Chapter 11

Evaluating the distribution and density of harbour porpoises (*Phocoena phocoena*) in selected areas in German waters

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Abstract

The harbour porpoise (*Phocoena phocoena*) is a small cetacean species occurring both in the German North Sea and Baltic Sea. In the process of designating marine protected areas in the framework of the European Habitats Directive (NATURA 2000), the German Federal Agency of Nature Conservation (BfN) identified candidate areas to be eventually proposed as Sites of Community Importance (pSCI). To evaluate the importance of these sites for harbour porpoises, their distribution and density were studied by conducting aerial surveys in the sites from May 2002 to September 2003 (further surveys are ongoing). Densities in the study areas were compared between study years as well as between the selected areas. The relative importance of sites was assessed by taking into account the overall distribution of porpoises in German waters. Surveys followed the standard line-transect methodology for aerial surveys. Only summer flights in the period from May to August were used for further analysis since the coverage by flights in autumn and winter was very low due to unfavourable weather conditions. In the German North Sea, 338 sightings of porpoise groups (440 individuals in total) were recorded in the summer of 2002, and 656 sightings (812 individuals in total) in the summer of 2003. In the Baltic Sea, sighting numbers in the same period were much smaller: 50 sightings (110 individuals) in 2002 and 34 sightings (43 individuals) in 2003. The main results showed clear aggregations and high densities of porpoises in the areas off the North Friesian islands of Sylt and Amrum, where there are high concentrations of the species in the summer months, which is their reproduction period. There seems to

be a sharp gradient of density running from north to south. The highest density in both years was found in the study area *Sylt Outer Reef* (*Sylter Außenriff*), followed by the *Doggerbank*. Lowest densities were calculated for *Borkum Reef Ground* (*Borkum-Riffgrund*). The mean density did not differ significantly between study years in the same area. Harbour porpoise distribution in the Baltic Sea showed higher densities in the western part, namely in the *Kiel Bight* (*Kieler Bucht*) and *Flensburg Fjord* (*Flensburger Förde*), and in the eastern part close to the border of Poland. But all sightings east of the island of Rügen (study area *Pommeranian Bay* (*Pommersche Bucht*)) were only made in 2002. Thus, there is an enormous variation in the presence of habour porpoise in this area between the years. Currently surveys continue to determine how this area is used by harbour porpoises. Besides this, a clear west–east gradient in harbour porpoise density could be ascertained. The other two Baltic Sea study areas *Fehmarn Belt* (*Fehmarnbelt*) and *Kadet Trench* (*Kadetrinne*) are also used by porpoises, especially the area around the island of Fehmarn, but due to the small sizes of the areas additional investigation methods are applied, such as stationary acoustics (see chapter 12).

1 Introduction

The harbour or common porpoise (*Phocoena phocoena*) is the smallest cetacean species inhabiting temperate and cold waters throughout the northern hemisphere. Due to its occurrence, mainly in coastal or shelf waters, the porpoise is threatened by a variety of anthropogenic impacts including by-catch in fishery (Vinther 1999, ASCOBANS 2000) and habitat degradation due to, for example, chemical pollution (Jepson et al. 1999, Siebert et al. 1999). The harbour porpoise is the only cetacean species found on a regular basis in both the German North Sea and Baltic Sea (Reijnders 1992, Benke and Siebert 1994, Schulze 1996, Benke et al. 1998, Hammond et al. 2002). In EU waters, this species is listed in Appendix II of the Bern Convention (implemented in 1982), in Appendix II of the Convention on the Conservation of Migratory Species (CMS; implemented in 1983), in Annex II and IV of the EU Habitats and Species Directive (implemented in 1992), in Annex V of the Convention for the Protection of the Marine Environment of the Northeast Atlantic (Oslo and Paris Convention OSPAR, implemented in 1998), as well as in the German red list of Endangered Species (Boye et al. 1998). The Agreement on the Conservation of Small Cetaceans of the Baltic and

North Seas (ASCOBANS) was concluded in 1991 under the auspices of the CMS (or Bonn Convention) and entered into force in 1994.

