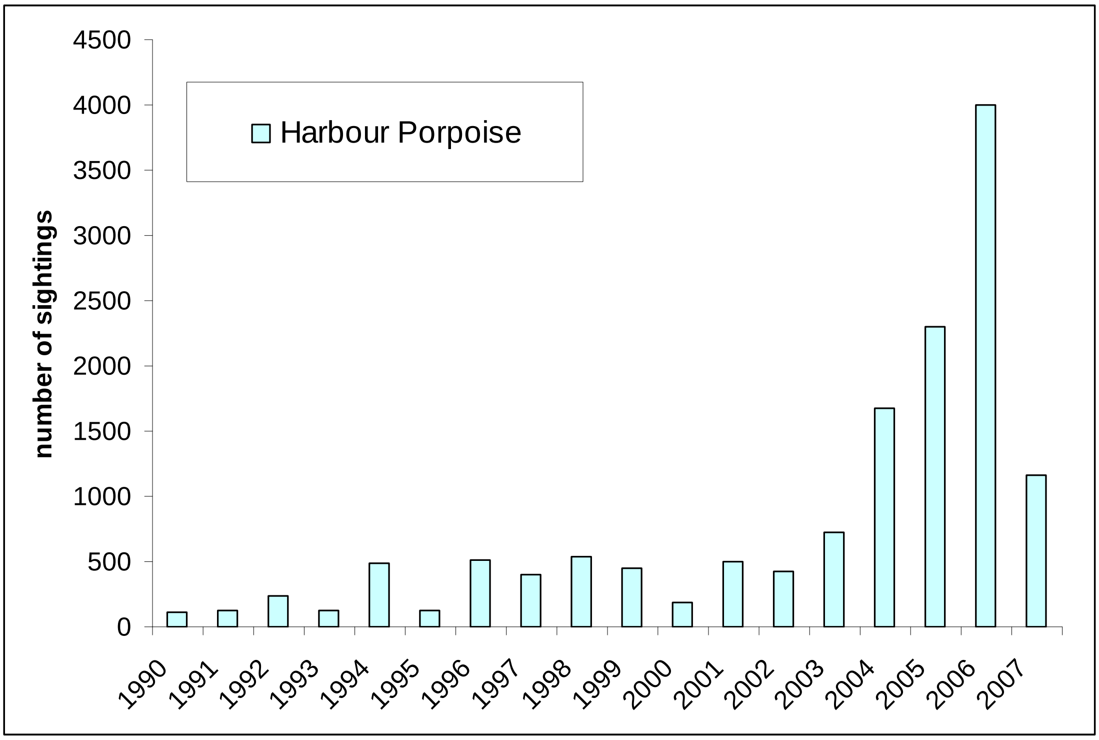
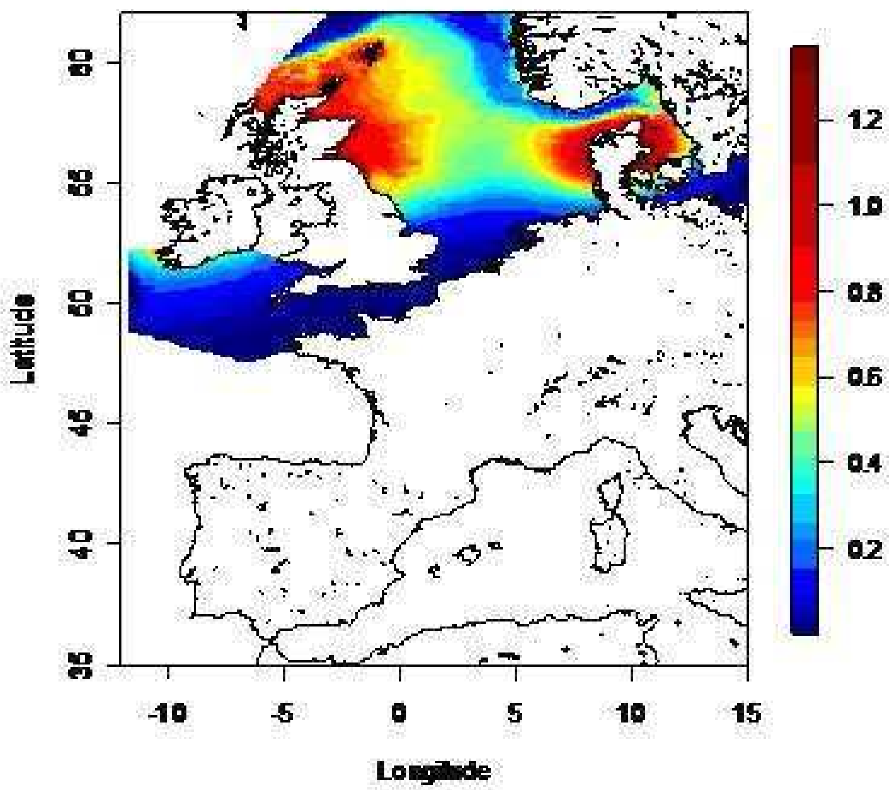
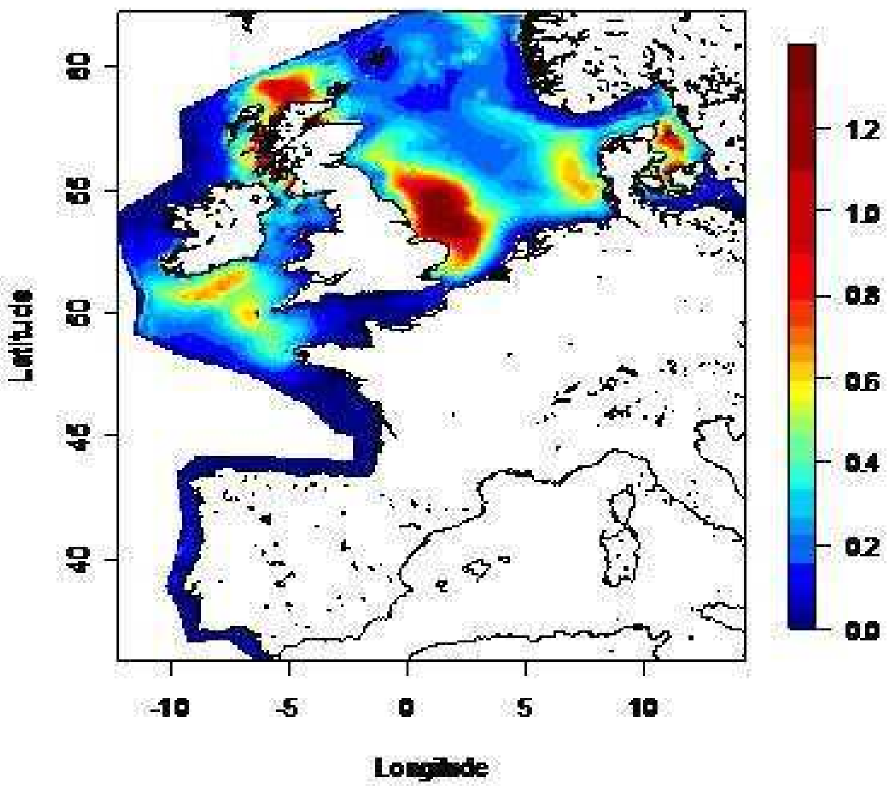


Figure 18. Sightings of harbour porpoises in Dutch North Sea waters (51-56°N, 2-8°E) since 1990. Adapted from Camphuysen (http://home.wxs.nl/~camphuys/NLflippers.html). This graph shows the observed increase in harbour porpoises in Dutch waters over the last years.

The number of harbour porpoise sightings in the Dutch North Sea coastal waters is consistently low until the mid-1990s as shown by effort corrected sightings (Reijnders et al. 2005) The increase has continued (see Figure 18) and seasonal patterns in occurrence is observable (Reijnders et al. 2005 and Figure 20).



A.



B.

Figure 19. Harbour porpoise estimated density surface (animals per km^2) in (a) 1994 and (b) 2005. These maps are based on survey data collected in the SCANS I and SCANS II surveys, which are only single assessments of the population. The models predict the occurrence of harbour porpoises for the month of July in the respective study areas. The comparison of the two survey years indicates the differences of distribution of harbour porpoises in the North Sea. The resolution of the prediction is not fine enough to allow an interpretation within high or low density areas in Dutch national waters.

