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University of Aarhus · Denmark

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Jonas Teilmann [1]
Signe Sveegaard [1]
Rune Dietz [1]
Ib Krag Petersen [1]
Per Berggren [2]
Geneviéve Desportes [3]

[1] National Environmental Research Institute, University of Aarhus, Denmark
[2] Stockholm University, Sweden
[3] GDNATUR, Denmark

Data sheet

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Authors: Jonas Teilmann[1], Signe Sveegaard[1], Rune Dietz[1], Ib Krag Petersen[2], Per Berggren[3] & Genevieve Desportes[4]

Departments: [1]Department of Arctic Environment, [2]Department of Wildlife Ecology and Biodiversity, [3]Department of Zoology & [4]GDNATUR, Denmark

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Abstract: Designating protected areas for harbour porpoises implies identifying areas of high harbour porpoise density with particular focus on the distribution in the breeding season. The aim of this report is to collate all relevant data on movements and density of the harbour porpoises in Danish and adjacent waters in order to identify areas with high density or key habitat for harbour porpoises in Denmark that may be used to designate protected areas under the Habitats Directive. Comprehensive data from satellite tracking, aerial and ship surveys as well as acoustic surveys from ship has been collected from 1991 to 2007 in Danish waters. In this study the primary source of data for identifying key habitats is satellite tracking of 63 harbour porpoises in the period 1997-2007, aerial surveys, as well as acoustic recordings with a hydrofon array in 2007. The high density areas are described separately based on the four management units proposed based on previous population structure studies. Each high density area is ranked based on our current knowledge of population structure, density, seasonal variation in distribution and other relevant information. The rankings are defined as 1=high importance, 2=medium importance and 3=lower importance. Sixteen areas were found to have high density and were ranked as follows: **Inner Danish Waters:** Northern Little Belt (2), Southern Little Belt (1), Southern Samsø Belt (2), Northern Samsø Belt (3), Northern Øresund (1), Store Middelgrund (2), Kalundborg Fjord (1), Great Belt (1), Smålands-farvandet (3), Flensborg Fjord (1), Fehmarn Belt (1), Kadet Trench (2). **Northern North Sea:** Tip of Jylland (1), Skagerrak (along Norwegian Trench, 2). **Southern North Sea:** Horns Rev (1), German Bight (1).

Keywords: Harbour porpoise, marsvin, Phocoena phocoena, high density, key habitat, satellite tracking, aerial surveys, acoustic surveys, Inner Danish Waters, North Sea, Skagerrak, Kattegat, Belt Seas, Øresund, Western Baltic.

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Summary

Designating protected areas for harbour porpoises implies identifying areas of high porpoise density with particular focus on the distribution during the breeding season. This report collates all relevant data on movements and density of the harbour porpoises in Danish and adjacent waters in order to identify key habitats, i.e. areas with high density, for harbour porpoises in Denmark that may be useful when designating protected areas under the Habitats Directive.

Comprehensive data from satellite tracking, aerial and ship surveys as well as acoustic surveys from ship have been collected from 1991 to 2007 in Danish waters. In this study the primary source of data for identifying key habitats is satellite tracking of 63 harbour porpoises in the period 1997-2007. The only major areas that were not covered by the tagged animals were the Southern North Sea and the waters around Bornholm. In the Southern North Sea, data from aerial surveys was used to identify high density areas. Data from the area around Bornholm were too limited to determine harbour porpoise distribution and density. In northern North Sea and Inner Danish Waters acoustic ship surveys and aerial surveys were used as an independent method to confirm the presence of the high density areas found by analysis of the satellite tracking data.

The high density areas are described separately based on the management units proposed based on previous population structure studies. Four management areas are proposed but only in three areas there are data enough to identify high density areas. The three areas are: 1. The Inner Danish Waters (south of Læsø in Kattegat) through the belts and Øresund to the Western Baltic (west of Bornholm). 2. The Skagerrak/northern North Sea/northern Kattegat (north of Læsø and north of Ringkøbing), 3. The southern North Sea (south of Ringkøbing). Each high density area is ranked based on our current knowledge of population structure, density, seasonal variation in distribution and other relevant information. The rankings are defined as 1=high importance, 2=medium importance and 3=lower importance.

Sixteen areas were found to have high density and were ranked as follows for the three areas: Inner Danish Waters: Northern Little Belt (2), southern Little Belt (1), southern Samsø Belt (2), northern Samsø Belt (3), Northern Øresund (1), Store Middelgrund (2), Kalundborg Fjord (1), Great Belt (1), Smålandsfarvandet (3), Flensborg Fjord (1), Fehmarn Belt (1), Kadet Trench (2). Northern North Sea: Tip of Jylland (1), Skagerrak (along Norwegian Trench, 2). Southern North Sea: Horns Rev (1), German Bight (1).

Dansk resumé

Udpegning af beskyttede områder for marsvin kræver kendskab til den geografiske fordeling og koncentrationsområder særligt i yngletiden. Denne rapport samler alle relevante data om marsvins bevægelser og fordeling i danske og tilstødende farvande for at kunne udpege særlig vigtige områder med høj tæthed af marsvin. Disse områder kan indgå som en vigtig del af grundlaget for udpegning af habitatområder under EU's Habitatdirektiv.

Fra 1991-2007 er der indsamlet omfattende data fra satellitsporing, fly- og skibsoptællinger samt akustiske optællinger af marsvin i danske farvande. I dette studie indgår satellitsporing af 63 marsvin fra 1997-2007 som det vigtigste datasæt til udpegning af vigtige habitater. De eneste farvande, som ikke er dækket af satellitsporing, er den sydlige del af den danske Nordsø og farvandet omkring Bornholm. I den sydlige Nordsø er udpegningen baseret på flyoptællinger, mens der ikke findes data, der kan understøtte vigtige områder omkring Bornholm. I den nordlige Nordsø og i de indre danske farvande blev akustiske optællinger brugt som en uafhængig metode til at verificere de vigtige områder identificeret ud fra satellitsporingsdata.

Baseret på populations studier og bevægelser af marsvinene er udpegningen af vigtige områder i de danske farvande opdelt i fire midlertidige forvaltningsområder. Dog er det kun i de følgende tre områder, at der er data nok til at lave en udpegning: 1. De indre danske farvande (syd for Læsø) inkl. den vestlige Østersø, 2. Nordlige Kattegat (nord for Læsø), Skagerrak og den nordlige Nordsø (nord for Ringkøbing) og 3. Den sydlige Nordsø (syd for Ringkøbing). Indenfor hvert forvaltningsområde er de vigtigste områder for marsvin prioriteret på baggrund af vores nuværende viden om populationer, tætheder, sæsonvariation, tilstedeværelsen af voksne hunner og andre relevante informationer. Prioriteringen er defineret som 1=meget vigtigt område, 2=medium vigtigt område og 3=mindre vigtigt område. I alt er 16 områder udvalgt og prioriteret (se tal i parentes herunder og figur 16), og de fordeler sig indenfor de tre forvaltningsområder som følger:

De indre danske farvande: Nordlige Lillebælt (2), Sydlige Lillebælt (1), Sydlige Samsø Bælt (2), Nordlige Samsø Bælt (3), Nordlige Øresund (1), Store Middelgrund (2), Kalundborg Fjord (1), Storebælt (1), Smålandsfarvandet (3), Flensborg Fjord (1), Fehmarn Bælt (1), Kadetrenden (2).

Nordlige Nordsø: Omkring det nordlige Jylland (1), Skagerrak (langs med Norskerenden, 2).

Sydlige Nordsø: Horns Rev (1), Tyske Bugt (1).

1 Introduction

1.1 Status of harbour porpoises in Danish waters

The harbour porpoise (*Phocoena phocoena*) has a northern circumpolar distribution (Gaskin 1984). It is the most common cetacean in Danish waters and the only cetacean known to breed here.

Based on satellite tracked porpoises and studies of genetics and morphology, the harbour porpoise is believed to be divided in several populations throughout its range. In Danish waters, studies on satellite telemetry and genetic studies have identified at least two populations (or perhaps subpopulations); one in the Northern North Sea including Skagerrak and one in the Inner Danish Waters including Kattegat (Andersen *et al.* 2001, Teilmann *et al.* 2004). A third population existed in the Baltic Sea until the 1960s, but it has since undergone a severe decline and was estimated to 599 (95% CI 200-3300) animals in 1995 (Hiby & Lovell 1996) and 93 (95% CI 10-460) in 2002 (Berggren et al. 2004). Little is known about its current distribution, but its status is highly critical (Koschinski 2002). It is currently unknown whether the porpoises residing in the Southern North Sea are genetically connected with the Northern North Sea population or belong to a separate fourth population in the southern North Sea.

The harbour porpoise has been observed in most parts of the Danish seas (e.g. Kinze *et al.* 2003, Hammond *et al.* 2002). However, porpoises are not believed to be evenly distributed throughout their range (Teilmann *et al.* 2004). The distribution is presumably linked to the distribution of prey, which in turn is linked to parameters such as hydrography and bathymetry, but little is known about the relationship between porpoises and their prey.

To date there have been two major abundance surveys conducted in Danish waters SCANS in 1994 and SCANS-II in 2005. During these two surveys the North Sea and adjacent waters were divided into several survey blocks without attention to national borders (Hammond *et al.* 2002). The total abundance estimate for harbour porpoises in the entire North Sea area was 288,000 porpoise in 1994 and 231,000 in 2005 (DSM estimate, Hammond *et al.* in prep). The density of porpoises has changed significantly in the North Sea between the two surveys. In the Northern North Sea the abundance estimate has decreased by about 100,000 animals from 1994 to 2005 while the estimate has increased by about 44,000 animals in the southern North Sea. It is likely that the majority of the changes from north to south in the North Sea are due to a displacement of animals, but a decrease in the north due to other causes e.g. bycatch and a true population increase in the south could also play a role.

For the Kattegat, Belt Seas and western Baltic Sea, the abundance estimate was 22,127 (CV=0.28) in 1994 and 13,600 (CV=0.33) in 2005 using density surface modelling (DSM, Teilmann unpubl. data). When Skagerrak is added to this area (area I in Hammond et al. 2002) the DSM abundance estimates for 1994 is 31,715 (CV=0.25) porpoises and for 2005 15,557 (CV=0.30) porpoises (Hammond *et al.* in prep). Due to large confidence intervals in line transect surveys, this 38-51% decline was however, not statistically significant, but should give reason for concern.

1.2 National and international protection of harbour porpoises

The harbour porpoise is listed in annex II and IV of the Habitats Directive (92/43/EEC), annex II of the Bern convention, annex II of the Bonn convention and annex II of the Convention on the international Trade in Endangered Species (CITES). Furthermore, it is covered by the terms of the Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS, a regional agreement under the Bonn Convention) and by HELCOM (The Helsinki Commission; protection of the marine environment of the Baltic Sea from all sources of pollution). HELCOMs definition of the Baltic Sea includes the inner Danish waters (as well as the Kattegat and the southern Skagerrak. Other international bodies with an interest in harbour porpoises include the International Council for the Exploration of the Sea (ICES), which provides scientific advice relevant to the management of fish stocks and other species (including marine mammals) and the International Whaling Commission (IWC). Although constrained from giving management advice regarding small cetaceans, the IWC has provided an important forum for assessing the status of small cetaceans, including harbour porpoises.

The harbour porpoise is also protected nationally in Denmark. In order, to address and implement the international regulations, the Ministry of Environment and Energy has made two action plans for the protection of harbour porpoises; one in 1998 (Miljøministeriet 1998) and a revision of this in 2005 (Miljøministeriet 2005). The action plan in 1998 concluded that more information about the distribution, population structure, movements and abundance of porpoises was needed. The revised action plan recommended certain research and concluded that Denmark will support international commitments to protect harbour porpoises and reduce incidental by-catch. The action plan will be revised again in 2010 (Miljøministeriet 2005).

By implementing the EU Habitat Directive all member states also fulfil the requirements of the Rio Convention on biodiversity, the Ramsar Convention on protection of wetlands and the Bonn Convention on migrating species. Furthermore both HELCOM and OSPAR (The Convention for the Protection of the Marine Environment of the North-East Atlantic) have agreed that the marine Natura 2000 sites qualify for the inclusion into the OSPAR/HELCOM network of marine protected areas (European Commission, 2007). The Directive was agreed upon in 1992 with the purpose of preserving biodiversity by protecting natural habitats and species of importance to the EU. All member states are thus legally obligated to protect the habitats and species listed in annex II of the Directive by selecting Special Areas of Conservation (SAC). The overall purpose of the directive is to maintain or restore populations of wild species at a “favourable status”. According to Article 1(e) the conservation status will be taken as "favourable" when it is sustainable, its natural range stable, and its habitat large enough to maintain its population on a long term basis. Together with Special Protection Areas (SPAs) designated according to the Birds Directive (79/409/EEC), the SACs will form a coherent European network of protected areas namely the Natura 2000 network. The Natura 2000 network includes both marine and terrestrial areas and is scheduled to be completed by 2012 (European Commission 2007).