Until recently very little data existed on the distribution of harbour porpoises in German waters. Most information on the distribution and population numbers were based on results of the SCANS survey (**S**mall **C**etacean **A**bundance in the **N**orth **S**ea and Adjacent Waters) conducted in July 1994 (Hammond et al. 1995, Hammond et al. 2002). Unfortunately, the coverage during SCANS did not include some areas of the German Exclusive Economic Zone (EEZ), such as the region east of the island of Rügen close to the Polish border in the Baltic Sea, and some parts off the Eastern Friesian Islands, between the estuary of the river Elbe and the Dutch border in the North Sea. In July 2005 SCANS II will take place (http://biology.st-andrews.ac.uk/scans2).

In the process of designating Marine Protected Areas (MPAs) in the framework of the European Habitats Directive (NATURA 2000), the German Federal Agency of Nature Conservation (BfN) selected study areas of particular ecological importance in 2002. This is explained in the introduction and chapter 4 of this book. To evaluate the importance of these sites for harbour porpoises, their distribution and density were studied by conducting aerial surveys in the sites from May 2002 to September 2003. Densities in the study areas were compared between study years and selected areas. The importance of the sites was discussed by taking into account the overall distribution of porpoises in German waters. Answers to the following questions were sought:

- Are harbour porpoises evenly distributed within the study area or is it possible to identify areas of lower or higher density?
- How are the study areas used by porpoises?

2 Methods

2.1 Study Area

Two approaches in survey design were used to answer the above-mentioned questions:
(1) The study area included the EEZ of Germany as well as the 12-nautical mile zone along the coastline of the German North Sea and Baltic Sea (figure 1a). It was divided into 7 substrata (A to G): four located in the North Sea (A–D) and three in the Baltic Sea (E–G). According to their size (A = 3,903 km^2, B = 11,650 km^2, C = 13,668 km^2, D = 11,834 km^2,

E = 4,696 km^2, F = 7,248 km^2 and G = 10,990 km^2), each region could be surveyed within one day (4–8 hours). In the Baltic Sea, the substrata E and F were extended into Danish waters for logistical reasons so that the northern boundary of the area was determined by the inner Danish islands. These surveys were conducted in the framework of the project MINOS (Marine warm-blooded animals in the North and Baltic Seas: Foundations for assessment of offshore wind farms), funded within the German government's research focus on renewable energies (Investment-in-future program, ZIP, see chapter 14).

(2) The six study areas were surveyed in more detail, that is, more frequently. In the German part of the North Sea these areas were: area 1 = 1,527 km^2, area 2 = 1,336 km^2 and area 3 = 5,085 km^2. In the German Baltic Sea area 4 = 435 km^2, area 5 = 1,001 km^2 and area 6 = 3,137 km^2 were surveyed (figure 1b). These surveys were funded by the BfN.

2.2 Survey Design and Data Acquisition

The surveys followed standard line-transect methodology for aerial surveys (Hiby and Hammond 1989, Buckland et al. 2001). Flights were conducted along a predetermined parallel track design, randomly superimposed on the study area. The direction of transect lines was either north-south or east-west to follow depth gradients (figures 1a and 1b). The aircraft used was a high-winged twin engine Partenavia 68, equipped with bubble windows, flying at an altitude of 183 metres (600 feet) and with a speed of 167 to 186 km/hr (90 to 100 knots). Bubble windows allowed for an unobstructed view on the track. Every four seconds, the aircraft's position was recorded automatically onto a laptop computer connected to a GPS. All sighting positions were stored as well. Sea state (according to the Beaufort scale), glare, cloud cover (parts of eight), turbidity (judged visually: from 0 – clear water with several metres of visibility – to 2 – very turbid water with no visibility under the surface) and sighting probability (judged subjectively as 'good', 'moderate' or 'poor' by observers as the probability of sighting a porpoise given all environmental conditions) were entered at the beginning of each transect and whenever any environmental condition changed. The sighting data was acquired by two observers at the same time, each positioned by a bubble window on both sides of the aircraft. Sighting data included species, declination angle (measured with an inclinometer when the porpoise group was abeam the aircraft), group size, presence of calves, behaviour, swimming direction, cue, reaction to the survey plane, location of porpoise (at surface or under water). A third person,