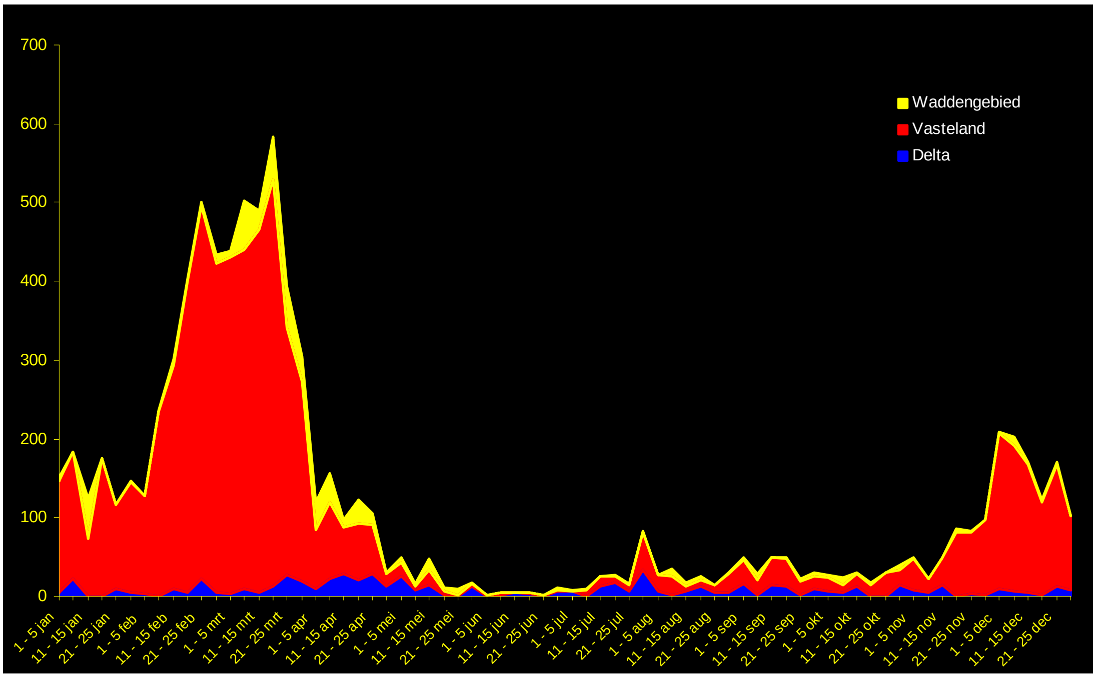


Figure 20. Seasonal pattern of harbour porpoises reported from coastal sites in the Netherlands since 1970 (Marine Mammal Database, updated 3/1/2004, http://home.planet.nl/~camphuys/Bruinvis.html). Waddengebied = Wadden Sea area, Vasteland = Mainland coast, Delta = Delta area.

6 Bottlenose dolphin (*Tursiops truncatus*)

6.1 Population size

In the North Sea bottlenose dolphins appear to have a patchy distribution (Figure 21) mainly restricted to the costs of Scotland, Wales and Ireland (White & Webb 1995, Wilson et al. 1999, Ingram 2000, Baines et al. 2002). Abundance estimates are mainly based on photo-identification recapture studies of small populations that are resident in inshore areas (White & Webb 1995, ICES 1996, Wilson et al. 1999, Ingram 2000, Baines et al. 2002, ICES 2002). The population of bottlenose dolphins in the Moray Firth is estimated at 129 (95% CI 110–174) animals (Wilson et al. 1997). A collaborative photo-identification project has catalogued 85 individuals in the Channel, including northwest France (Liret et al. 1998). The most recent overall abundance estimate is based on the SCANS-II survey conducted in July 2005 which estimates around 650 bottlenose dolphins in the northern and central North Sea (ICES 2008). Estimates for the western shelf waters and Channel are around 8000 animals and for the shelf waters of France, Spain and Portugal around 4300 animals (ICES 2008). Additionally to these "inshore" bottlenose dolphins a relatively large and more transient offshore population of bottlenose dolphins beyond the shelf break exists (Wells & Scott 1999).

6.2 Important areas

In Europe, the distribution of bottlenose dolphins is believed to have contracted during the last century, particularly in the North Sea (Verwey & Wolff 1981). Historically bottlenose dolphins have occurred regularly along the Dutch coast in the beginning of the 20th century. Wolff (2000) notes that bottlenose dolphins have disappeared along the Dutch coast in the last few decades. Prior to this, bottlenose dolphins were moving into the former Zuiderzee every spring apparently following herring shoals. The herring disappeared in this area in 1937, but bottlenose dolphins still stranded on the coast until around 1965. Then the numbers dropped further and the bottlenose dolphin is not considered a resident species in the south-eastern North Sea any longer (Verwey & Wolff 1981, Bakker & Smeenk 1990). Since many sighting reports of this species exist Van der Meij & Camphuysen 2006) choose to maintain this status of 'regular visitor'.
A large influx of dophins took place in 2004, when schools of between 40 and 100 bottlenose dolphins were observed between Texel and the mainland coast of Noord-Holland (Van der Meij & Camphuysen 2006). In total, between 1970 and 2005, 21 bottlenose dolphins have stranded on Dutch shores and 400 individuals were reported in 66 sightings (Van der Meij & Camphuysen 2006). Note that the sightings come from a variety of sources and that the investigated area is larger than the Dutch EEZ (Figure 23).

The species is listed as "data deficient" by IUCN. The species is listed in Appendix II of CITES and in Annexes II and IV of the EU Habitats Directive.

6.2.1 Reproduction areas

In the North Sea, bottlenose dolphins are found in the Moray Firth and off eastern Scotland and in coastal areas of the western Channel (Figure 21). Distribution in these areas varies seasonally (Wilson et al. 1997) but births and mating both occur in the summer months in these resident areas, which are thus in a sense reproduction areas. Strandings along the Dutch coast include "neonates", which are calves that are recently born. These strandings occur mainly between May and September and reflect the calving time. In Dutch waters reproduction areas for bottlenose dolphins cannot be defined.

6.2.2 Foraging areas

There is an indication that the Dutch bottlenose dolphins were mainly feeding on herring. In general, bottlenose dolphins in the North Sea feed on a variety of fish species, the most dominant being cod, whiting and pollack. As most cetaceans bottlenose dolphins can adapt to changes in fish occurrence by changing their distribution. If their prey is associated with certain oceanographic features (e.g. shallow banks, grain size of sediment, frontal systems) then the bottlenose dolphin is likely to be also associated with these areas. In Dutch waters sightings of bottlenose dolphins are very rare and foraging areas can not be defined for this species.

6.2.3 Migration routes

Worldwide coastal populations of bottlenose dolphins exhibit various movement patterns, including seasonal migrations, year-round home ranges, periodic residency, and a combination of occasional long-range movements and repeated residency (Wells & Scott 1999). Bottlenose dolphins in the North Sea seem to be primarily resident in a specific area. However, animals can change their distribution, normally in response to prey availability (Wilson et al. 1997).
There is no information on migration routes of bottlenose dolphins in Dutch waters.

6.2.4 Other areas

Figure 22 gives an overview of recorded sightings in Dutch waters over the last decades. The data indicates that bottlenose dolphins have been and are sighted occasionally; however, presently no resident populations exist in Dutch North Sea waters.

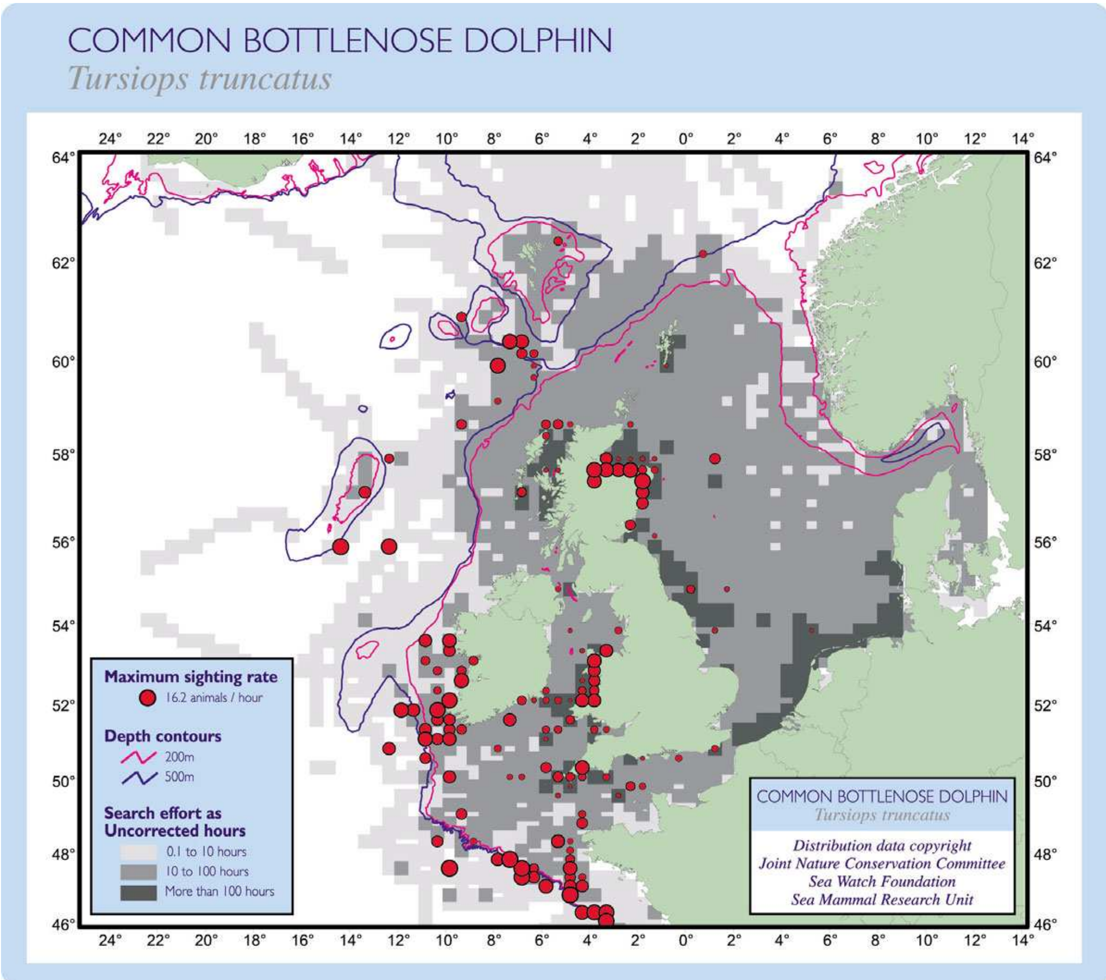


Figure 21. Distribution of bottlenose dolphins (Reid et al. 2003). This map is based on a combination of three different databases. The underlying effort (grey) is not equal for all areas and all seasons. This map combines data from all seasons, over a period of 10 years (1979-1998), with the most recent data 10 years old. This map should not be used as an accurate representation of current distribution patterns of bottlenose dolphins in the North Sea, but it can give an indication of how the general distribution of bottlenose dolphins was during the period studied, taking the limitations mentioned above into account.