1.3 Aim and approach of this report

A proper conservation of cetaceans involving the designation of protected areas depends on knowledge of several aspects of their population ecology. Ideally, information of population size, structure and seasonal movements and distribution as well as data on mortality and breeding rates should be available. However, this is rarely the case. To assist with identifying protected areas for migratory species such as harbour porpoise, an *ad hoc* meeting was convened by the European Commission on 14 December 2000 (EC (2001) Habitats Committee, Hab. 01/05). The meeting concluded that "it is possible to identify areas representing crucial factors for the life cycle of this species".

These areas would be identifiable on the basis of:

- the continuous or regular presence of the species (although subject to seasonal variations);
- good population density (in relation to neighbouring areas);
- high ratio of young to adults during certain periods of the year.

Thus, designating protected areas for harbour porpoises implies identifying areas of high porpoise density with particular focus on the distribution during the breeding season.

This report collates data on movements and density of the harbour porpoises in Danish and adjacent waters in order to identify areas of high porpoise density in Denmark. The report is based on available relevant data from previous studies as well as survey data collected in 2007 during the present project.

Several methods may be used to determine distribution and density of cetaceans. These methods are described and evaluated in Appendix 4. In this study the primary source of data for identifying key habitats / high density areas in Danish waters originates from the satellite tracking of 50 harbour porpoises in the period 1997-2002 (a joint project between the Danish Institute for Fisheries Research, the Fjord and Belt Centre, NERI and University of Southern Denmark, Teilmann *et al.*, 2004) and another 13 from 2003-2007 (by NERI and University of Kiel, FTZ). The only major areas that were not visited by the tagged animals were the southern North Sea and the waters around Bornholm. In the southern North Sea, only data from aerial surveys could give guidance on distribution of high density areas. Data from the area around Bornholm was too limited to determine harbour porpoise distribution and density. Acoustic ship surveys and aerial surveys are used as an independent method to confirm the presence of the high density areas found by satellite telemetry (a collaborative project between NERI and Stockholm University).

2 Methods

2.1 Satellite tracking

The 63 tagged porpoises were all unintentionally trapped in pound nets in the Danish waters from Skagen to Gedser (Figure 1). Pound nets are used all around Denmark (except for the North Sea) in the spring to catch primarily herring, mackerel and garfish, and in the autumn to catch eel. A pound net consists of a lead net extending from the beach out to a distance of 1km and ending in a trap. In some cases several pound nets are lined up in one row perpendicular to the coast line. The trap consists of a wide opening that guide the fish into the final trap, which is a bag net open at the surface. The circumference of the bag is 40-80m with a mesh size of about 2cm. The meshes are too small for entanglement and the harbour porpoises are rarely injured and can swim around freely and dive to depths of 5-10m.

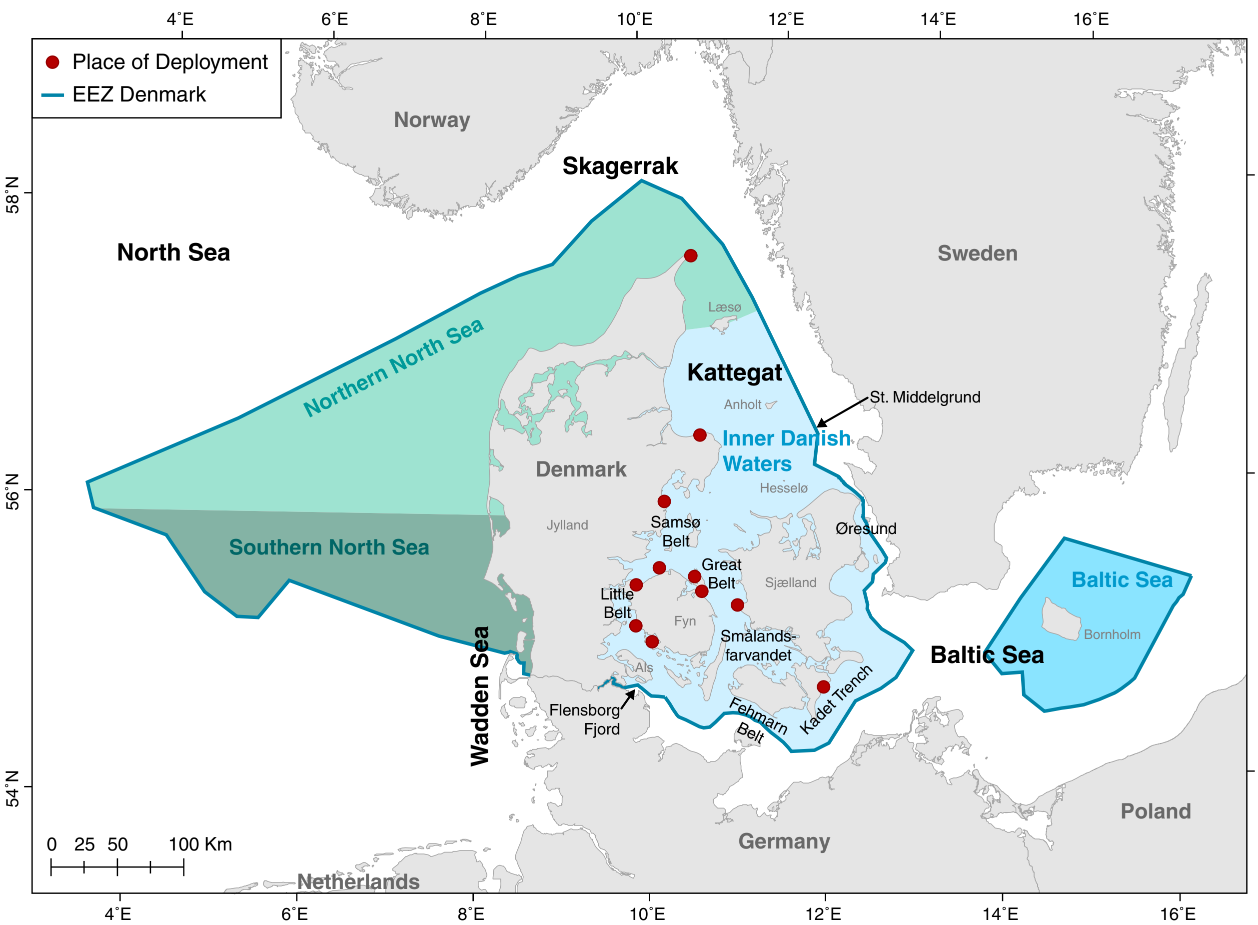


Figure 1. Map of the study area with names mentioned in the text indicated. The locations of the pound nets where the harbour porpoises were caught and tagged are indicated with a red dot. The suggested separation of the Danish waters into four harbour porpoises management (se p. 11) areas are shown in four different colours (southern North Sea, Skagerrak/northern North Sea, Inner Danish Waters and Baltic Sea).

A network of pound net fishermen was established in 1997. They reported when they observed a live porpoise in their nets. The fishermen were instructed to close the entrance to the net when a porpoise was found to prevent the animal escaping before the field team arrived, normally within a few hours. Compensation was paid to the fishermen for assistance with animal handling and for keeping the net closed until a porpoise was tagged and released.

The harbour porpoises (Appendix 1) were equipped with Argos satellite transmitters produced by Wildlife Computers, or Telonics from USA or Sirtrack from New Zealand. All tags had a transmission repetition rate of 45 sec. Transmissions were only possible in air, so a saltwater switch (SWS) ensured that transmissions would occur only when the animal was at the surface.

Only animals considered to be in good health (no abnormalities and with a normal blubber thickness, see Lockyer *et al.* 2003) were equipped with a satellite tag. After application of local anaesthesia (Lidocain 5% ointment), the two or three holes were made in the dorsal fin using a 5mm stainless steel cork borer-type utensil. Five millimeter threaded POM (polyoxymethylen or polyacetal) pins coated with polyester tubing (Sulzer Vascutek, Renfrewshire, Scotland) or silicone tubes as used in human surgery to protect the tissue, were fitted through the saddle and the dorsal fin and fastened using iron nuts in both ends, except in some tags that had internal thread. The pins were coated with antiseptic ointment (Betadine) just before use. The iron nuts would rust away and the tag fall off after an estimated one year period. The tissue samples inside the cork borer were saved for genetic analyses. Full data and sample sets for health check, body condition and reproductive status were taken when possible, including total length, girths, blubber thickness, full blood, serum and plasma, blood cytology, vaginal and blow cytology and bacteriology (Teilmann *et al.* 2004). The animals were kept under constant surveillance for their breathing and heart rate by a heart rate monitor (POLAR). When breathing had long intervals or was very irregular or if the heart rate was below 50 bpm, water was poured over the animal to trigger respiration. In the few cases where this was not sufficient the animals were lowered into the water in a cradle. The animals were handled on the boat for about 20-30 minutes until release.

24 porpoises were tagged on the border between Skagerrak and Kattegat on the northern tip of Denmark (Skagen, Jylland) and 39 were tagged in Kattegat, Little Belt, Great Belt or Western Baltic (Inner Danish Waters, IDW) from 1997 to 2007. All animals from the northern group stayed in the overlapping zone between the two groups in the northern Kattegat (see all year in figure 3 and 10) or in the Skagerrak and North Sea. Porpoises tagged in IDW stayed in the overlapping zone or south of this area except for five animals. Three of these stayed the majority of time in IDW and remain in this group through the analysis while the other two animals tagged close to the overlapping zone (Fjellerup Strand, #200306170 and #200606171, see tracks in Appendix 1) moved immediately after tagging into the Skagerrak and North Sea and stayed there for the entire contact period. These two animals were therefore grouped with the animals tagged in Skagen in the analysis shown in this report.

Table 1 provides an overview of how many animals divided by sex and age that have been tracked in each month. The majority of animals were tracked from April to November for both areas. In the Inner Danish Waters no adult females were tracked during December through March and no males during January through March. For Skagerrak this is the case for the months June-July. The number of young animals in both areas is rather high year round. The limited information on adult animals should be kept in mind when interpreting the data.

Table 1. List of tagged animals divided by age, sex and month in which locations were received. IDW: Inner Danish Waters.

Area	Age group	Total no. HP	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
IDW	Adult Females	6	0	0	0	8	6	5	3	2	1	1	1	0
	Adult Males	5	0	0	0	4	5	5	4	1	1	2	2	1
	Young	26	6	5	5	11	16	15	14	13	7	8	11	7
	Total	37	6	5	5	23	27	25	21	15	9	11	14	8
Skagerrak	Adult Females	2	2	2	2	1	1	0	0	1	1	1	2	2
	Adult Males	5	2	2	1	1	1	0	0	3	2	1	1	1
	Young	19	5	2	3	3	8	11	8	11	13	10	11	9
	Total	26	9	6	6	5	10	11	8	15	16	12	14	12
Both	All	63	15	11	11	28	37	36	29	30	25	23	28	20

Based on the satellite tracked porpoises we propose that the Danish waters be divided into four management areas for harbour porpoises (see coloured areas in Figure 1). These are 1) southern North Sea, 2) northern North Sea and Skagerrak, 3) Inner Danish Waters and Kattegat and 4) The Baltic Sea proper. The division of the North Sea area is based on the fact that of the 24 animals marked at Skagen, only 4 spend sometimes into the southern area and all came back to the Northen area again, which could indicate some structure in the population. Although there is no genetic data today to infirm or confirm such a structure, the results from the SCANS surveys indicate that the density of porpoises has behaved differently in the Northern and the Southern North sea strata, and we believe that a precautionary management division is the safest approach for the conservation of porpoises implemented through identification of high density areas in Danish waters. The division between the northern North Sea and the inner Danish waters should be in the northern Kattegat around the latitude of Læsø which seem to be in the middle of an overlapping zone where the animals tagged north and south of Læsø have some contact (see individual tracks in Appendix 1). The waters around Bornholm is part of the Baltic proper and only one of the tagged animals moved east of the inner Danish waters into this region (see map of 199906420 in Appendix 1). We suggest that the porpoises in these four areas should be managed separately until more substantial evidence suggests otherwise. It should be noted that the IWC (International Whaling Commission) and ASCOBANS (The Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas) for fishery management purpose generally use the ICES area IIId as the area for the Baltic Sea porpoise population. This area covers the water east of the Danish islands and therefore a part of the management area called Inner Danish Waters in this report. As the population structure in the area is unclear no definite population border based on scientific evidence can be made. The number of management units should be revised as more information about population structure become available.