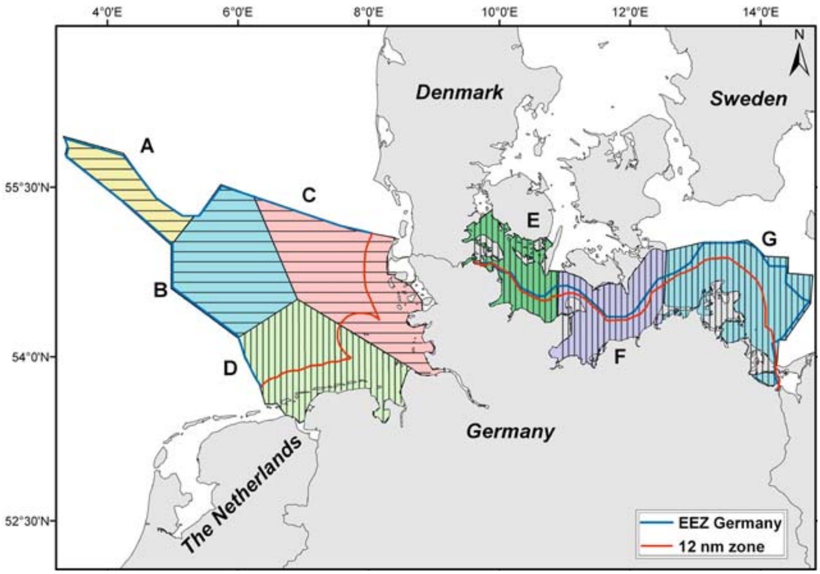

Figure 1a. Study areas of the project MINOS. Transect lines for aerial surveys are indicated by the solid lines. Transect lines are equispaced: 10 km in the North Sea (except area D with 6 km space) and 6 km in all Baltic Sea study areas

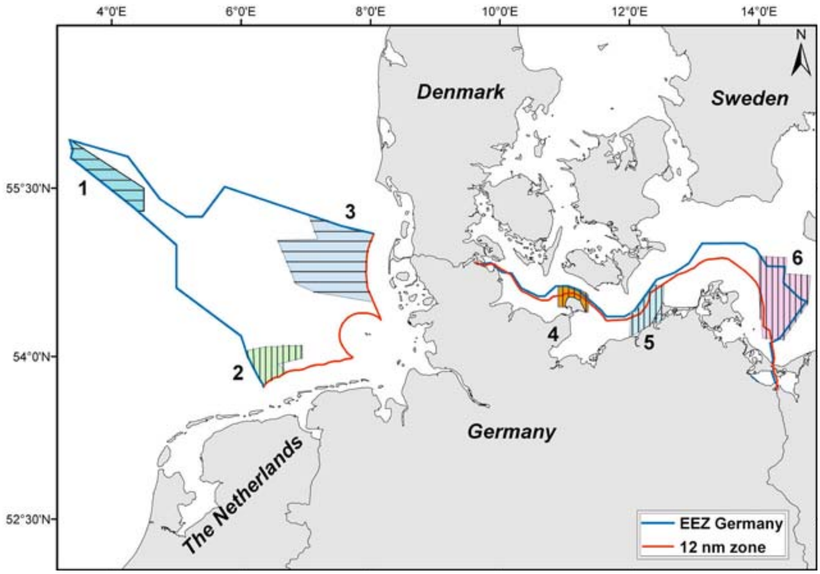

Figure 1b. Intensified study areas in the German EEZ (potential MPAs). Transect lines for aerial surveys are indicated by the solid lines. Transect lines are equispaced: 10 km in the North Sea (except area 2 with 6 km space) and 6 km in all Baltic Sea study areas. 1–*Doggerbank*, 2–*Borkum Reef Ground*, 3–*Sylt Outer Reef*, 4–*Fehmarn Belt*, 5–*Kadet Trench* and 6–*Pommeranian Bay*

the navigator, entered the reported data simultaneously into the laptop equipped with the VOR software (designed by Lex Hiby and Phil Lovell, and described in Hammond et al. 1995). The program continuously recorded the position of the aircraft. The VOR software records the time and position when sighting or effort events occur and it also allows direct entry of data to be associated with the sighting events.