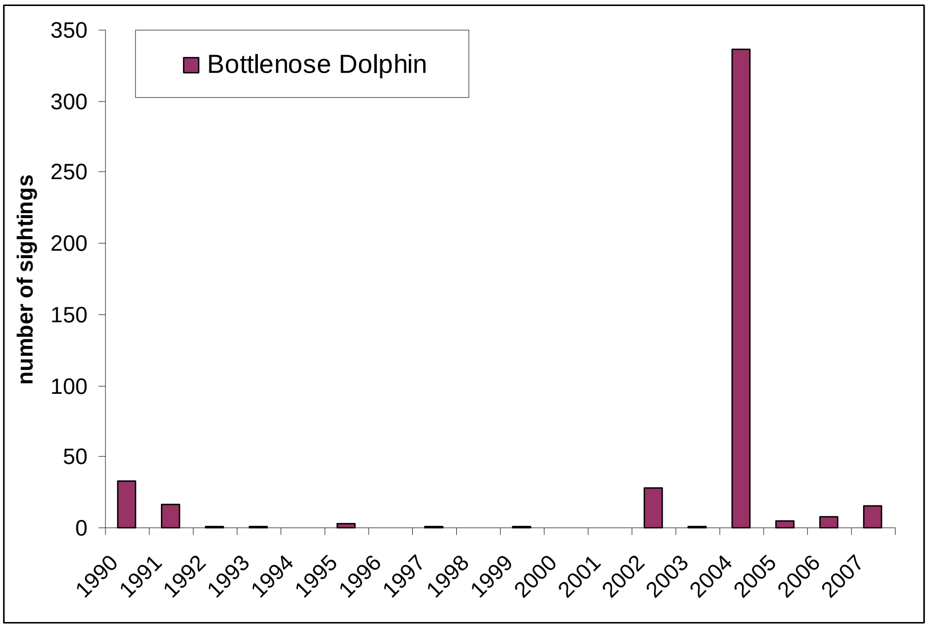


Figure 22: Sightings of bottlenose dolphins in Dutch North Sea waters (51-56°N, 2-8°E) since 1990. Adapted from Camphuysen (http://home.wxs.nl/~camphuys/NLflippers.html).

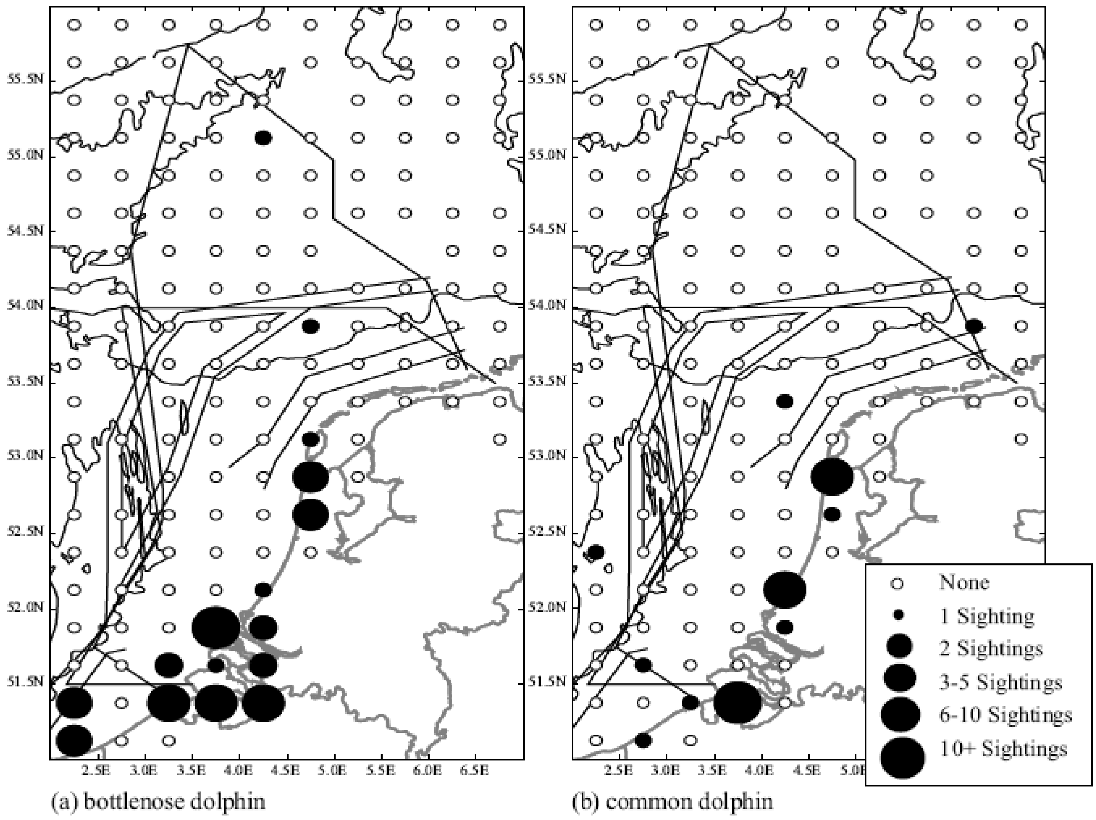


Figure 23. Bottlenose and common dolphin sightings (Van der Meij & Camphuysen 2006). Distribution of reported sightings and live-strandings per 15'N x 30'E rectangle in the southern North Sea. Rectangles for which cetacean sightings of any kind are known are indicated as open circles. Black symbols represent the number of positive sightings (a) bottlenose dolphins (88 sightings) and (b) common dolphins (41 sightings).

7 White-beaked dolphin (*Lagenorhynchus albirostris*)

7.1 Population size

The total number of white-beaked dolphins throughout the North Atlantic thus may be in the high tens or low hundreds of thousands (Reeves et al. 1999 and refs. therein). The SCANS survey in 1994 provided an estimate of 7856 white-beaked dolphins for the North Sea. The most recent survey in 2005 estimated 10,600 animals for the northern and central North Sea and 12,100 animals for the western shelf waters.
The species is not listed by IUCN (despite being considerably rarer and with a narrower distribution than harbour porpoise). The species is listed in Appendix II of CITES and in Annex IV of the EU Habitats Directive.

In the Southern North Sea, the white-beaked dolphin is one of the most frequently encountered cetaceans. Between 1970 and 2005, 1883 individuals were encountered during 232 sightings at sea (Van der Meij & Camphuysen 2006). Note that the sightings come from a variety of sources and that the investigated area is larger than the Dutch EEZ. For details see Van der Meij & Camphuysen 2006. Sightings came mostly from waters around the Dogger Bank with frequent sightings between the Outer Silver Pit, the mainland coast of Noord-Holland, de Bruine Bank (Brown Ridge) in the central Southern Bight and waters in the Northern Channel (Van der Meij & Camphuysen 2006) (Figure 26). The reported sightings indicate a clearly bimodal seasonal pattern, with peaks in late spring (March-May) and mid-winter (December) and are not due to corresponding observer effort (Van der Meij & Camphuysen 2006).

7.2 Important areas

This species has a wide distribution with the northernmost part of the range occurring right up to the edge of the pack-ice (Carwardine 1995). The species is found in the immediate offshore waters of the North Atlantic (Rice 1998). The main concentrations around the British Isles are off northern Scotland and along portions of the Atlantic coast of Ireland. White-beaked dolphins are also common in the northern and central North Sea, as well as in the Kattegat and Skagerrak between Denmark, Norway and Sweden (Figure 24). It is considered the most common dolphin species off south-eastern Greenland, in Denmark Strait and the seas around Iceland (Reeves et al. 1999, Kinze et al. 1997). White-beaked dolphins have also been recorded in France, the north coast of Spain, the Strait of Gibraltar, and the Mediterranean Sea (Rice 1998). Although it occurs as far south as Portugal, it is rarely seen south of Britain (Carwardine 1995) and only occasionally in inner Danish waters (Reeves et al. 1999) and the Baltic proper (Kinze 2002). In Dutch waters it is the most common delphinid stranded.

7.2.1 Reproduction areas

There appears to be a calving peak in summer and early autumn, but not much is known about reproduction in this species (Camphuysen & Peet 2006, Jefferson et al. 1993). No reproduction areas in Dutch waters can be identified for white-beaked dolphins.

7.2.2 Foraging areas

White-beaked dolphins feed on a wide range of prey, including clupeids (e.g. herring), gadids (e.g. Atlantic cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), poor-cod (*Trisopterus minutus*, *T. luscus*), whiting (*Merlangius merlangus*), capelin (*Mallotus villosus*) and hake (*Merluccius merluccius*). Other studies include *Scomber*, *Pleuronectes*, *Limanda*, *Eleginus* and *Hyperoplus* as well as squid, octopus and benthic crustaceans as prey (Reeves et al. 1999).
No specific feeding areas in Dutch waters can be identified for white-beaked dolphins.