2.1.1 Treatment of satellite data

The locations of satellite tagged animals are positioned according to the ARGOS system driven by Service Argos (for more details see:
http://www.dmu.dk/Dyr+og+planter/Dyr+satellitsporing/Positionering+af+dyr+med+Argos/
The satellite transmitters on the animals were programmed to send signals (uplinks) at periodic intervals. These uplinks are received by polar orbiting satellites and the position and time determined. According to the strength of the signal, number of uplinks received during a satellite overpass and other factors, the quality of the location is determined. The locations are saved and send from the satellite to an earth based receiver connected to the Internet, which allows download of the data by the user.

The locations received from Argos were filtered by the Argos-Filter v7.03 (D. Douglas, USGS, Alaska Science Center, Alaska, USA). The filter assesses plausibility of every Argos location using two different methodologies based on: 1) time period and distances between consecutive locations; and 2) rates and bearings among consecutive movement vectors. Both filters independently move chronologically through the raw location file for each animal, evaluating 3 locations at a time (more details in Sveegaard 2006).

2.1.2 Analysis in ArcGIS

The telemetry data were imported into ArcGIS 9.1 (ESRI) and the positions mapped with the Zone 32 (N) Universal Transverse Mercator (UTM) projection, using the WGS 1984 datum. All locations on land were removed except for locations within 1000m from the shore. This buffer was selected based on Vincent *et al.* (2002) who found an average location inaccuracy of around 1000m on captive satellite tagged seals. To avoid loosing a lot of data in coastal areas we accept a buffer zone of 1000m from the coast where we include all locations.

2.1.3 The kernel density estimator

To localize high density habitats for harbour porpoises, kernel density grids were produced in ArcGIS using the fixed kernel density estimator (Hawth's Analysis Tool, Beyer 2004). The kernel density estimator calculates a fixed kernel density estimate based on the total number of locations. The user can optionally create volume contours representing a user defined percentage of locations in the smallest possible area. For this report a high resolution (10% intervals) in kernel volume contours was chosen to give the best basis for selecting areas of relevant size and animal density. Given the high number of tagged animals we assume that the satellite locations represents the distribution of the population i.e. the percentile will represent the same percentage of the total population to be present within that area. For instance, the 50th percentile contains 50% of the locations and thereby 50% of the time was spent within that area. This also means that the 10th percentile area represents the core area with the highest density and the 90th percentile area represents the lowest density and almost the entire range of the porpoises. We defined high density areas as kernel percent volume contours of 30% density or higher (10% and 20%). This is a subjectively chosen threshold and the volume contours of lower levels (≥=40%) should not be disregarded.

Consequently, the exact boundaries of the 30% volume contour should be considered advisory in relation to high density areas.

The kernel density can be calculated on either all locations received or one location per day for each animal. Since the different satellite transmitters used over the year had different settings and because the number of receiving satellites and their sensitivity has been increased, the daily number of locations received varies by animal. We therefore selected the most accurate location per day for all the kernel analysis in this report. Furthermore the duration of contact with each animal varies from 10 to 348 days. It can be argued that if all porpoises have an equal probability to be anywhere in the study area, all locations should be weighted equally, even though some animals have transmitted for more days than others and therefore contribute more to the kernel output. The other option is to weight animals equally, which means that animals with a short contact will contribute as much as one with long contact. This will give a better picture of the individual habitat preferences. In all the kernel density maps based on satellite tracking in this report, we will only use the latter approach where animals are weighted equally.

2.1.4 Correlation between place of deployment and distribution of porpoises

Preferably animals should be tagged randomly throughout the study area, however, tagging sites were restricted to the areas where pound net fishery is carried out and where porpoises were caught. It was therefore not possible to make a random selection of animals throughout the Danish waters. To examine the correlation between place of deployment and the locations from each of the harbour porpoises, the distance in straight line from place of deployment to all following locations was calculated.

Figure 2 shows that from the day of deployment and the two following days there is a significant increase in distance (22,9 km/day) from the place of deployment to the position of the porpoise (Linear regression; P<0.05). From day 3 and onward there is still a significant increase (Linear regression; P>0.05) in distance to position of the porpoise, however, this increase is only of 0.2 km/day.

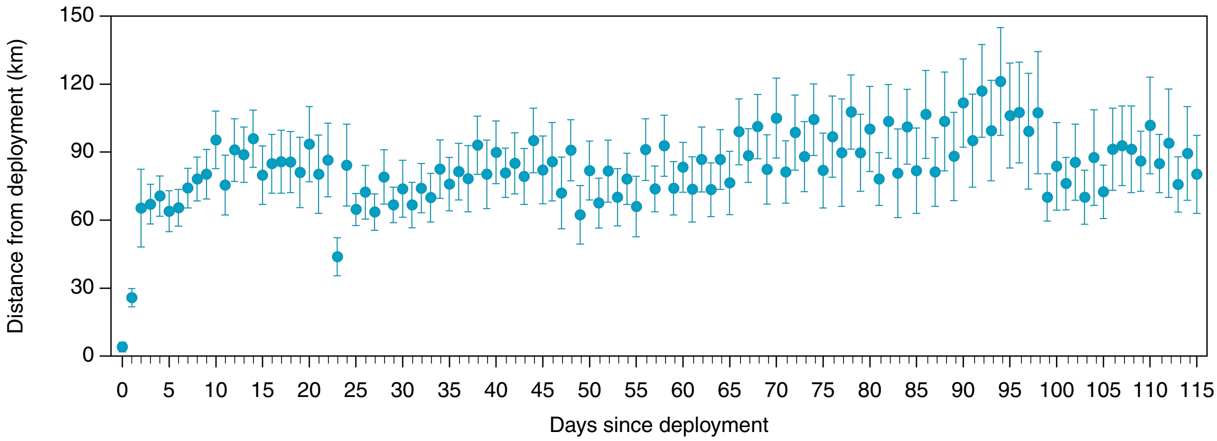


Figure 2. Relationship between number of days since deployment of satellite tags and average distance (km) from place of deployment. 34 porpoises from the Kattegat and Belt Seas are included in the figure. Only day 0 to 115 are shown, since the number of active transmitters hereafter was very low. Error bars show Standard Error.

The porpoises were on average 85 km away from the tagging site in straight line, which means that they seem not to have site fidelity to the tagging place within a period of about 100 days. This is also illustrated in that one of the areas with highest density is the northern part of Øresund is more than 100 km away from the nearest places of deployment. To prevent overrepresentation of the deployment areas, all locations from day 0 to 2 after tagging were excluded.

2.2 Acoustic surveys

Harbour porpoises make distinctive narrow band echolocation click sounds to navigate and find food. The dominant frequencies in the clicks range from 115 to 145 kHz (Teilmann *et al.* 2002). The clicks can be readily discriminated from other ocean sounds using a hydrophone. Acoustic detection can be automated using modern signal processing techniques and high processing power in modern computers. Acoustic detection systems have a number of advantages over visual. They are less affected by meteorological conditions. The acoustic surveys can be carried out at night and in poor weather conditions and are often more predictable and consistent in their performance than human visual observers. However, with the present techniques only relative abundance can be estimated from recording porpoise clicks but acoustic surveys can be a good way of monitoring trends in abundance over time.

Six acoustic ship surveys were carried out in 2007. The surveys covered the whole year every second month from January to November (see appendix 3 for dates). The surveys were designed to pass through the high density areas determined by the satellite tracking in Skagerrak, Kattegat, northern Øresund, Great Belt and Samsø Belt in three days (72hrs). The survey in August was extended to also cover the high density areas in the western Baltic to see how that would match the satellite tracking data and the aerial survey data collected by FTZ in Germany (see section below). The surveys started and ended in Gothenburg where the survey ship "Skagerak", owned by Göteborg University Marine Research Centre, was based. The ship is 38m long, 9m wide and has draught of 3.8m. A 200m Kevlar reinforced cable with two high frequency hydrophones in the end were towed after the ship. The speed was kept at 10 knots and the hydrophone was towed at 5m depth. The cable was connected to a buffer box and a high speed sound card in a computer. The system automatically recorded echolocation clicks from harbour porpoises and other background noise and simultaneously collected time and GPS location, except for some short periods where the system stopped functioning. Two operators assembled the system and monitored the data collection every hour during the surveys. This system was developed by Douglas Gillespie (IFAW) for the SCANS-II EU project, surveying cetaceans in European shelf waters during the summer 2005. It is essential that the vessel towing the acoustic hydrophones is relatively quiet so the porpoise signals can be detected. "Skagerak" was used during SCANS-II since it was relatively silent and had many detections during SCANS-II. The acoustic and visual data from SCANS-II in July 2005 are presented in this report and can be directly compared to the six surveys from 2007.

2.2.1 Data analysis

All automatically detected porpoise clicks were evaluated after the surveys, to make sure that the frequency spectrum and click intervals matched the criteria set by SCANS-II (Hammond *et al.* in prep.). During visual inspection of data all encounters were categorized as either "single tracks" or "multiple tracks" and consequently in the analysis given the value 1 or 2 porpoise encounters, respectively. All data were entered in ArcGIS where the trackline was divided into 10km transects and the average detection rate (porpoises/km) was calculated. Both maps for individual surveys as well as average maps for summer and winter and all year were produced.

2.3 Aerial surveys

Monitoring harbour porpoises using aerial and ship-based methods have been used in Danish waters since 1991 (Heide-Jørgensen *et al.* 1992, Hammond *et al.* 2002). For both vessel and aircraft surveys, line transect sampling is typically used to estimate abundance (Hiby & Hammond 1989, Buckland *et al.* 2001; 2004, for more details see Appendix 4). In this report, the abundance estimates will not be used. Instead the observations will be used as an indicator of distribution or the kernel density estimator will be used to show the distribution of density concentrations. The kernel density estimation is identical to that used for the satellite tracking data (see details above) with the exception that instead of weighting each porpoise, we weighted each observation according to the number of porpoises sighted in the group. Our criteria for using kernel are that the area has a high and even coverage so that the risk of overlooking important areas between transects is very small. Ideally spatial modelling or density surface modelling would be a more sophisticated method of analysing survey data. For future analyses it is recommended to use the model described by Hedley *et al.* (1999) and further developed during SCANS-II (Hammond *et al.* in prep.).

Two sets of aerial survey data are available:

1. Surveys carried out by NERI (DMU, Department of Biodiversity and Wildlife Ecology). These surveys consist of more than 60 flights from 1999-2007 mainly carried out to survey birds but harbour porpoises were also recorded. During 2007 three surveys in the Southern North Sea were made under the present project to extend the knowledge of this area.

2. Surveys carried out by FTZ in Büsum (part of Kiel University) during 2002-2006. In the western Baltic the effort consist of 43 flight days covering 25.308km while in the southern North Sea the effort consist of 75 flight days covering 37.140km. The surveys were dedicated to observations of harbour porpoises and covered the entire German North Sea and Baltic Sea but also the Danish part of the Western Baltic to the Southern coasts of Fyn and Sjælland.

All surveys carried out by NERI were performed from an altitude of 250 feet (76m). The majority of observations derive from line transect surveys (Petersen *et al.* 2006). The FTZ surveys were performed from an altitude of 600 feet (app. 200m).

3 Results and Discussion

The evidence for high density areas will be described separately based on the three management units proposed above (we have no data from the fourth area around Bornholm). According to Figure 1, the three areas are:

- The **Inner Danish Waters** (south of Læsø) through the belts and Øresund to the Western Baltic (excl. Bornholm).
- The **Skagerrak/Northern North Sea** (north of Ringkøbing), incl. Northern Kattegat north of Læsø.
- The **Southern North Sea** (south of Ringkøbing).

3.1 Inner Danish Waters

3.1.1 Satellite tracking

Kernel maps of high density areas for each month are given in Appendix 2, while an average map for summer, winter and all year can be found below.

Several areas were identified with higher density than other areas throughout the year, while some are only important during summer or winter:

1. Little Belt, especially around Als (all year), the middle part (winter) and the northern part (summer).
2. Flensborg Fjord (mainly summer).
3. Great Belt especially around the bridge (all year) and Kalundborg Fjord (winter).
4. Southern Samsø Belt (mostly summer).
5. Northern Samsø Belt (summer).
6. Fehmarn Belt (all year).
7. Store Middelgrund (summer).
8. The northern part of Øresund (summer)
9. The Kadet Trench (winter)
10. Smålandsfarvandet (all year)
11. South of Anholt (winter).