2.3 Data Analysis

Using line-transect and distance sampling methodology as well as the Hiby and Lovell racetrack method, an effective strip width (esw)[1] including g(0)[2] under the different subjective sighting conditions 'good' and 'moderate' was calculated. Details about the method are provided by Hiby and Lovell (1998). Tracks flown in 'poor' sighting condition were excluded from analysis. The racetrack method provides data for the calculation of g(0). Briefly: 30 seconds after a porpoise sighting, the pilot leaves the transect (observers also stop scanning for porpoises), conducts a circle for about 180 seconds and returns to a point in the transect about 30 seconds before the original sighting was made. After being rejoined again with the transect, observers continue searching. Thus, this part of the transect line is surveyed twice (see diagram). The synchronous recording of GPS data, abeam times and declination angles allow the positions of pods sighted on the first and second over-flights to be calculated relative to the aircraft locations at those times. Given a decision as to which of the pods seen on the first and second over-flights were duplicates, the likelihood of those positions can be maximised with respect to g(0), the parameters of the g(y) function and a number of other 'nuisance' parameters: the mean density of porpoise pods in those regions of the survey area inhabited by porpoises, the proportion of the area covered by those regions, and the parameters of the function describing the shift in location of pods between the first and second over-flights.

All survey data was summarised for every 4-second interval, coinciding with roughly 200 metres of flown distance. For each interval the number of porpoises, the exact distance flown, and the effective strip-width (based on the specific g(0) of the survey team) was determined. The distance was

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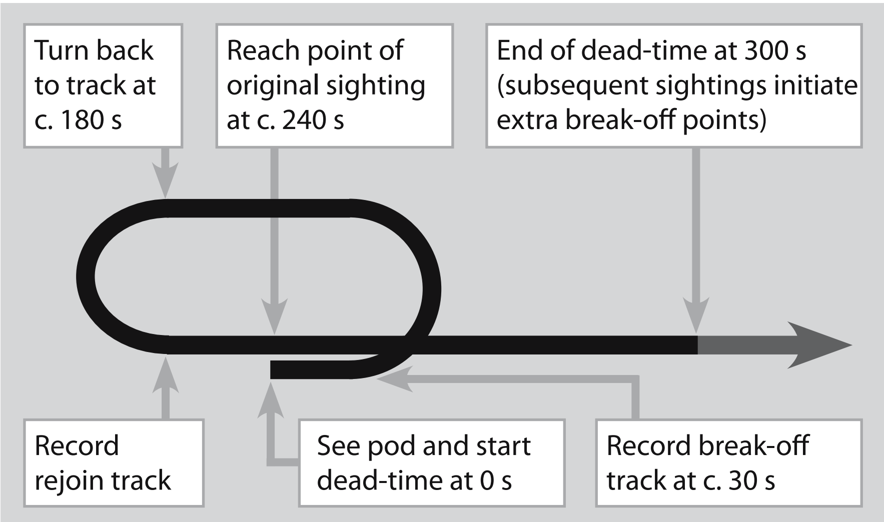
1 esw = the half-strip width of the area searched effectively on each side of the line transect (Buckland et al. 2001).

2 g(0) = probability of detection on the transect line, usually assumed to be 1. In the case of marine mammals that spend substantial periods underwater and thus avoid detection, this parameter must be estimated from other type of information (Buckland et al. 2001).

multiplied with the total strip-width to obtain the area (in km^2) surveyed effectively (i.e., km^2 on effort). Finally the absolute densities (animals/km^2) of harbour porpoises were calculated.

For the purpose of this paper, only summer flights in the period May to August were used for further analysis since the coverage in autumn and winter was very low due to unfavourable weather conditions. Thus, the presented results show the mean summer density of porpoises rather than a snapshot of abundance. Both data sets obtained from May to August 2002 and from May to August 2003 were pooled. For further analysis, the survey area was divided into geographic grid cells of 10 x 10 km (5.4 x 5.4 nautical miles). For each cell the total number of porpoises was divided by the total sum of km^2 covered on effort. This resulted in density of porpoises per grid cell. Data were analysed and visualised using a Geographical Information System (GIS) software (ArcGIS 8.2).



In order to estimate whether densities of harbour porpoises in the same respective areas differed between years and also whether densities differed between areas (in the same respective year), we first determined 95% confidence limits of densities separately for each area and year, based on the track lines covered. These confidence limits estimate an interval that is likely to include the 'true' density. We then checked whether a density of a given area and year fell within the confidence limits of the area and year to which it should be compared. If the density fell outside this range, we concluded that the densities determined for the two areas differed significantly ($p \leq 0.05$) from one another. In order to determine confidence limits, we used a bootstrapping method[3] and determined accelerated bias-corrected 95% confidence limits according to the method described in Manly (1997).