7.2.3 Migration routes

White-beaked dolphins can make inshore - offshore or north - south movements with the seasons (wintering in the south or offshore). Around Britain, they seem to be present all year round (but with seasonal peaks of abundance in spring) (Carwardine 1995, Northridge et al. 1997).
In Dutch waters no migration routes for white-beaked dolphins can be identified.

7.2.4 Other areas

Figure 26 gives an overview of recorded sightings in Dutch waters over the last decades. The data indicates that white-beaked dolphins have been and are sighted regularly.

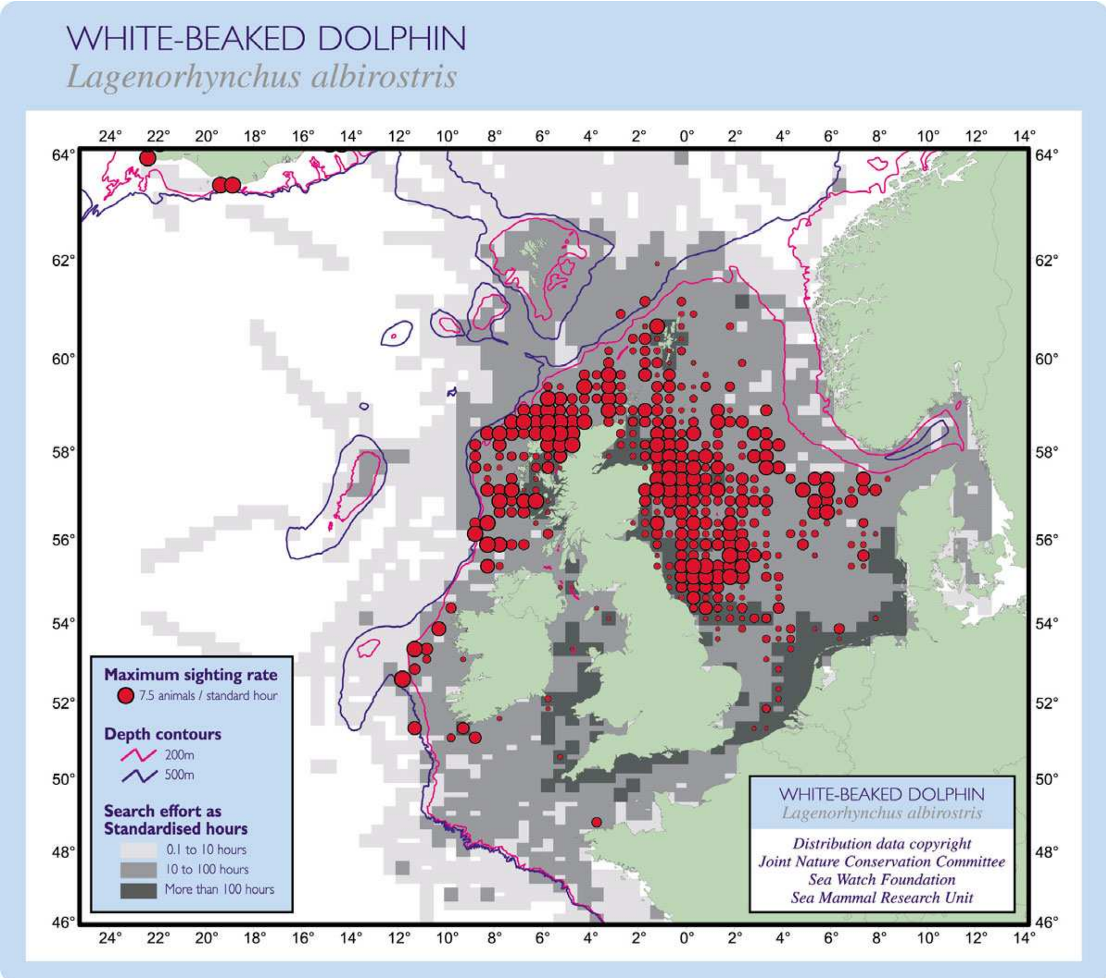


Figure 24. Distribution of white-beaked dolphins (Reid et al. 2003). These data are based on a combination of three different databases. The underlying effort (grey) is not equal for all areas and all seasons. This map combines data from all seasons, over a period of 10 years (1979-1998), with the most recent data 10 years old. This map should not be used as an accurate representation of current distribution patterns of White-beaked dolphins in the North Sea, but it can give an indication of how the general distribution of this species was during the period studied, taking the limitations mentioned above into account.

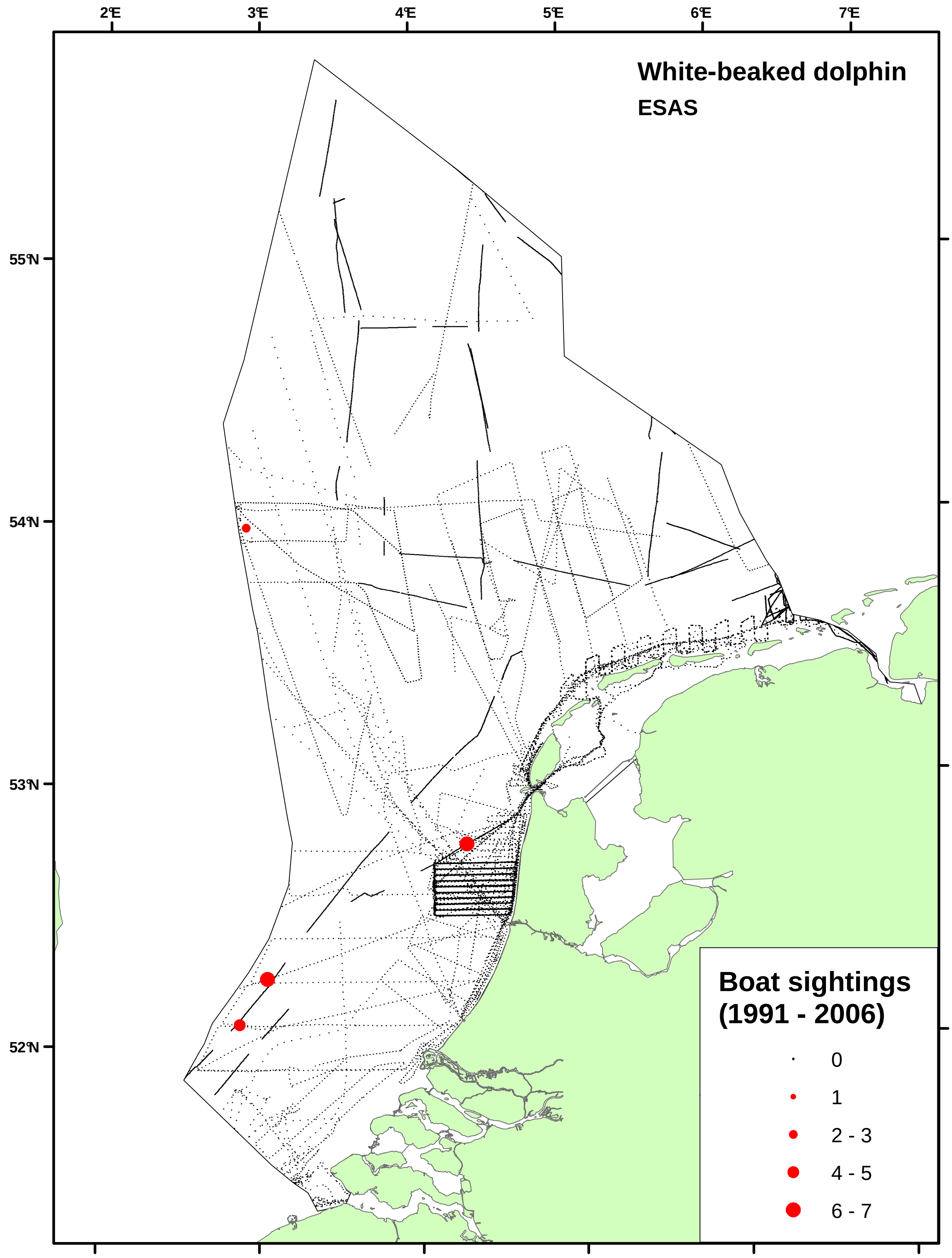


Figure 25. Boat sightings of white-beaked dolphins from 1996 to 2006 based on the ESAS (European Seabirds at Sea) database. The data presented here were not corrected for possible differences in sighting probability between surveys, e.g. due to differences in weather. Effort and sightings are combined over a 15 year period. Effort is not equal between years and over the study area. This map provides information on white-beaked dolphin occurrence in Dutch waters throughout the year. This map can not be used to determine high density or low density areas (e.g. suitable areas for offshore construction) or abundance estimates of white-beaked dolphins.