In Appendix 2 kernels for each month are shown. These maps should be evaluated with some care since the number of animals is limited in some months (especially in the winter, see Table 1) and the results may therefore not be representative for the entire population.

According to satellite tagged mother and calf pairs, the females seem to nurse their offspring for about a year and give birth in most years (Teilmann *et al*. 2007, Lockyer & Kinze 2003). The year-round distribution of adult females therefore represents all phases of the breeding cycle and important areas for the survival of the species.

The 8 adult females satellite tagged are shown in Figure 3 but the limited number of animals may not give the complete picture of their distribution and density. It should also be noted that the biggest threat to porpoises are currently by-catch in bottom set gillnets (e.g. www.ascobans.org). Mostly young animals are by-caught in gillnets, while fewer than 5% of stranded and by-caught animals are older than 12 years (Lockyer & Kinze 2003). This may resemble the natural population structure or perhaps that the younger animals are more susceptible to entanglement in gillnets than older and more experienced animals. It is therefore not only important to protect the adult females. In relation to bycatch, the young harbour porpoises, that may be especially vulnerable, should be considered.

The 8 tagged adult females spent the majority of their time in 5 areas (Figure 1 and 3):

1. The coastal waters around Als and Flensborg Fjord in the southern Little Belt.
2. The Great Belt north of the bridge, extending north between Samsø and Sjælland and into the southern Kattegat to app. $56^0$10'N.
3. Store Middelgrund.
4. The northern part of Øresund.
5. To some extend also Fehmarn Belt, an area in the middle of Aalborg Bugt in the middle of Kattegat and a more widespread area northwest of Jylland.

The validity of the important areas for adult female porpoises based on kernel densities should be interpreted with caution due to the relatively low number of adult porpoises tracked in this study. However, studies based on line transect surveys (Hammond *et al.* 1995) or opportunistic sightings and strandings (Kinze 2003) also found the waters around Fyn to contain a high rate of mother and calf observations in comparison to the surrounding areas. Kinze (2003) also documented many observations of mother and calves in Øresund.

To illustrate how the porpoises used the high density areas we have analysed the 30% kernel areas with respect to number of animals visiting, i.e. whether they stayed for a short time (defined as "corridor"; 2 days or less), or whether they stayed for longer (defined as "foraging area"; subjectively defined as more than 2 days since porpoises eat almost every day (Lockyer *et al.* 2003)). The average number of days that the foraging animals stayed in these areas were also determined (Table 2). Not all the areas mentioned above will be included as only some of them include part of the 30% kernel. In the Inner Danish waters the Great Belt was visited by most porpoises (19 of the 37 porpoises). Half of these move through to other areas while the rest stayed for an average of 29 days. Northern Øresund, Kalundborg Fjord, Little Belt and Flensborg Fjord were also visited by many animals (n=10, 14, 13, 11, respectively). In these four areas 20% move on after one or two days while the rest stayed for an average of 15, 8, 34 and 31 days, respectively. Fehmarn Belt was also visited by many animals (n=13) but only about one third stay for an average of 7 days, while the rest use the area as a corridor to other areas. The remaining areas St. Middelgrund and northern Samsø Belt were only visited by few animals 3 and 4, respectively. Only one animal in each of these areas stayed for more than 2 days and in northern Samsø Belt the animal stayed for 91 days (Table 2).

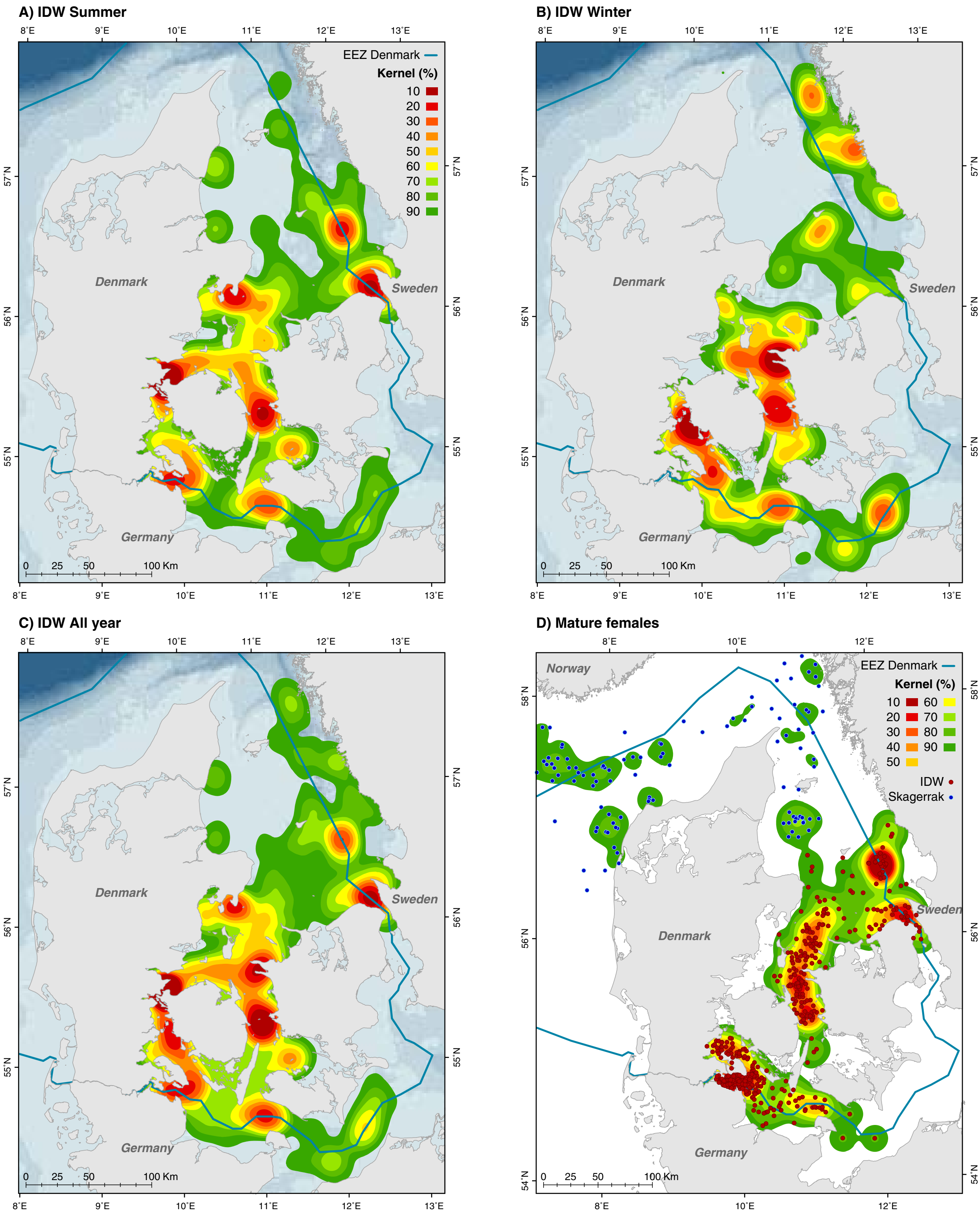


Figure 3. Kernel density estimation in 10% intervals based on 37 harbour porpoises tagged in the Inner Danish Waters area between 1997-2007 (the lower percent the higher density). The summer and winter situation is given in panel A and B and the all year average in panel C. Kernel and the transmitted locations for the 8 satellite tracked mature females tracked all year are shown in panel D. Note that the locations for each day are shown in blue for the 2 animals tagged in Skagen and red for the 6 animals tagged in the Inner Danish Waters.

Table 2. High density areas for satellite tagged harbour porpoises (HP). Number of animals, the assumed behaviour and the number of days spent within the 30% kernel area are listed. Data are taken from the "all year" kernels for the Inner Danish Waters (Figure 3) and Skagen (Figure 10), respectively.

Area	Total No. HP	Corridor % animals	Foraging % animals	Foraging Av. no. days in area
Tip of Jylland	25	4.0	96.0	20
St. Middelgrund	3	66.7	33.3	13
Northern Øresund	10	20.0	80.0	15
Northern Samsø Belt	4	75.0	25.0	91
Kalundborg Fjord	14	21.4	78.6	8
Great Belt	19	47.4	52.6	29
Fehmarn Belt	13	61.5	38.5	7
Little Belt	13	23.1	76.9	34
Flensborg Fjord	11	18.2	81.8	31

3.1.2 Acoustic surveys

The six acoustic surveys are shown separately in Appendix 3. The average for the summer, winter and all year acoustic surveys with the satellite tracking kernels for the same periods is shown in Figure 4. The acoustic detection rate cannot be related directly to absolute density but give a relative estimate of density. By inspecting the data visually, we generally find a good concordance between the concentrations of acoustic detections and high density kernels. Especially the concordance for Great Belt and northern Øresund are obvious with high density throughout the year with both methods in the Great Belt and high density during summer and low density during winter for both methods in northern Øresund (Figure 4 and Appendix 3). During the August/September survey also the western Baltic was surveyed. However, no obvious concordance was seen although the detection rate was slightly higher in the Flensborg Fjord area and in Fehmarn Belt (Appendix 3).

To evaluate the correlation between the acoustic surveys and the satellite tracking kernels we analysed the average detection rate for all surveys combined (porpoise/km) in each kernel percentage area determined by the satellite tracked porpoises (Figure 5). There is generally a good correlation between the high density areas defined by the two methods. The highest densities are found in the 10% and 20% kernels (not significantly different), while the 30 to 60% kernels are similar at a somewhat lower level.

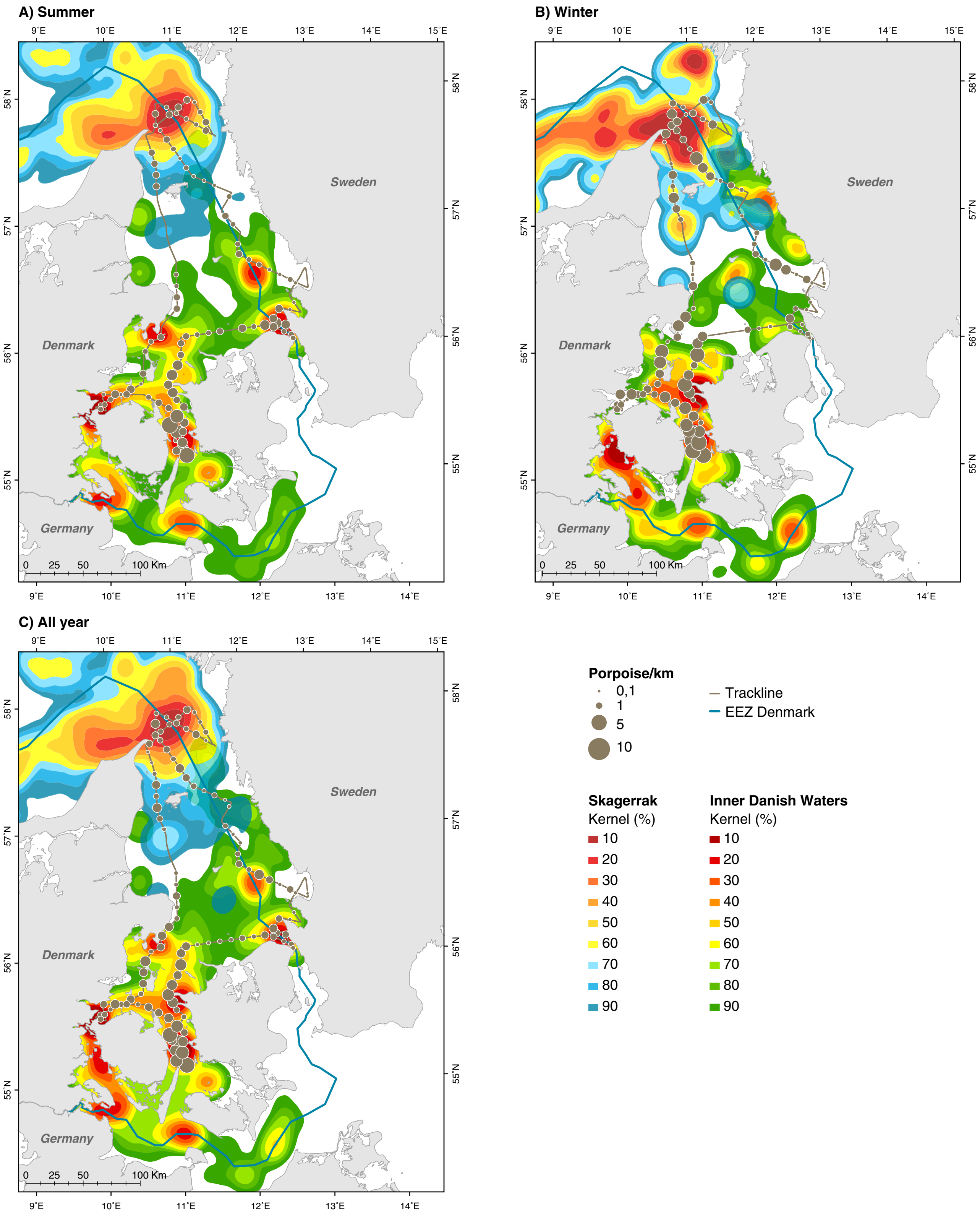
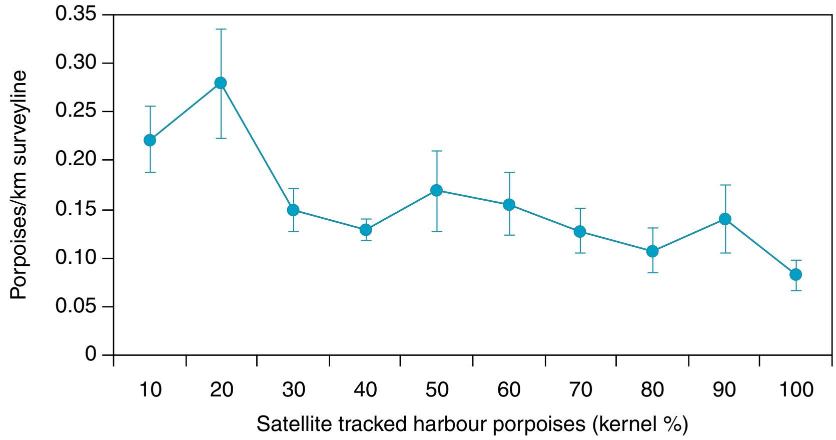