3 Results

3.1 General results

The effective half-strip width calculated, based on the distance of the sightings to the tracklines, was 0.128 km with a g(0) of 0.568 in good conditions. The effective half-strip width was reduced to 0.036 km with a g(0) of 0.164 in moderate conditions. Tracks flown in 'poor' sighting condition were excluded from analysis. Due to the still comparatively low number of racetracks, the 95% confidence limits on g(0) estimated under 'good' conditions remained wide and spanned over almost the entire range from 0 to 1. Additional racetrack flights will be conducted in the near future. The increased number of racetracks is likely to reduce the 95% confidence limit and thus provide a better estimate of g(0).

North Sea

Between 20 May and 3 August 2002, 338 sightings of harbour porpoise pods were made. A total of 440 animals were recorded, 9 (2.0%) of them were calves. Between 27 May and 10 August 2003, 656 harbour porpoise pods were sighted. A total of 812 animals were counted, 51 (6.3%) of them were calves. Detailed information per flight date is provided in tables 1a and 1b.

[3] In principle, this technique is based on repeated random selection of density values determined for single transect lines. The sampling is done with replacement. Once the number of transects sampled equals the number of transects in the study area, the density is determined for the study area as a whole. Confidence limits are then determined by repeating the sampling procedure many times and cutting off the most extreme 5% of the derived distribution of densities. The particular method applied (accelerated bias-corrected confidence limits) corrects for potentially asymmetric distributions. We used 1,000 bootstraps to derive the confidence limit.

Table 1a. Aerial surveys conducted in the German North Sea in 2002

2002	Area	Number of sightings	Number of porpoises	Number of calves	km	km^2
20 May	2	6	7	0	54.2	1.9
27, 28 May	3	200	261	3	544.7	83.1
28 May	1	2	4	0	154.4	4.1
4 June	C	13	13	0	420.9	45.6
10 June	C	6	9	0	156.4	1.0
17, 18 June	D	25	42	3	1,203.4	173.3
15 July	C	4	5	0	396.1	21.3
20 July	B	26	31	0	331.6	49.8
20 July	C	12	14	0	117.7	23.9
29 July	C	43	53	3	493.7	53.9
3 August	B	1	1	0	273.2	5.8
Sum		338	440	9	4,146.3	463.7

Table 1b. Aerial surveys conducted in the German North Sea in 2003

2003	Area	Number of sightings	Number of porpoises	Number of calves	km	km^2
27 May	3	221	238	4	493.3	103.6
28 May	2	14	14	0	249.7	53.6
30 May	1	38	49	1	167.6	43.0
27 June	C	291	376	29	696.4	141.5
13 July	B	14	18	1	242.1	39.2
31 July	D	2	4	2	249.8	25.5
4 August	A	29	36	2	326.8	62.1
4 August	B	16	25	7	71.8	18.4
7 August	3	31	52	5	430.2	53.0
10 August	2	0	0	0	110.3	7.9
Sum		656	812	51	303.8	547.8

Baltic Sea

Between 18 May and 15 August 2002, 50 sightings of harbour porpoise pods were obtained. A total of 110 animals were counted, one of them (0.9%) was a calf. Between 10 May and 1 August 2003, 34 harbour porpoise pods were sighted. A total of 43 animals were counted, two of them (4.7%) were calves. Detailed information per flight date is provided in tables 2a and 2b.

Table 2a. Aerial surveys conducted in the German Baltic Sea in 2002

2002	Area	Number of sightings	Number of porpoises	Number of calves	km	km²
18 May	5	0	0	0	165.6	9.1
18 May	6	5	8	0	263.8	47.0
19 May	4	6	9	0	63.7	7.9
12 July	G	32	84	1	834.3	124.8
15 August	F	7	9	0	732.3	105.5
Sum		50	110	1	2,059.7	294.3

Table 2b. Aerial surveys conducted in the German Baltic Sea in 2003

2003	Area	Number of sightings	Number of porpoises	Number of calves	km	km²
10 May	4	0	0	0	75.2	13.5
14 May	6	0	0	0	158.2	8.1
7 June	G	0	0	0	654.5	133.1
17 June	F	0	0	0	363.9	49.2
17 June	G	0	0	0	107.8	3.6
18 June	F	1	1	0	394.7	46.3
28 June	E	25	30	2	534.7	110.9
1 August	F	8	12	0	438.9	83.2
Sum		34	43	2	2,727.9	447.9

3.2 Distribution of harbour porpoises in German waters

Due to the fact that sighting conditions varied between survey days and areas and sometimes even changed within one day making it often impossible to cover an area in a day, the conducted effort differed between areas (see tables 1 and 2; figures 2a and 3a).