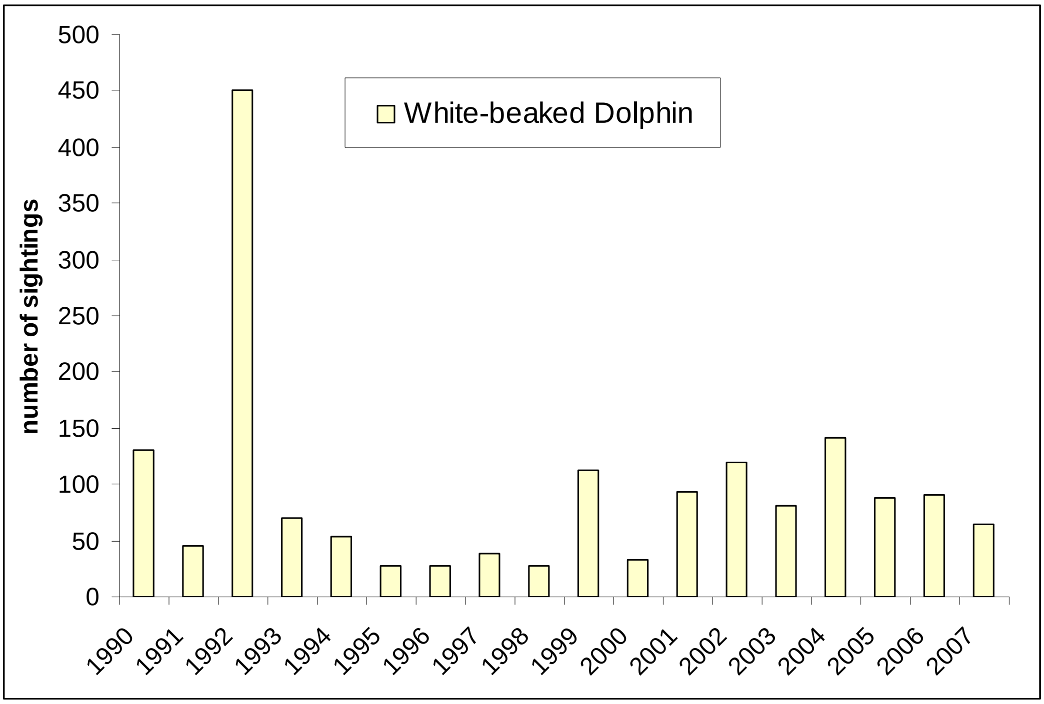


Figure 26. Sightings of white-beaked dolphins in Dutch North Sea waters (51-56°N, 2-8°E) since 1990. Adapted from Camphuysen (http://home.wxs.nl/~camphuys/NLflippers.html).

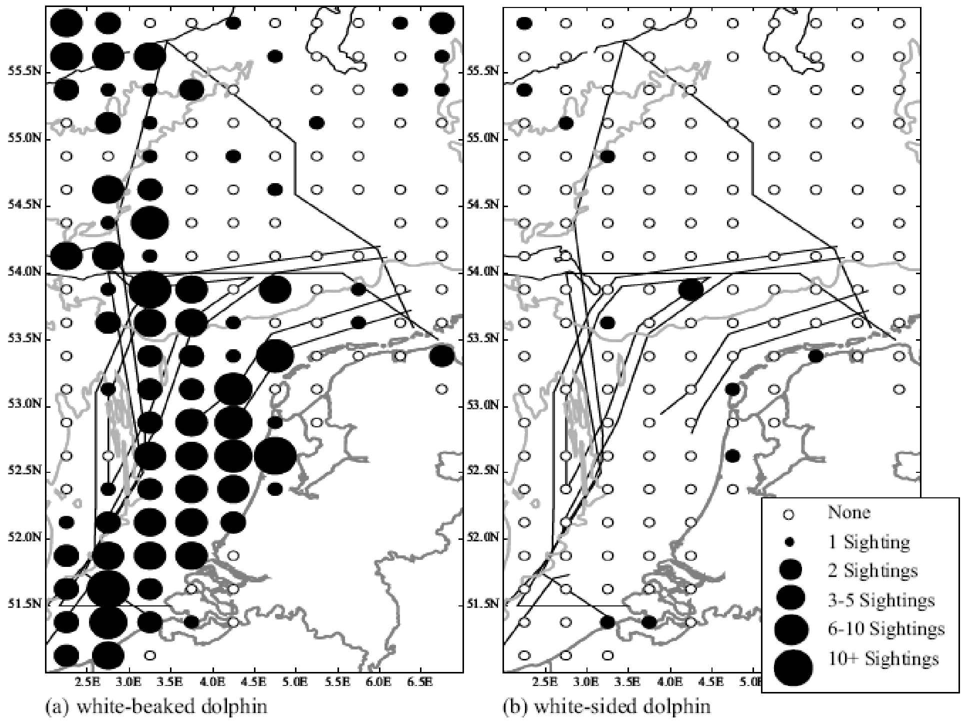


Figure 27. Sightings of white-beaked and white-sided dolphins (Van der Meij & Camphuysen 2006). Distribution of reported sightings and live-strandings per 15'N x 30'E rectangle in the southern North Sea. Rectangles for which cetacean sightings of any kind are known are indicated as open circles. Black symbols represent the number of positive sightings (a) white-beaked dolphins (232 sightings) and (b) white-sided dolphins (12 sightings).

8 Minke whale (*Balaenoptera acutorostrata*)

8.1 Population size

In the Northeast Atlantic, minke whales range from the Barents Sea to Portugal, and east into the western Mediterranean during summer. The wintering range is poorly known but includes waters from the southern North Sea to the Straits of Gibraltar (Rice 1998). The current population estimate for the North Atlantic minke whale is thought to be in excess of 100,000 (Sigurjonsson 1995). Population estimates for the North Sea are available from the SCANS I survey for July 1994 (Hammond et al. 2002) at 8400 animals. For the SCANS II survey (July 2005) the estimate is 10,541 for the northern and central North Sea and 8072 animals for the Western shelf waters and the Channel (ICES 2008).

8.2 Important areas

The species is frequently seen in inshore northern and western coastal waters of the UK, and occasional records have been reported from the channel coast of mainland Europe, the Mediterranean, and the Azores and Portugal (see Figure 28).

During the 1994 SCANS survey, minke whales were mostly detected in the north-western North Sea (north of 55°N and west of about 4°E) and in the western English Channel. In general they appear to be more abundant in the western part of the North Sea (but with a cluster of sightings in the centre of the North Sea between 56°30' and 58°30' N and 0-2° E) (Reid et al. 2003, Figure 28).

Limited information is available on variations in abundance and distribution over time, but at this point in time the Northeast Atlantic population appears to be stable.

The species is listed as lower risk/near threatened by IUCN. The species is listed in Appendix I of CITES and in Annex IV of the EU Habitats Directive.

8.2.1 Reproduction areas

Breeding in minke whales is believed to be an annual event. Pregnancy has been estimated to last 10 months and lactation is thought to last 4-6 months. Conception occurs when the whale is lactating in the warmer waters at low latitudes before migration occurs. Birth occurs after the whale has returned from its feeding grounds to the warmer waters once again. The timing of conception and birth varies between regions. In the North Atlantic conception takes place from December to May with a peak month of February with birth taking place from October to March with a peak in December.The short lactation period in minke whales usually means that the calves are weaned before they arrive on summer feedings grounds and as a result calves accompanying adult females are rarely documented.
Most probably there are no breeding areas in the North Sea or in Dutch waters of the North Sea.

8.2.2 Foraging areas

Minke whales are known to feed on a variety of prey species using a range of feeding behaviours. Off the west coast of Scotland minke whales lunge feed on small shoaling fish such as herring, sprat and possibly sand eel. They can also feed on krill as well as larger fish such as mature Arctic cod and haddock.
In the North Sea, minke whales had a more a mixed diet consisting primarily of sandeel, mackerel and whiting (Olsen & Holst 2001), indicating that pelagic foraging is important for minke whales in relatively shallow continental shelf waters. However, the finding of haddock in one stomach shows that demersal foraging also occurs in North Sea minke whales. Both cod and haddock are described as demersal predators on sandeel (Adlerstein et al. 1998). The lesser sandeel and herring are prey of the minke whale in British waters (Nordøy & Blix 1992) and these species are known to exhibit habitat preferences in terms of bathymetry and seabed sediment type. Sandeel prefer shallow waters and seabed sediments of coarse sand and fine gravel (Macer 1966, Reay 1970, Wright & Begg 1997). Maravelias et al. (2000) showed that aggregations of pre-spawning

herring in the northern North Sea preferred zooplankton-rich waters at depths between 100 and 150 m. Spawning herring favour gravel beds, generally within 30 to 50 km of the coast (Saville & Bailey 1980, Blaxter 1990).

It has been shown that minke whale distribution is related to prey habitat (Macleod et al. 2004). For the distribution of minkes in Dutch waters it can thus be hypothesized that areas with occurrence of pelagic prey species such as sandeel or herring might be of importance to minke whales.
During the occasional visits the Dutch North Sea is most probably used as feeding areas or passed during migration. It is also possible that some individuals stay throughout the whole year and do not migrate. Considering the growing population more frequent visits could be expected.

8.2.3 Migration routes

Minke whales have a worldwide distribution but most are seasonal in occurrence due to their migration from their calving and breeding grounds in the tropics to their feeding grounds towards the polar regions. The winter breeding distribution of minkes whales is poorly documented and mating behaviour has actually not been directly observed for this species. Minke whales will group up and travel in certain age and sex classes and will appear in areas at different times. For example, during the summer in the North Atlantic, sexual and age segregation occurs with the mature females predominating in the early summer months in the coastal regions and also in the most northern regions during most of the season whilst the males migrate north in open seas. The immature whales are believed to migrate slightly later and remain further south.
For the Dutch North Sea direct information on migratory patterns and sex or age segregation in possible patterns is not available. In Dutch waters strandings of minke whales occur throughout the year, whereas sightings occur more often in the summer months (Figure 31) (adapted from Camphuysen & Peet 2006). Most of the sightings occur further offshore such as on the Doggerbank (Camphuysen & Peet 2006), indicating that they are probably used as feeding areas.