Figure 4. Maps of the acoustic vessel surveys showing the trackline and the detection rate in dots. The size of the dots corresponds to the number of detections per km calculated for every 10 km. The underlying kernel contours from the satellite tracking show the high density areas (the lower percent the higher density). Kernels from Skagerrak and Inner Danish Water animals are shown separately. Panel A shows the summer (May-October) average based on surveys from May, August and October. The extended part of the survey in August is excluded in these maps (see appendix 3). Panel B shows the winter (November-April) average based on surveys from November, January and March. Panel C shows the all year average based on all six surveys.

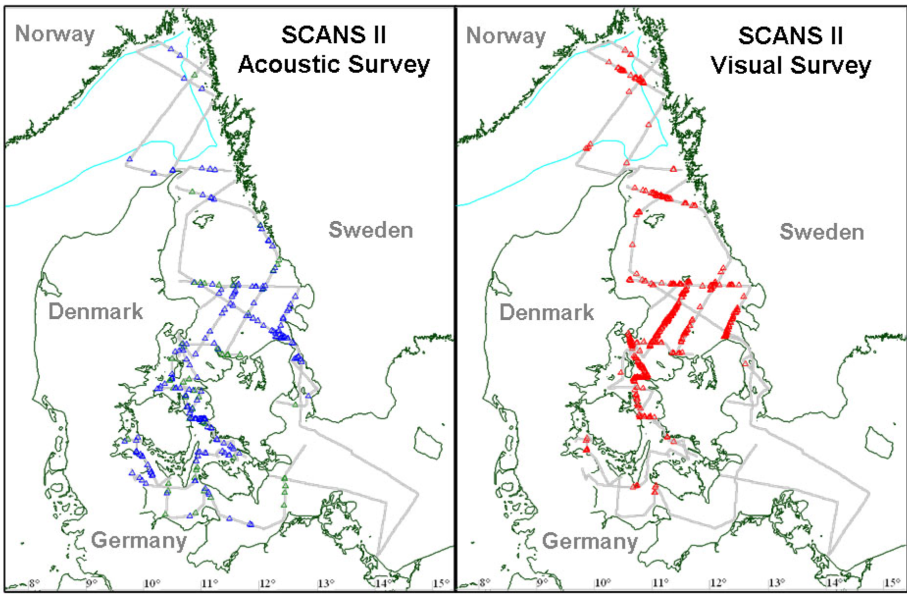
Figure 5. Average detection rate from the acoustic surveys divided by the different kernel percentage areas from the satellite tracked porpoises. The calculations are based on the all year average in Figure 4. Standard Error is shown as error bars.



SCANS-II

During July 2005 the vessel "*Skagerak*" surveyed the Skagerrak, Kattegat, Belt Seas, Øresund and western Baltic. Both visual and acoustic survey techniques were applied. According to Figure 6 concentrations of acoustic detections are found around the northern Øresund, Great Belt and around Als. This picture is somewhat different for the visual sightings where many sightings were made in the northern Skagerrak, northern Kattegat and throughout the southern Kattegat and east of Samsø (Figure 6). It should be noted that the visual sightings are not corrected for sighting conditions (although only data collected in Beaufort Sea state 0-2 were included) which will influence the chance of observing animals. The acoustic detections are not affected by the weather conditions below sea state 5. The visual and acoustic datasets as illustrated in Figure 6 can therefore not be directly compared as there are differences in the effort, e.g. the acoustic equipment was out of the water or weather conditions prevented visual sightings.

Figure 6. Survey plot from the vessel "Skagerak" during SCANS-II, 29 June – 14 July 2005. Acoustic detections are shown with blue triangles on the left panel. Visual sightings are shown with red triangles on the right panel. The sailed route is shown as a grey line.



The visual sightings from the 8 vessels and 3 aircrafts were analysed using density surface modelling (spatial modelling) and compared to the corresponding survey in 1994 (Figure 7). The main result is that the high density of harbour porpoises around Scotland in 1994 has moved south to the west coast of England in 2005. High densities around Denmark in 1994 have decreased especially around the northern part of Jylland (Figure 7). It should be noted that the basis for these finding are only two summer surveys, although these surveys covers the widest area, results should be interpreted with some caution and be confirmed in future studies.

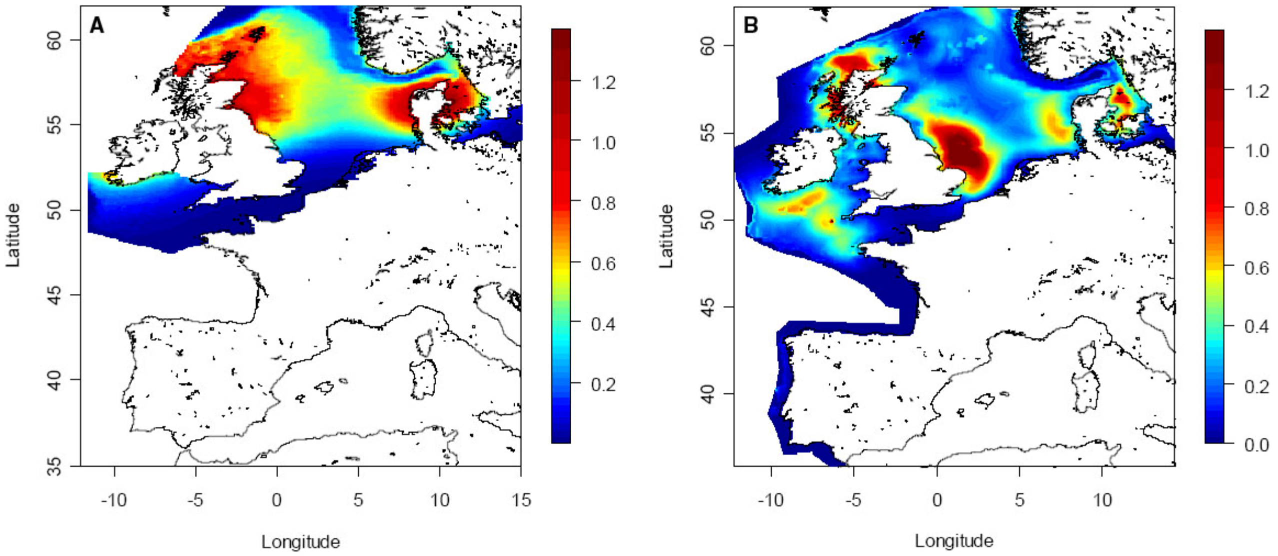


Figure 7. Density surface modelling of the SCANS I and II data collected during July 1994 and 2005. The maps are based on the visual sightings. Panel A show the density distribution in 1994 and panel B the density in 2005. The colours indicate the absolute density in animals/km^2 (from Hammond et al. in prep.).

3.1.3 Aerial surveys

In the western Baltic the FTZ in Büsum (part of Kiel University) conducted regular aerial surveys throughout the year from 2002 to 2006 (Gilles *et al.* 2006; 2007). Figure 8 show the relative density of individuals per km^2 in 10x10 km squares. There is a general increasing trend from east to west and the highest densities are found around Als and the western part of Fehmarn Belt. These two areas correspond to the high density areas previously identified based on satellite trackings (Figure 3).

Surveys conducted by NERI in Aalborg Bugt (Figure 9) observed harbour porpoises all over the survey area with the highest densities concentrating along the slope from the shallow plateau to the east and the deep water to towards Sweden (see depth contours in Appendix 1). Other areas with higher density are northeast of Djursland and in the southern part of the underwater channel between Læsø and Jylland. None of these areas were identified as particularly important with any of the other methods. This probably means that there are local higher density areas in Aalborg Bugt but the whole area may be of less importance on a population level.

Figure 8. Mean density of harbour porpoises (individuals/km^2) based on 12 complete aerial surveys of the area. Data from the study years 2002-2006 were pooled. Grid cell size: 10x10 km, transect spacing 6 km (data from Gilles et al. 2006, 2007).

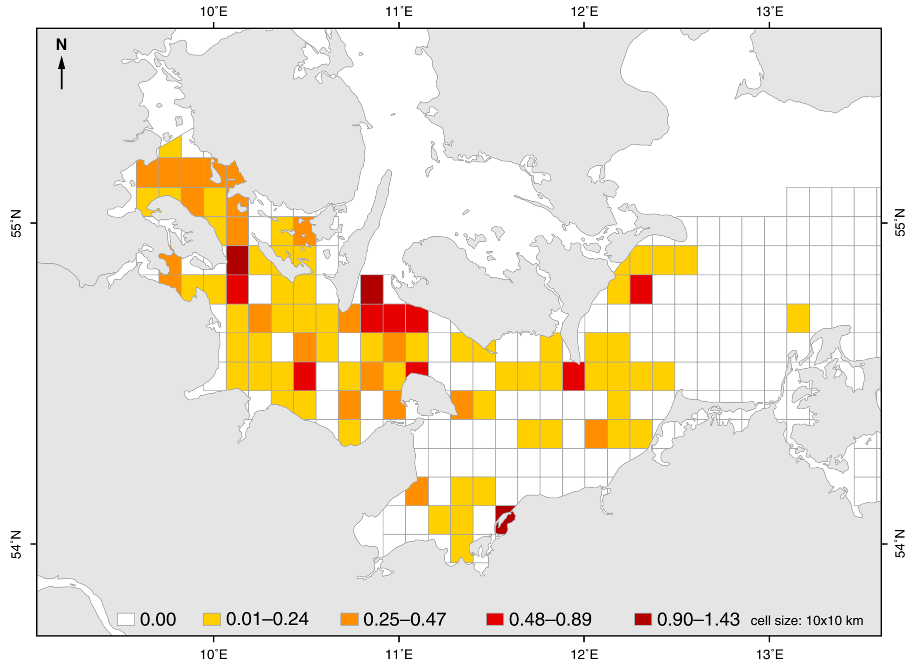
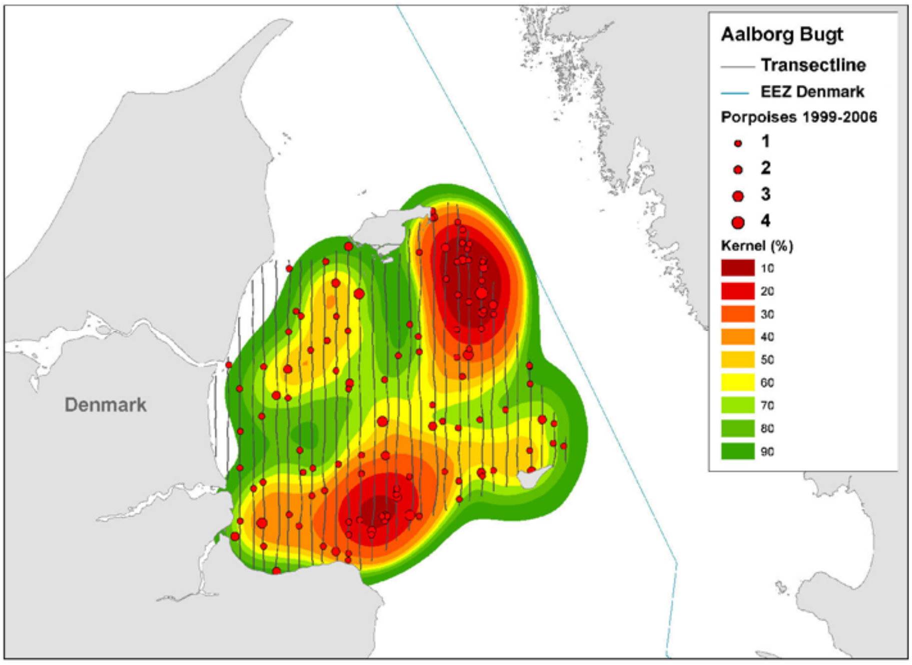


Figure 9. Density kernel map of harbour porpoises based on 16 aerial surveys conducted in Aalborg Bugt from 1999 to 2006 covering the whole year (the lower percent the higher density). Observations and aerial tracks are shown.