Figure 2b shows harbour porpoise distribution in the **North Sea** study area for the pooled summer flights in 2002 and 2003, respectively. Porpoise density varied over the study area. The north of the survey area showed the highest densities of porpoises. During the flights in May, aggregations of porpoises were seen, indicated by locally high sighting rates of about 40 sightings per 10 km flown distance. Especially the areas off the North Friesian islands of Sylt and Amrum revealed a great abundance of harbour porpoises in the summer months. There seems to be a sharp gradient of density from the northern part to the southern part along the coast. But sighting conditions in the southern

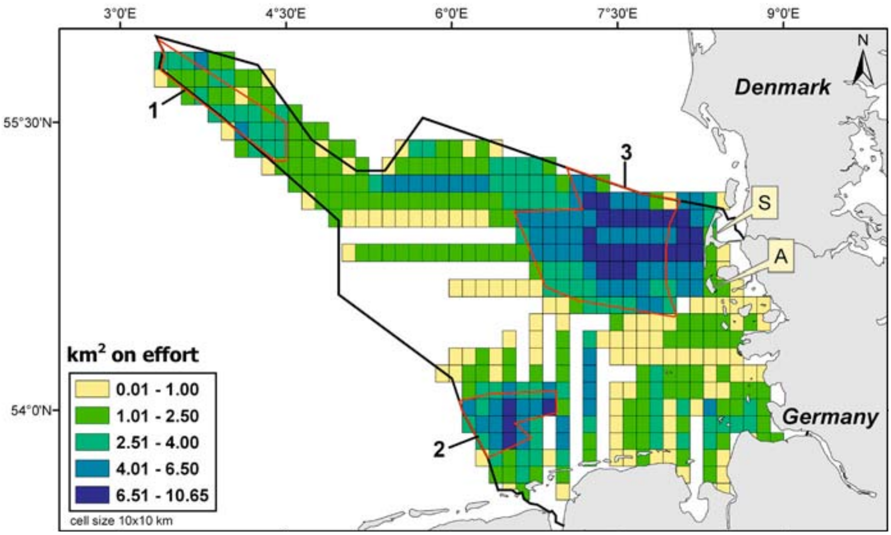


Figure 2a. Km² on effort (i.e., km² surveyed effectively) during the aerial surveys from May to August 2002 and May to August 2003. S=island of Sylt, A=island of Amrum. Map projection: Mercator

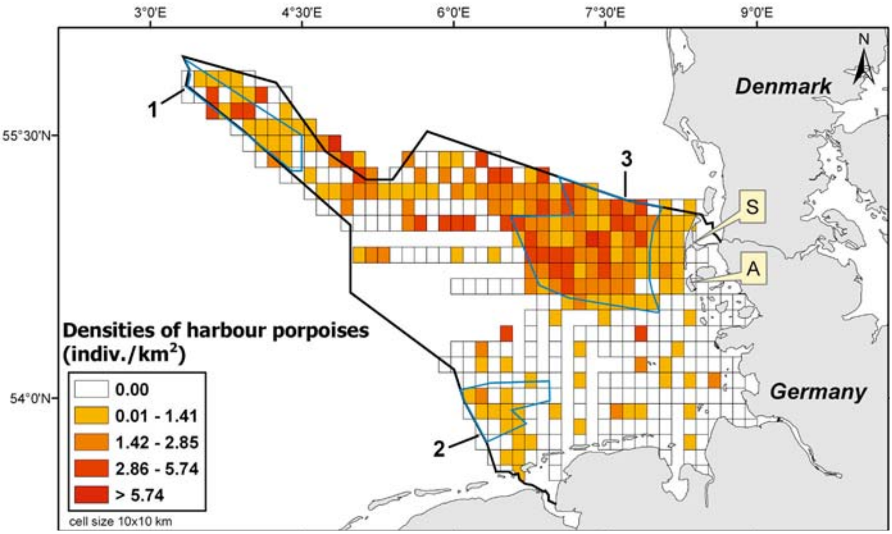


Figure 2b. Summer distribution of harbour porpoises in the German EEZ (black solid line) of the North Sea. All flights conducted in good or moderate conditions between May to August 2002 and May to August 2003 were pooled. S=island of Sylt, A=island of Amrum. Map projection: Mercator