8.2.4 Other areas

Figure 30 gives an overview of recorded sightings in Dutch waters over the last decades. The data indicates that minke whales have been and are sighted regularly.
Since the 1970's 10 minke whales have been washed ashore in the Netherlands. Between 1970 and 2005, 39 individuals have been recorded in the southern North Sea in 24 sightings (Van der Meij & Camphuysen 2006). Note that the sightings come from a variety of sources and that the investigated area is larger than the Dutch EEZ.

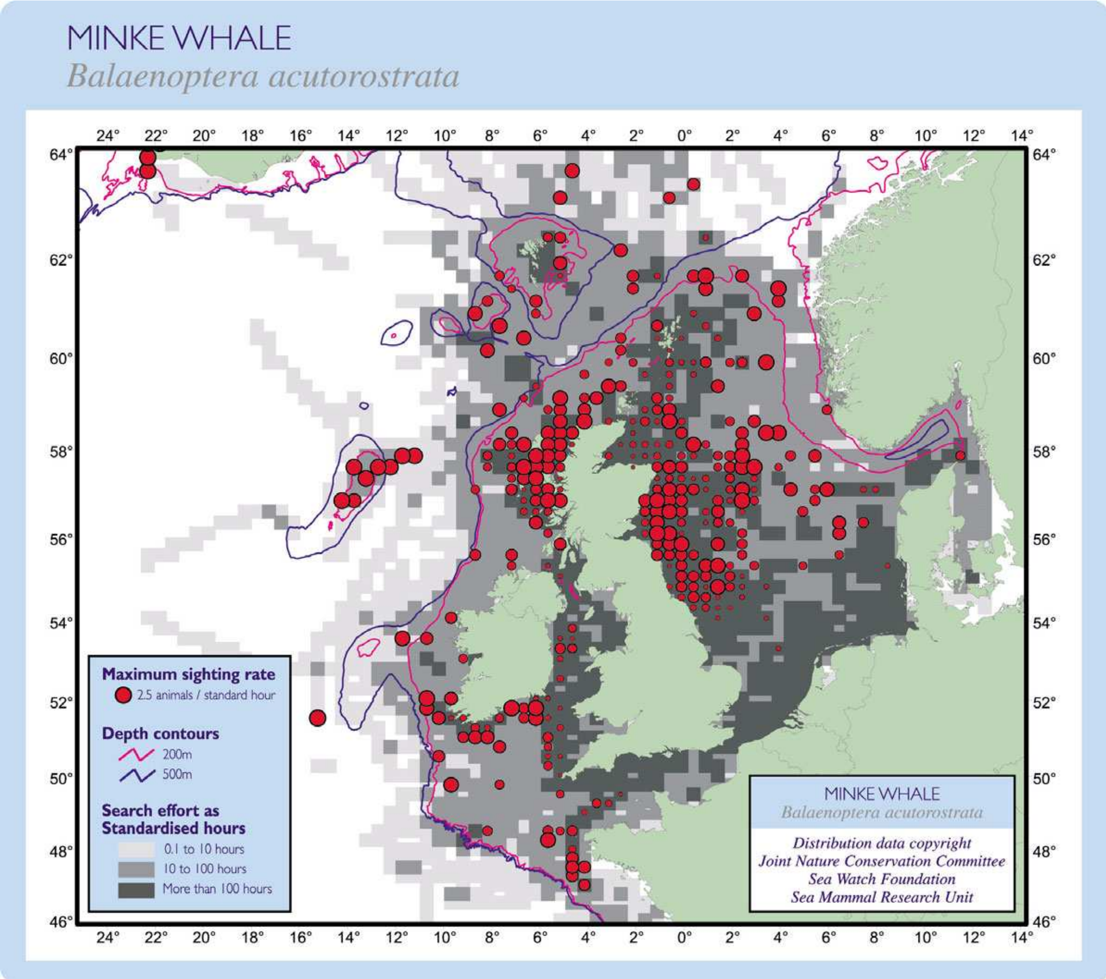


Figure 28. Distribution of minke whales (Reid et al. 2003). These data are based on a combination of three different databases. The underlying effort (grey) is not equal for all areas and all seasons. This map combines data from all seasons, over a period of 10 years (1979-1998), with the most recent data 10 years old. This map should not be used as an accurate representation of current distribution patterns of minke whales in the North Sea, but it can give an indication of how the general distribution of this species was during the period studied, taking the limitations mentioned above into account.

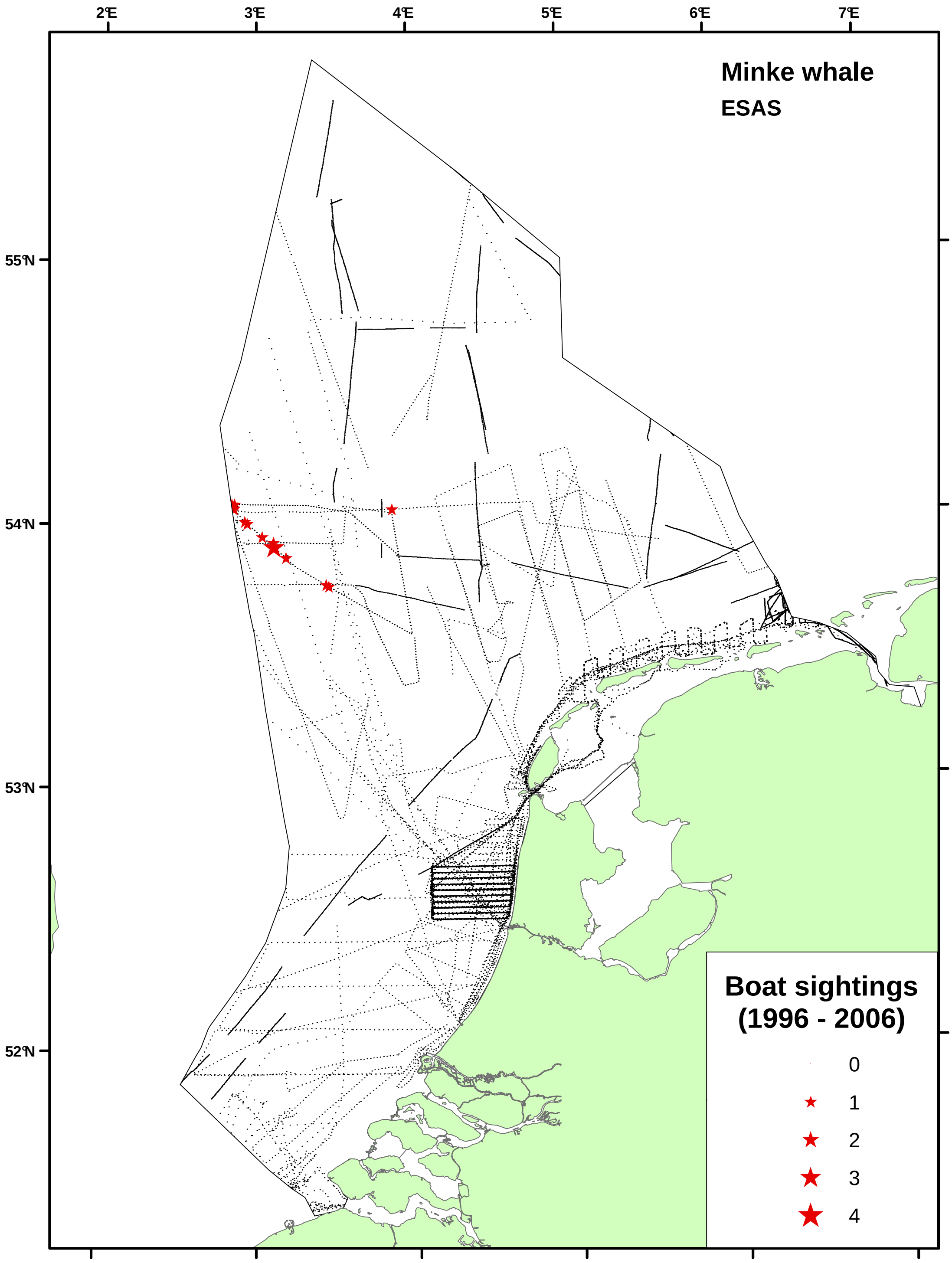


Figure 29: Boat sightings of minke whales from 1996 to 2006 based on the ESAS (European Seabirds at Sea) database. The data presented here were not corrected for possible differences in sighting probability between surveys, e.g. due to differences in weather. Effort and sightings are combined over a 10 year period. Effort is not equal between years and over the study area. This map provides information on minke whale occurrence in Dutch waters throughout the year. This map can not be used to determine high density or low density areas (e.g. suitable areas for offshore construction) or abundance estimates of minke whales.