3.2 Skagerrak/Northern North Sea

3.2.1 Satellite tracking

In the Skagerrak/Northern North Sea the high density of harbour porpoises is concentrated around Skagen (the northern tip of Jylland, Figure 10 and Appendix 2). This area includes the northern part of Kattegat and extends east to the Swedish coast. The high density area is limited to the north by the slope to the Norwegian Trench extending down to 700m depth. Only few porpoises move outside the 200m depth contour (see tracklines in Appendix 1). In the summer time the porpoises concentrate in a smaller area around the northern tip of Jylland while they spread westwards along the slope to the deep water during winter. Several animals moved far north to the waters around the Shetland Islands during winter. All animals except one spent time within the 30% kernel area for all year (Table 2 and Figure 10). This may not be a surprise since the area is centred around the place of tagging. However, only one animal left the area within day 0-2 that was excluded from the analysis (see Methods) and only one animal used the area as a corridor and spent less than 2 days here. The remaining 25 animals were on average 20 days in the area at some point of the tracking period (Table 2).

3.2.2 Acoustic surveys

The six acoustic surveys are shown separately in Appendix 3. The average for the summer, winter and all year acoustic surveys, with the kernels for the same periods, are shown in Figure 4. The acoustic detection rate cannot be related directly to absolute density but give a relative estimate of density. The only area in the Skagerrak/northern North Sea that was covered by acoustic surveys was the waters between Skagen and the Swedish west coast. This area has the highest density of harbour porpoises according to the kernel maps from satellite tracking (Figure 10). A good concordance was found between high density from acoustic surveys and satellite tracking (Figure 4 and Appendix 3)

3.2.3 Aerial surveys

The three aerial surveys from the Skagerrak/northern North Sea covered the area west of where the acoustic surveys ended (Figure11). The highest densities are found in the northern part of the survey area close to the slopes towards the deep Norwegian Trench and thus correspond well with the findings from the satellite tracking (Figure 10).

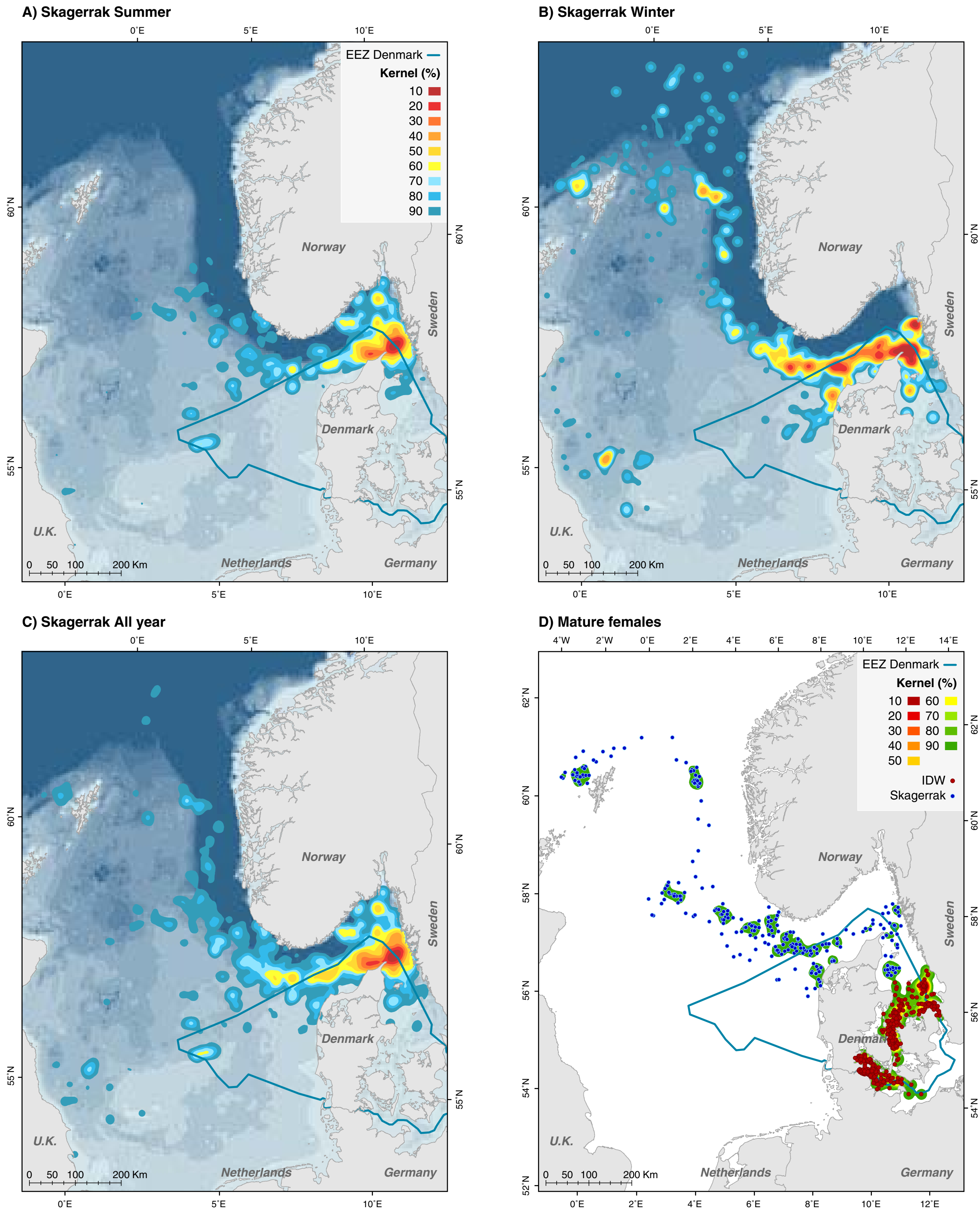


Figure 10. Kernel density estimation in 10% intervals based on 26 harbour porpoises tagged in Skagen (the lower percent the higher density). The summer and winter situation is given in panel A and B and the all year average in panel C. Kernel for the 8 satellite tracked mature females are shown in panel D. Note that the locations for each day are shown in blue for the 2 animals tagged in Skagen and red for the 6 animals tagged in the Inner Danish waters.

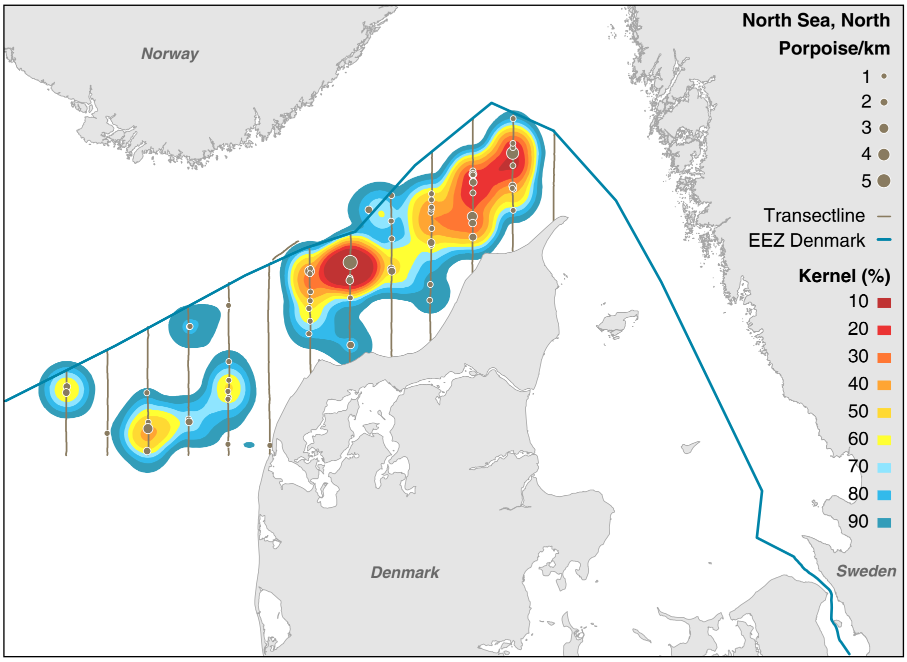


Figure 11. Kernel density map of harbour porpoises based on 3 aerial surveys conducted in Skagerrak/northern North Sea in 2006-2007 covering the summer and fall from August to October (the lower percent the higher density). Observations and track-lines as well as the national border are shown.

3.3 Southern North Sea

3.3.1 Aerial surveys

In the southern part of the Danish North Sea aerial surveys are the only basis for determining high density areas. The best surveyed area is around Horns Rev where 33 surveys were carried out from 1999 to 2005 (Figure 12). High density is primarily found along the reef in two concentration areas. In February, March and May 2003 and in March 2004 four aerial surveys were performed in the southern parts of Danish North Sea (Figure 13). Additional surveys were conducted to complement data from this area. Data from the four surveys of 2003 and 2004 are shown as kernels in Figure 13 and three surveys from 2007 are presented in Appendix 6 (one survey was aborted due to poor weather conditions and the remaining two surveys had too few observations to perform a kernel analysis). The coverage and timing of the different aerial surveys in this area prevent pooling all data into one kernel analysis. Therefore the relative importance of the high density areas around Horns Rev and the area along the German border cannot be compared until spatial modelling has been performed. The surveys along the border to Germany show a high density area midway along the survey area about 50-100km off the coast. This area complements the high density found in the German aerial surveys, where the highest densities are found just south of the border, and with a clear decrease in density closer to land. A similar area was seen from the SCANS-II survey in 2005 (Figure 7). During this survey the high density extends northwest across the Danish North Sea sector.

Figure 12. Kernel density map of harbour porpoise observations based on 33 aerial surveys conducted around Horns Rev from 1999 to 2005 covering the whole year (the lower percent the higher density). Observations and tracklines are shown.