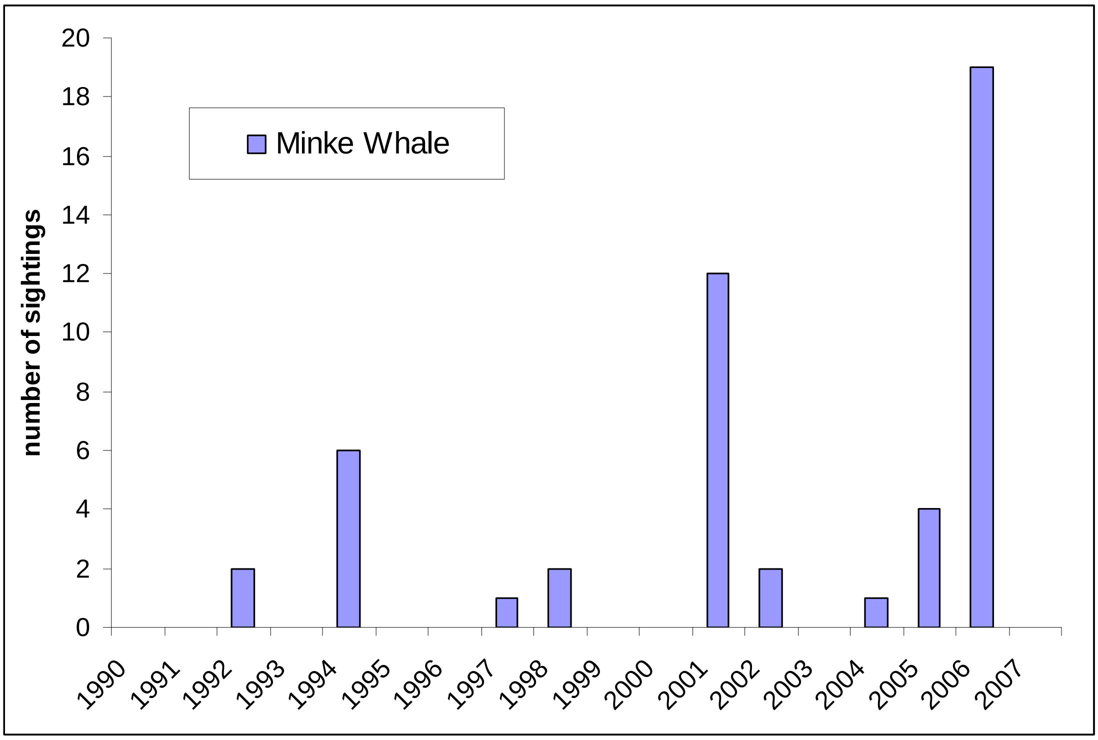


Figure 30: Sightings of minke whales in Dutch North Sea waters (51-56°N, 2-8°E) since 1990. Adapted from Camphuysen (http://home.wxs.nl/~camphuys/NLflippers.html).

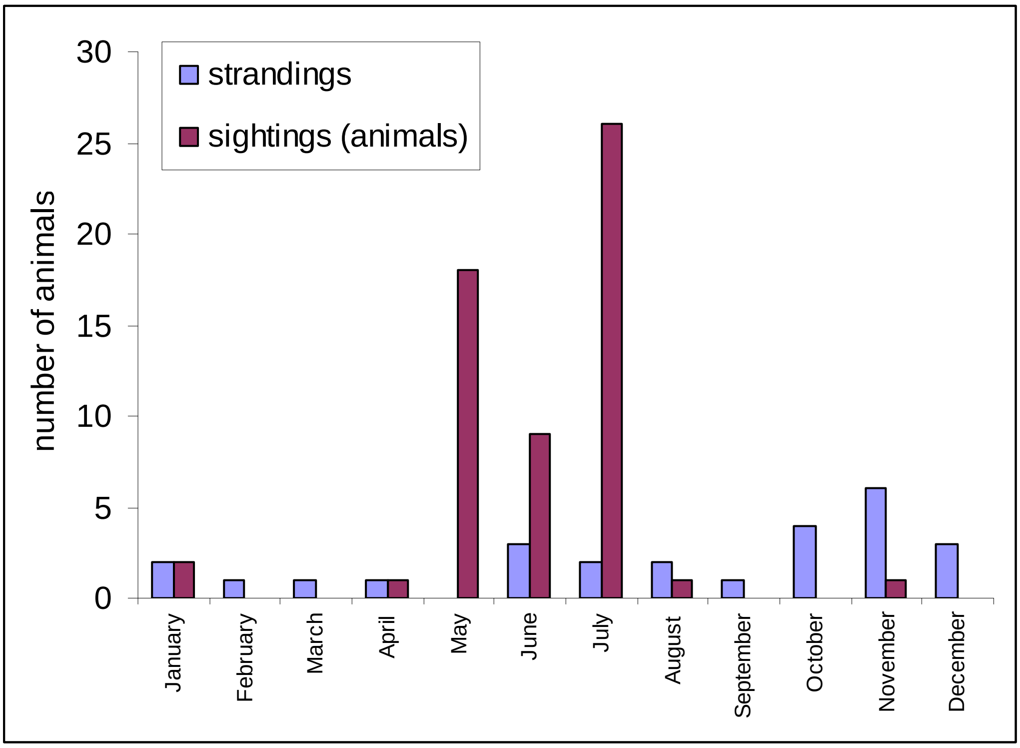


Figure 31. Overview of strandings and sightings (number of animals seen) per month in Dutch waters (combined data for the years 1990 to 2005).

9 Conclusions

This overview shows that large numbers of marine mammals are present in the southern North Sea. Despite their popularity with the public, the knowledge on these species is limited. For some species it barely exceeds the acknowledgment that the animals occur in the area (i.e. minke whales). Even for the species most studied, the harbour seal, we are only starting to define areas that could be of more importance than others.
Marine mammals are predominantly aquatic rendering them cryptic and therefore more difficult to observe. Hence collecting information is certainly not straightforward and often expensive, however not impossible. An additional difficulty in understanding habitat use or distribution could be that the animals might not show preference for fixed habitats but rather follow to some extent the changes in the environment (i.e. currents, prey migration).

9.1 Knowledge gaps

In general, abundance and distribution data for all species in the NCP is insufficient (Table 2).
For seals, indirect methods such as tagging individual animals, quantifying their habitat preference and using this to predict the distribution for the entire population seem to be the best way to define critical habitat. However, large individual variation requires data from many animals before the model estimates can be considered generally valid.
The grey seal map presented in this report highlights the influence of few individuals on our distribution estimates. A few animals showed a migration to the UK and consequently dominating the current view of their distribution. More grey seals should be tracked in order to improve our understanding of the distribution, and population structure of grey seals in the Netherlands. Once this is available, studies should concentrate on relating distribution to both biotic and abiotic environmental features. Finally the obtained model should be checked (ground truth).

For cetaceans the lack of information is even greater. In general data has been collected *ad hoc* or at large time intervals (e.g SCANS, twice in ten years). The most detailed information on the distribution of a cetacean species is for the harbour porpoise, but even for this species data on their coastal distribution is confined to stranding data and counts from shore. On a very small scale, passive acoustic data is available in relation to the wind farm near Egmond aan Zee, but these data are only available as we speak. Regular, standardized and dedicated surveys in order to define and maybe explain temporal changes in density distribution are still lacking for harbour porpoise and other species.

Once acceptable distribution data is available, models could be developed to define the affinity (including seasonal variation) of marine mammals for certain habitats. Only then will it be possible to estimate possible effects of changes in human activity on the populations sufficiently and to prevent unacceptable interferences by careful planning of the intended activities.

Table 2. Overview of the available data on marine mammals in Dutch waters deemed necessary for an appropriate assessment of the effects of off shore wind farms.

	Harbour seal	Grey seal	Harbour porpoise	Bottlenose dolphin	White-beaked dolphin	Minke whale
Population size						
	good index	good index, lacking information on exchange with other colonies	lacks systematic surveys	only incidental data	only incidental data	only incidental data
Resting						
on land	Good :summer, some: winter	Some: summer, some: winter	-	-	-	-
at sea	maybe by analysis of existing data	more tagging needed	analysis of current data & more to data be collected	currently no data	currently no data	currently no data
Reproduction						
on land	good	Some: number of pups uncertain	-	-	-	-
at sea	currently no data	currently no data	currently no data	currently no data	currently no data	currently no data
Foraging						
	maybe by analysis of existing data	maybe by analysis of existing data	currently no data	currently no data	currently no data	currently no data
Migration						
	maybe by analysis of existing data	limited data available	currently no data	currently no data	currently no data	currently no data
Adequate knowledge for appropriate assessment of wind farms locations at sea						
	NO	**NO**	**NO**	**NO**	**NO**	**NO**
Amelioration of the knowledge gap in the short term						
	2008, first comprehensive model, including habitat and behaviour	2009, first tentative full model, not enough data?	3 suveys in 2008 along the North Sea coasts up to Texel	no funding	no funding	no funding

9.2 Plans for future research and overview of currently but not published research

9.2.1 Habitat models for grey and harbour seals

Ultimately seals make trips to sea to forage. Although their behaviour and their interactions with their prey species and other ecosystem components are complex, they may follow some simple rules to decide where to forage. For example, studies on grey seals foraging on the east coast of Scotland have revealed that they have strong preference for coarse sediment type (McConnell et al. 1999, Aarts et al. 2008). Quantifying such relations using many habitat characteristics (depth, sediment type, chlorophyll concentrations, etc), may help us in predicting their distribution.

A considerably step forward could also be made by incorporating inter- and intra-annual variation in abundance offshore. Previous sections of this report illustrated that during moult and reproduction, the amount of time spent ashore increases, and this could have direct consequences for their distribution and abundance at sea.