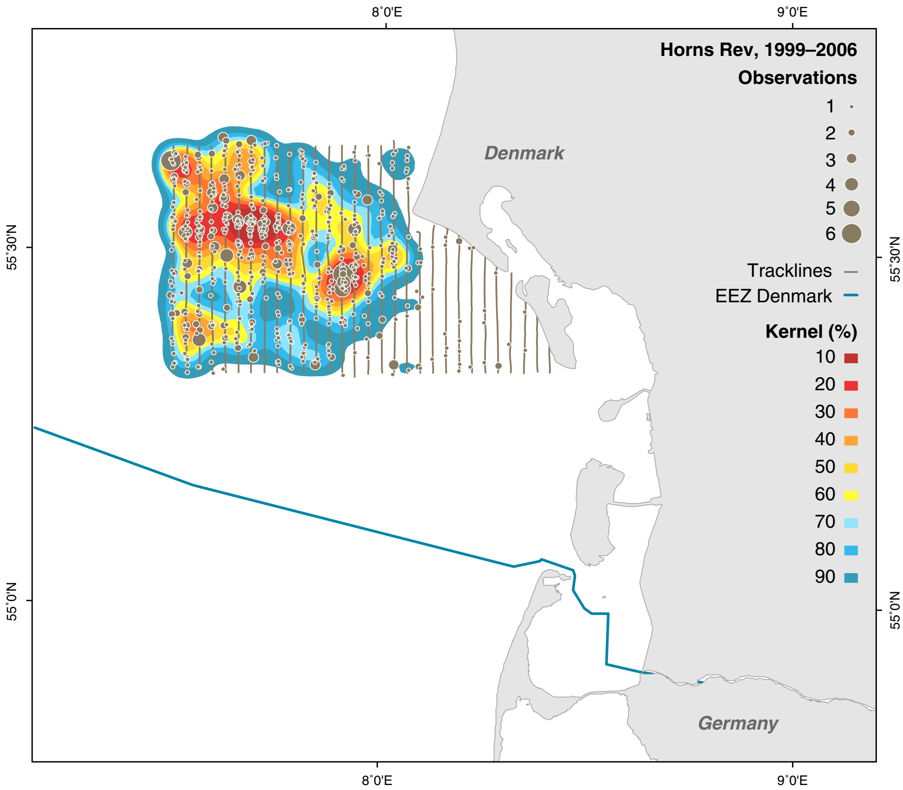
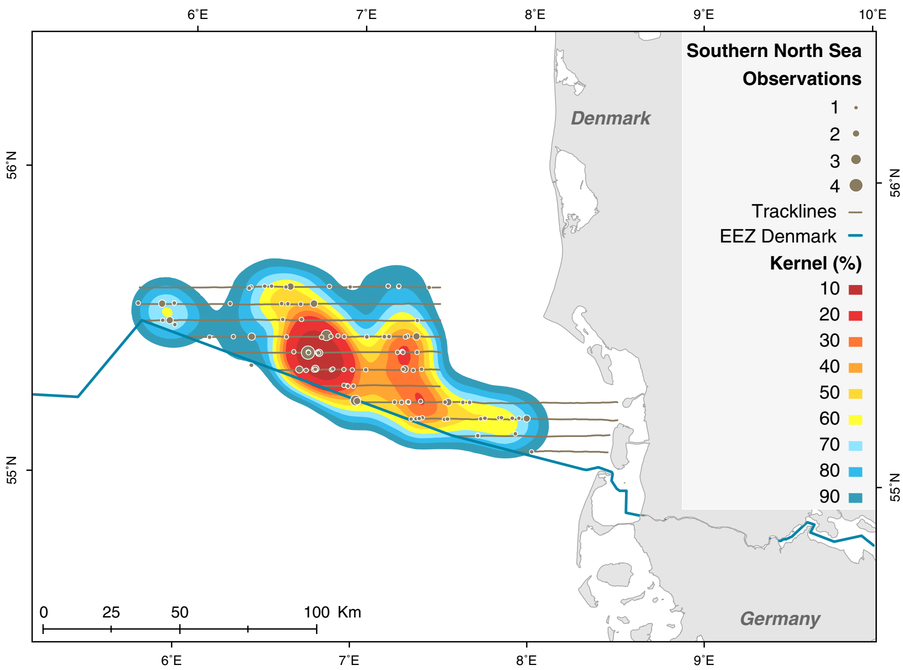


Figure 13. Kernel density map of harbour porpoise observations based on 3 aerial surveys conducted along the German border from February to May 2003 (the lower percent the higher density). Observations and tracklines are shown as well as the national border (blue line).



During the German surveys high concentrations of porpoises were also found at Doggerbank along the Danish border. It is possible that this high density continues on Danish territory and preliminary spatial modelling of the SCANS-II data confirms this (Anita Gilles, unpublished data). The German surveys also show that fewer animals are observed during autumn (September-November) compared to spring and summer (March-August). This is also confirmed by the Danish aerial surveys where far more porpoises are observed from March to September (Figure 15).

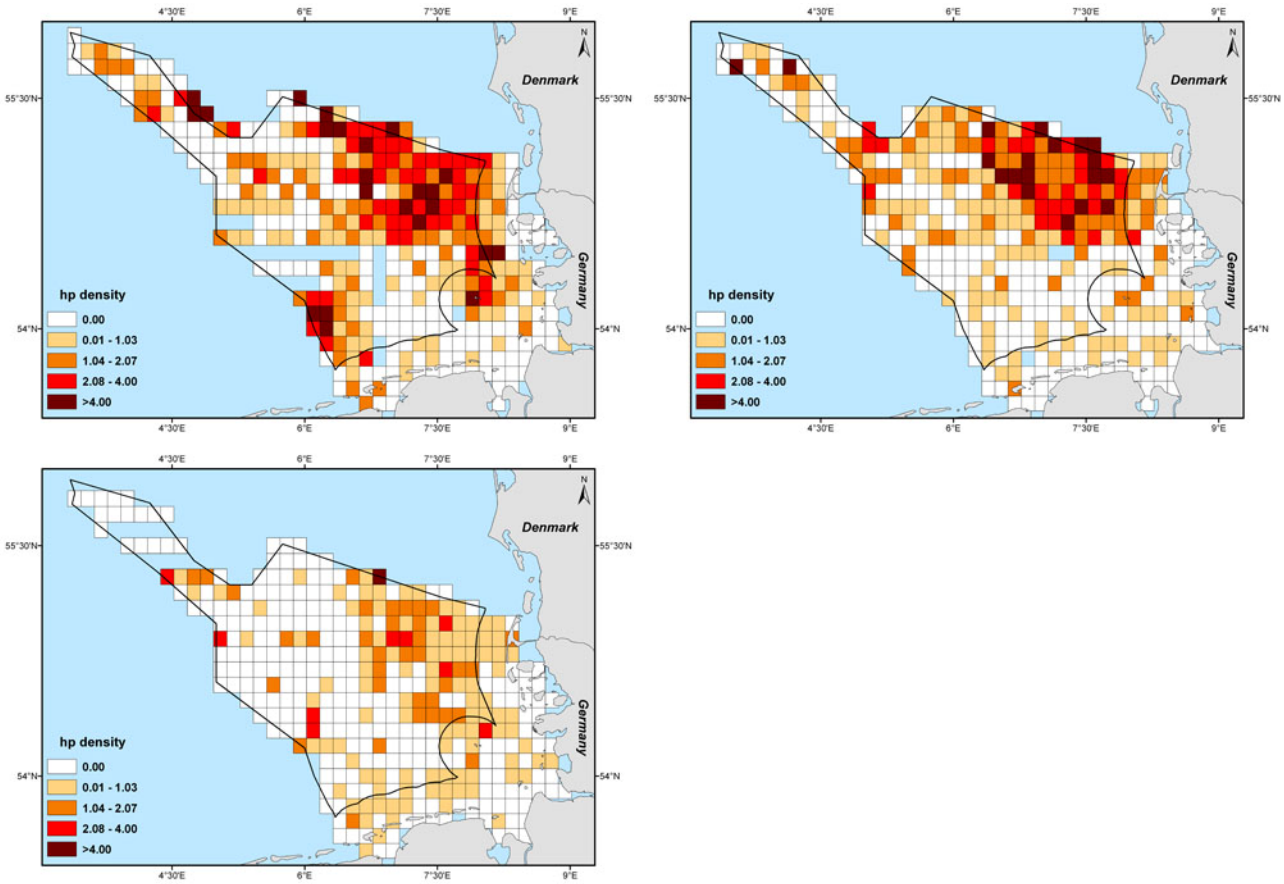
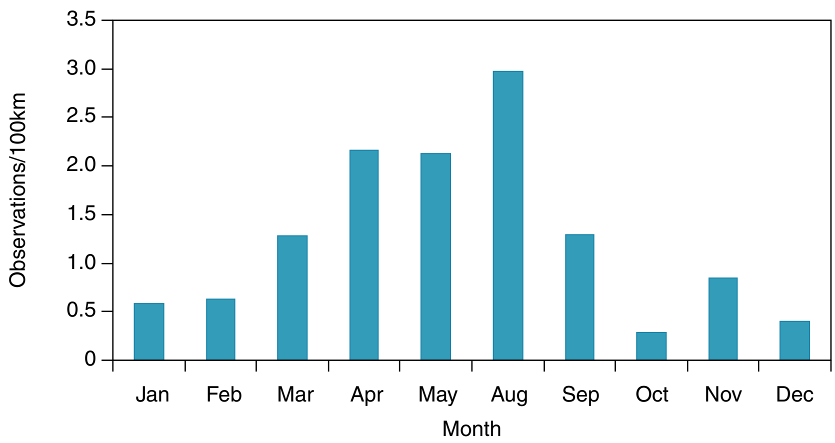


Figure 14. Mean density of harbour porpoises (individuals/km^2) based on 12 complete surveys of the area. Data from the study years 2002-2005 were pooled. Grid cell size: 10x10km, transect spacing 10km. Panel A show the spring density distribution (March-May). Panel B show summer (June-August). Panel C show fall (September-November). No data are available for the entire area during winter (data from Gilles et al. 2006, 2007).

Figure 15. Monthly sighting rate from aerial surveys in the Danish southern North Sea.



4 Conclusion

The first overview of harbour porpoises in Danish waters was brought by Teilmann et al. (2004) from a satellite tagging study. By combining these results with new satellite tagging data and data obtained from other methods, the new analysis provided in this report allow us to propose a ranking of the importance of areas for harbour porpoises in Danish waters.

Comprehensive data from satellite tracking, aerial and ship surveys as well as acoustic surveys from ship have been collected from 1991 to 2007. The data cover three of the four harbour porpoise proposed management areas in Danish waters. The following section summarises and ranks the high density areas found in each management area (Table 3). Ranking is based on the current knowledge of density, seasonal variation in distribution and other relevant factors presented in this report. The rankings are defined as 1=high importance, 2=medium importance and 3=lower importance. However, even the areas with lower ranking may be important and should not be disregarded. Numbers in parenthesis refer to the area number in Table 3 and Figure 16.

4.1 Inner Danish waters

Both satellite tracking, acoustic and aerial surveys show several high density areas.

***Little Belt (1, 2)* especially around Als (all year), the middle part (winter) and the northern part (summer).**

This area is supported by satellite tracking (13 porpoises) and the German surveys which found the waters around Als to be one of the most important areas in the Western Baltic. The northern part is only important during spring and summer from March-August while the high density seem to move south from September and rest of the year. According to the satellite trackings the waters around Als have high densities of porpoises all year except for December (Appendix 2) and also a high density of adult females (Figure 3). We further detected porpoises all year round during the acoustic surveys but not in particular high densities. However, Little Belt was only poorly covered during the surveys, so based on the strong evidence from the satellite trackings and the aerial surveys we rank both northern and southern Little Belt as 1.

***Southern Samsø Belt* (3) (mostly summer).**

The porpoises seem to move into the area from the east in April and stay until August. In September they move either south into the Little Belt or east again. The acoustic surveys detected porpoises year round but only in high densities during the winter month. During SCANS and SCANS-II Hammond *et al.* (2002; in prep) also detected relatively high densities of porpoises (Figure 6 and Figure 7). It seems that the Southern Samsø Belt has a stable but not particularly high density of porpoises and therefore we rank this area as 2.

***Northern Samsø Belt* (4) (summer).**

The area has a high density during May-August, but this is based on only 4 satellite porpoises and only one of these stayed for more than 2 days. This animal stayed within a small area for 91 days. Some porpoises were detected during the acoustic surveys in all six surveys and the area may be important. However, until more substantial evidence suggests otherwise, we rank this area as 3.

***Northern Øresund* (5) (summer)**

This area has very high densities during summer where 10 of the tagged porpoises moved into the area in April and left again in October (Appendix 2). The acoustic surveys also detected high densities of porpoises during the summer and also in November but none in January (Appendix 3). The SCANS-II survey had many detections here in July (Figure 6). We categorize the area as 1.

***Store Middelgrund* (6) (summer).**

This area was visited by 3 tagged porpoises, one of which was an adult female that stayed here for 13 days. During the acoustic surveys in March, August and November relatively large densities were detected on the track line closest to Store Middelgrund in comparison to neighbouring areas (see app. 3). However, since so few of the porpoises visited this area although it is relatively close to the high density area of Northern Øresund, we rank this area as 2.

***Great Belt* (7, 8) especially around the bridge (all year) and Kalundborg Fjord (winter).**

The highest density is concentrated around the narrow part of the Great Belt. Although the satellite trackings (19 porpoises) show little use of the Great Belt in February-March the acoustic surveys had many detections year round (Appendix 2 and 3). Many detections were made during the SCANS surveys in July (Figure 6 and 7). Waters around Kalundborg Fjord had high density during winter according to the satellite tracking (Figure 3). High density of adult females is found in the whole Great Belt (Figure 3D). Furthermore, Great Belt have been found to have high densities in previous visual surveys (see Appendix 5) and it is the main corridor for porpoises passing between northern and southern Danish waters (Table 2). We find that Great Belt is one of the most stable and important (perhaps the most important) area for porpoises in the Inner Danish Waters. It is ranked as 1.

***Smålandsfarvandet* (9) (all year)**

The satellite trackings show that porpoises are present throughout the year, but not in very high densities (Figure 3). This was confirmed by the acoustic survey conducted in August (Appendix 2). The area is ranked as 3.

***Flensborg Fjord* (10) (mostly summer).**

The inner part of Flensborg Fjord has particularly high densities from June to November while the porpoises move to the outer part during the rest of the year (11 porpoises, Appendix 2). High density of adult females was also found here (Figure 3). Table 3 shows that the fjord is an important foraging area for porpoises. Furthermore, previously conducted passive acoustic monitoring (using T-PODs) has proved a year round presence of porpoises (Sveegaard 2006). Based on passive acoustic monitoring Germany has designated the German part of Flensborg Fjord as a Special Area of Conservation. We rank it as 1.

***Fehmarn Belt* (11) (all year).**

Tagged animals were present here in all months except August and October. Peak densities are in April, June and December (app. 2). 13 tagged animals visited this area but only 5 of them stayed in the area more than two days and these only stayed for 7 days on average. This suggests that the area is mainly used as an important corridor to the eastern part of the area. Relatively high densities of females are also found here. Furthermore based on surveys and acoustic monitoring Germany have designated a part of Fehmarn Belt as Special Area of Conservation. We rank it as 1.

***The Kadet Trench* (12) (winter)**

The trench is a deep basin in a relatively shallow area. The tagged porpoise mostly used the area from September to December and in March (Appendix 3). The German aerial surveys and the only acoustic survey in the area (August) showed porpoises present in the area. The Kadet Trench is the most south eastern of the identified high density areas in Danish waters, and therefore potentially important in regard to the vulnerable Baltic Sea population. As with Fehmarn Belt Germany have identified a part of the Kadet Trench as Special Area of Conservation. The area is ranked as 2.

4.2 Northern North Sea

In the northern part of the Danish North Sea two high density areas have been identified:

***Tip of Jylland* (13) (All year)**

A relatively large almost circular area around the tip of Jylland show high densities of the tagged porpoises all year. The area is near the place of tagging, but since 96% of the tagged porpoises stay in the area for an average of 20 days (Table 2) we consider this area important, probably for foraging. The acoustic survey show higher densities around Skagen in comparison to the waters further south between Læsø and Anholt. We rank the “tip of Jylland” as 1.

***Skagerrak* (14) (All year)**

A rather large but not well defined area along the Norwegian Trench showed high density for the tagged porpoises all year and especially high in the winter (Figure 10). Aerial surveys confirm this picture (Figure 11). We rank this area in the Skagerrak Sea as 2.

4.3 Southern North Sea

No tagging data are available from this area. However, the area has been intensively surveyed from aircrafts by NERI and two high density areas have been identified.

For future research, we recommend satellite tracking porpoises in this area, which can confirm the densities found by surveys and deliver further information on high density areas further away from the coast as well as on the extent of this population and relatedness to other populations.

Horns Rev **(15) (Figure12) (All year)**
An intensely surveyed area from 1999-2005 due to wind farm constructions. Data covers the whole year and show a high density area about 30km from the coast (Figure 12). We rank Horns Rev as 1.

German Bight **(16) (All year)**
High densities from aerial surveys concentrate around and along the Danish/German border about 50-100 km from the Wadden Sea (Figure 13). This corresponds well to German surveys that have identified a high density area (Figure 14) directly aligned with the Danish EEZ. We rank the German Bight as 1.

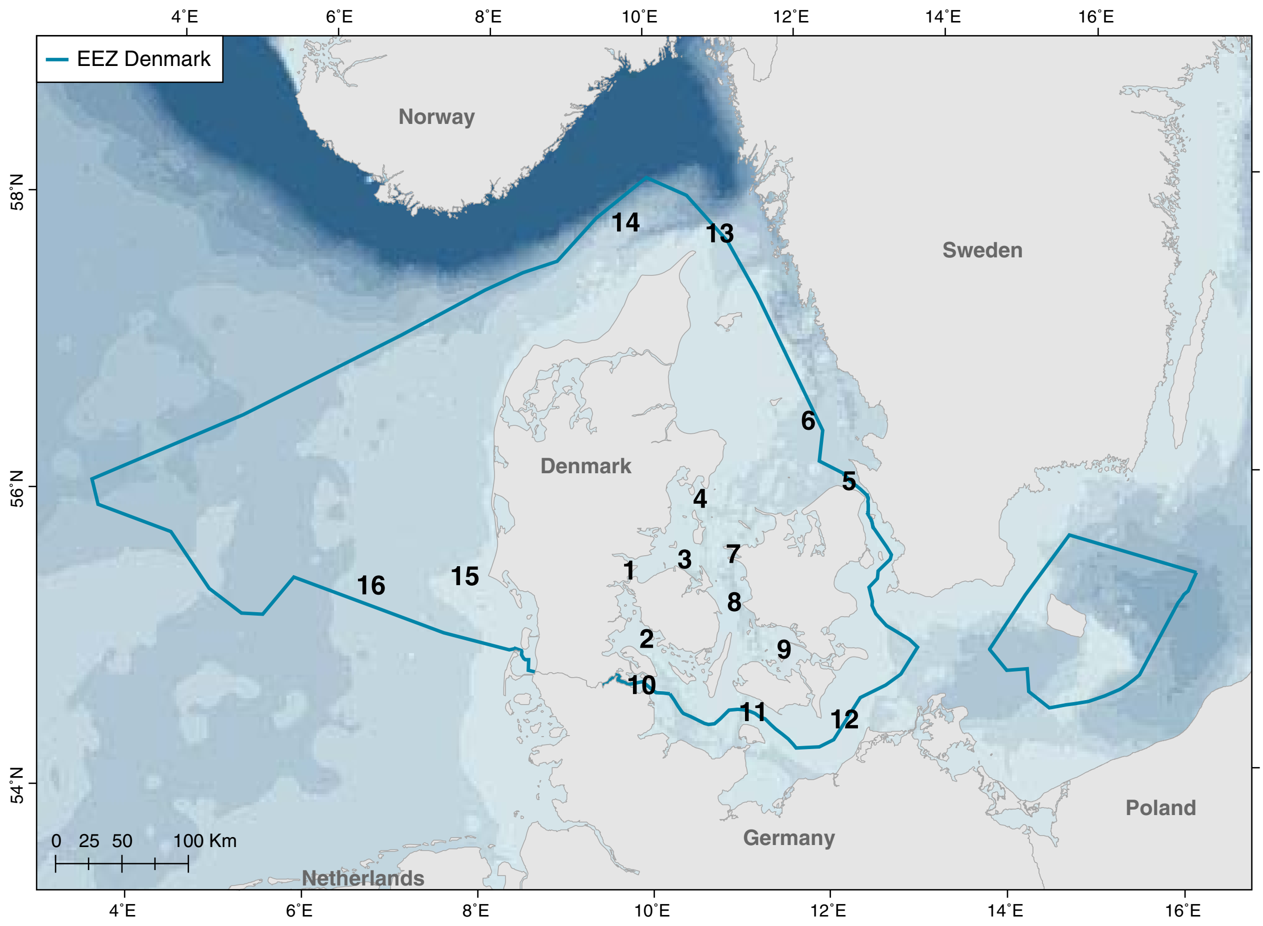


Figure 16. Map of Denmark and the Danish EEZ with numbers (in random order) indicating the high density areas for porpoises. Numbers refer to the numbers in Table 3 and the text.

Table 3. Summarized information on and prioritized ranking of all potential important areas for harbour porpoises (HP). Ranking are based on expert opinion of available data and defined as: 1 = high importance, 2 = medium importance, 3 = lower importance. % of tagged HP visiting the area (total IDW: 37 HP, total Skagerrak: 26 HP). Mat.Fem.= Mature females. Dash indicate no data. Management areas: IDW = Inner Danish Waters, NNS = Northern North Sea, SNS = Southern North Sea. High density ≥ 30% Kernel volume contour in the area. *only 1 HP stayed for a longer period of time.

No.	**Area**	**Satellite tracking**					**Acoustic Survey** High density		**Visual Survey**	**SCANS-II**	**Other**	**Management area**	**Ranking**
		% of tagged HP visiting the area	High summer density	High winter density	Foraging	Corridor	Summer	Winter	(German or DMU) High density	Visual and/or Acoustic	(See area description and Fig.)		1=high 2=medium 3=lower
1	Northern Little Belt	35%	Yes	No	Yes	Yes	No	No	-	-	-	IDW	2
2	Southern Little Belt	35%	No	Yes	Yes	Yes	Yes (Aug. app.3)	-	Yes (Fig. 8)	Yes	Mat.fem. (Fig. 3)	IDW	1
3	Southern Samsø Belt	-	No	Yes	-	-	No	No	-	Yes	-	IDW	2
4	Northern Samsø Belt	11%	Yes	No	Yes*	-	No	Yes	-	Yes	-	IDW	3
5	Northern Øresund	27%	Yes	No	Yes	No	Yes	No	-	Yes	Mat.fem. (Fig. 3)	IDW	1
6	Store Middelgrund	8%	Yes	No	Yes*	Yes	No	Yes	-	Yes	Mat.fem. (Fig. 3)	IDW	2
7	Kalundborg Fjord	28%	No	Yes	Yes	No	No	Yes	-	-	Mat.fem. (Fig. 3)	IDW	1
8	Great Belt	51%	Yes	Yes	Yes	Yes	Yes	Yes	-	Yes	Mat.fem. (Fig. 3)	IDW	1
9	Smålands-farvandet	-	No	No	-	-	-	-	-	Yes	-	IDW	3
10	Flensborg Fjord	30%	Yes	No	Yes	No	Yes (Aug. app.3)	-	Yes (Fig. 8)	-	Mat.fem. (Fig. 3)	IDW	1
11	Fehmarn Belt	35%	Yes	Yes	No	Yes	Yes (Aug. app.3)	-	Yes (Fig.8)	Yes	Mat.fem. (Fig. 3)	IDW	1
12	Kadet Trench	-	No	Yes	-	-	Yes (Aug. app.3)	-	No	-	-	IDW (Baltic Sea)	2
13	Tip of Jylland	93%	Yes	Yes	Yes	No	No	No	-	Yes	-	NNS	1
14	Skagerrak (along Norwegian Trench)	-	No	Yes	-	-	-	-	Yes	No	-	NNS	2
15	Horns Rev	-	-	-	-	-	-	-	Yes	-	-	SNS	1
16	German Bight	-	-	-	-	-	-	-	Yes	Yes	Yes (fig.14)	SNS	1

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Frederiksborgvej 399
PO Box 358
DK-4000 Roskilde
Denmark
Tel: +45 4630 1200
Fax: +45 4630 1114

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DK-8600 Silkeborg
Denmark
Tel: +45 8920 1400
Fax: +45 8920 1414

Monitoring, Advice and Research Secretariat
Department of Marine Ecology
Department of Terrestrial Ecology
Department of Freshwater Ecology

National Environmental Research Institute
Grenåvej 14, Kalø
DK-8410 Rønde
Denmark
Tel: +45 8920 1700
Fax: +45 8920 1514

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Designating protected areas for harbour porpoises implies identifying areas of high porpoise density with particular focus on the distribution in the breeding season. The aim of this report is to collate all relevant data on movements and density of the harbour porpoises in Danish and adjacent waters in order to identify areas with high density or key habitat for harbour porpoises in Denmark that may be used to designate protected areas under the Habitats Directive. Comprehensive data from satellite tracking, aerial and ship surveys as well as acoustic surveys from ship has been collected from 1991 to 2007 in Danish waters. In this study the primary source of data for identifying key habitats is satellite tracking of 63 harbour porpoises in the period 1997-2007, aerial surveys, as well as acoustic recordings with a hydrofon array in 2007. The high density areas are described separately based on the four management units proposed based on previous population structure studies. Each high density area is ranked based on our current knowledge of population structure, density, seasonal variation in distribution and other relevant information. The rankings are defined as 1=high importance, 2=medium importance and 3=lower importance. Sixteen areas were found to have high density and were ranked as follows: **Inner Danish Waters:** Northern Little Belt (2), Southern Little Belt (1), Southern Samsø Belt (2), Northern Samsø Belt (3), Northern Øresund (1), Store Middelgrund (2), Kalundborg Fjord (1), Great Belt (1), Smålands-farvandet (3), Flensborg Fjord (1), Fehmarn Belt (1), Kadet Trench (2). **Northern North Sea:** Tip of Jylland (1), Skagerrak (along Norwegian Trench, 2). **Southern North Sea:** Horns Rev (1), German Bight (1).

National Environmental Research Institute
University of Aarhus · Denmark

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