Finally, conservation and management of marine mammals requires an in-depth understanding of why individuals go at certain places. For example, windmill developments may facilitate or impede certain types of behaviours, such as resting; sound produced by offshore windmills may disturb animals, but alternatively it may reduce shipping activity. Currently IMARES is in the progress of linking both distribution and behavioural models.
The model is expected to help determine areas of importance for the seals, therefore assisting planning locations for human activities. One would expect some lack in detail for specific target areas, which then can be met by specific studies. Possibly, the model will give rise to more insight in fundamental questions such as individual variation in habitat use and the ability of the animals to adapt to changing environments.

9.2.2 Estimates on spatial abundance of harbour porpoise

The probability of observing individuals not only depends on the animals actually being there, but also on the probability of detecting them conditional on being present. This detection probability can depend on many factors such as wave-height, weather conditions and water clarity. Additionally and more importantly, the probability of detecting an animal becomes smaller when it is further away from the observer.

To take such factors into account, standard distance sampling line-transect methods have been developed (Buckland et al. 2001, 2004). Aerial surveys following this method have been shown to work well in practice, and as a consequence have been applied in many national and international projects. However, this method does only correct for the relative differences in detecting probability, but it does not correct for the fraction of harbour porpoises that are under water out of sight. For calculation of correction factors for missed porpoises the circle-back method or observations from one or two additional independent observers can be used.

Although areal surveys have been carried out in the past (by RIKZ now Waterdienst), most of these correction factors are taken into account, hence preventing their inability to estimate absolute abundance. Furthermore, water clarity is heterogeneous in space. For example areas close to shore are generally less clear and detection probability may be smaller, leading to underestimates of harbour porpoise densities in these coastal areas. This is particularly relevant for windmill development, since it is logistically desirable to have them close to shore.

The best approach to account for unequal detection probability is to develop aerial and ship-based line-transect surveys according to the internationally standards (Buckland et al. 2001, Buckland et al. 2004). However as long as of such data are not being collected; a considerable step forward could also be made by using all existing data and improving the analytical tools. In light of this, IMARES is carrying out three aerial surveys along the southern Dutch coast. The data could also be used to compare with the current monitoring by the Waterdienst. Additionally, IMARES is extending the analysis of the existing data described in section 2.1.3. Examples are the inclusion of wind data from offshore stations, explicitly modelling seasonal and yearly changes in distribution, the effect of water clarity on harbour porpoise sightings, and linking harbour porpoise observations with more biotic and abiotic environmental variables. These include sea surface temperature, chlorophyll concentrations and information on human activities such as shipping activity, sand extractions and offshore wind mill farms.

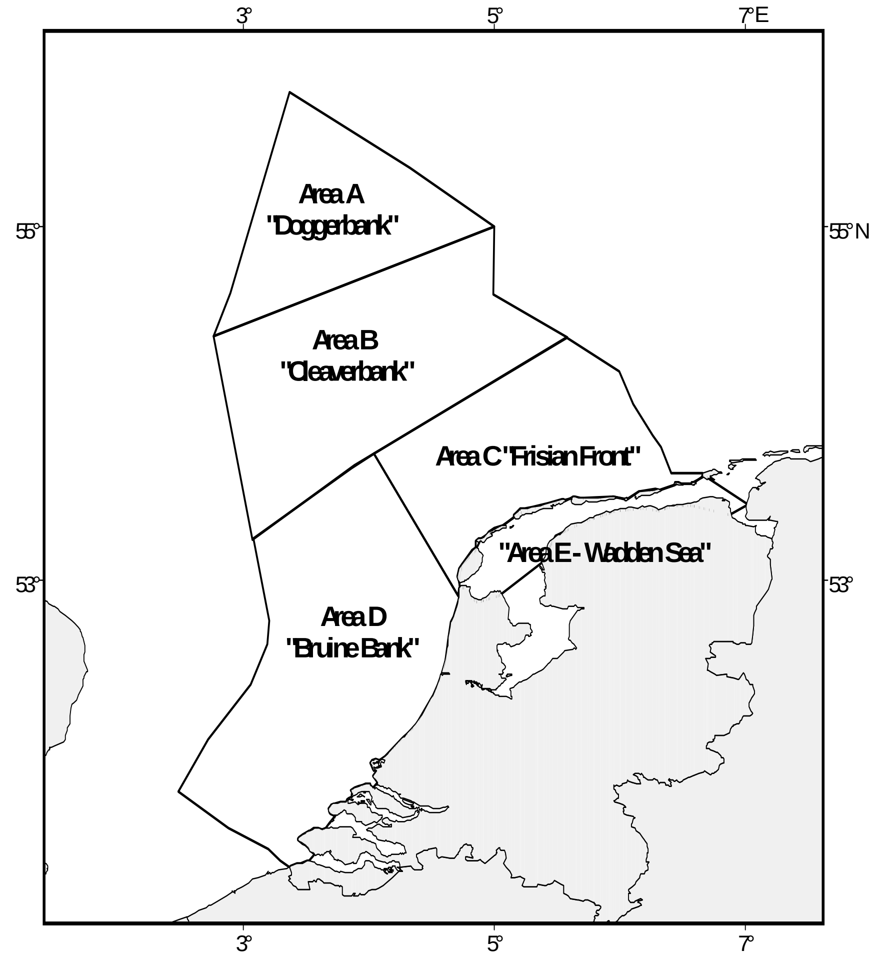


Figure 32. Subdivision in areas of the Dutch section of the North Sea.

Currently a research project is conducted through LNV to investigate harbour porpoise food preference and local abundance. Within this project dedicated aerial surveys using standard line transect distance sampling methodology (see above under methods) are conducted in a study area covering the waters from Texel to the Belgian coast to offshore distances of about 90 nautical miles (see area D, Figure 32). During the aerial surveys 10 track-lines are covered to count porpoises and use distance sampling methodology to obtain abundance estimates for this area, including confidence intervals and coefficients of variation. Including measurements of the survey errors allows an adequate interpretation of the data, e.g. when it is used to determine the percent of bycatch for the Dutch porpoise population.
In 2008 one survey has been conducted successfully in May, a second one is planned for August. As this method is now established at Wageningen IMARES the surveys could easily be extended to a larger area or be conducted at a higher frequency, e.g. to obtain more information on seasonal changes. An extension of the survey flights to the northern coastal area and the offshore waters (area C, Figure 32), would allow an estimation of abundance for harbour porpoises for the time of the survey. The results are stored in a database and can be used to obtain distribution maps, either directly from the surveys, or indirectly by using the data as a base for spatial modelling of porpoise distribution.

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11 List of figures

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13 Available databases

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15 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

Report C046/08
Project Number: 4396110301

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

Approved:	Peter Reijnders Senior researcher
Signature:	
Date:	19 June 2008

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Summary

In this report the current knowledge on abundance and spatial use of the North Sea by marine mammals is presented. 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 marine mammals in the North Sea, which are protected under the European Habitat Directive. Deltares will use this study as input for the generic 'Appropriate Assessment' (environmental impact study), as required by the Habitat Directive.

This report shows that large numbers of marine mammals are present in the southern North Sea. The identification of critical habitats for marine mammals is complex and not yet possible for lack of data. An overview of the available data is given in Table 1.

Table 1. Overview of the available data on marine mammals in Dutch waters deemed necessary for an appropriate assessment of the effects of off shore wind farms.

	Harbour seal	Grey seal	Harbour porpoise	Bottlenose dolphin	White-beaked dolphin	Minke whale
Population size						
	good index	good index, lacking information on exchange with other colonies	lacks systematic surveys	only incidental data	only incidental data	only incidental data
Resting						
on land	Good :summer, some: winter	Some: summer, some: winter	-	-	-	-
at sea	maybe by analysis of existing data	more tagging needed	analysis of current data & more to data be collected	currently no data	currently no data	currently no data
Reproduction						
on land	good	Some: number of pups uncertain	-	-	-	-
at sea	currently no data	currently no data	currently no data	currently no data	currently no data	currently no data
Foraging						
	maybe by analysis of existing data	maybe by analysis of existing data	currently no data	currently no data	currently no data	currently no data
Migration						
	maybe by analysis of existing data	limited data available	currently no data	currently no data	currently no data	currently no data
Adequate knowledge for appropriate assessment of wind farms locations at sea						
	NO	**NO**	**NO**	**NO**	**NO**	**NO**
Amelioration of the knowledge gap in the short term						
	2008, first comprehensive model, including habitat and behaviour	2009, first tentative full model, not enough data?	3 suveys in 2008 along the North Sea coasts up to Texel	no funding	no funding	no funding

Most progress has been made in the studies of harbour seals. Here, telemetry studies are very useful to study individual habitat preference and the data can be used for model input. Results of a first model study comprising all tagged seals is expected by the end of 2008 or early 2009. It is expected that additional studies will be needed before a complete model can be drawn. For grey seals, less data are

available and the regular exchange between the Dutch and British coasts complicates the matter. In both pinnipeds fundamental understanding of individual variation will be needed to estimate true effects of habitat changes on the populations.

The harbour porpoise is the most abundant species, but since no systematic counts are done, relatively little is known about this species in the southern North Sea. Regular, standardized and dedicated surveys in order to define and maybe explain temporal changes in density are still lacking for harbour porpoise and other cetacean species. As a result, abundance and distribution data for all species in the NCP is insufficient to assign importance of specific areas to marine mammals.