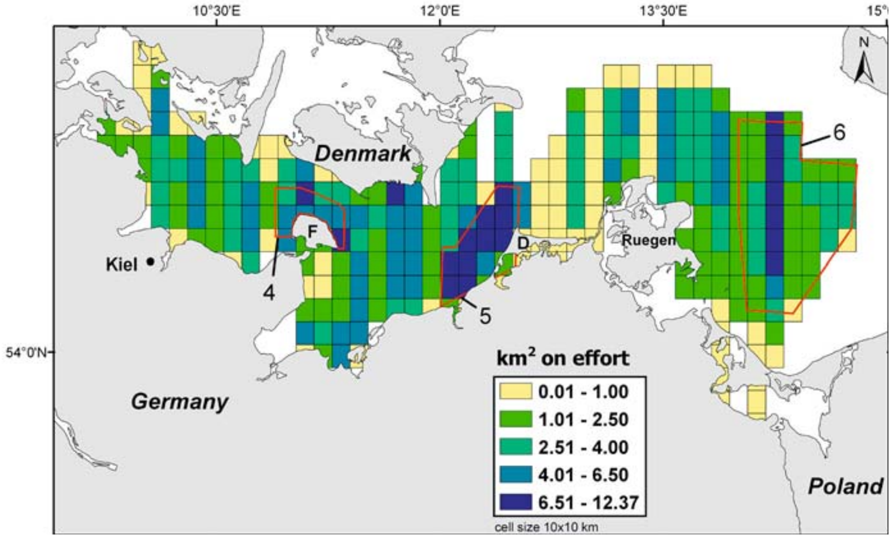


Figure 3a. Km^2 on effort (i.e., km^2 surveyed effectively) during the aerial surveys from May to August 2002 and May to August 2003. F=island of Fehmarn; D=Darss. Map projection: Mercator

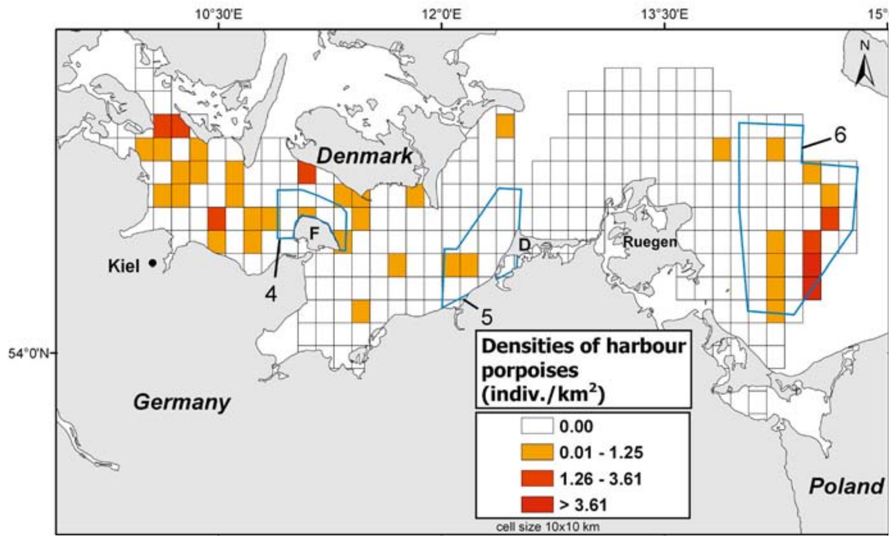


Figure 3b. Summer distribution of harbour porpoises in the Baltic Sea study area. All flights conducted in good or moderate conditions from May to August 2002 and May to August 2003 were pooled. F=island of Fehmarn; D=Darss. Map projection: Mercator

part of substrata B were unfavourable both during 2002 and 2003. Thus, no sightings were obtained in 'good' or 'moderate' conditions.

Harbour porpoise distribution in the **Baltic Sea** is shown in figure 3b. The density of porpoises showed higher values in the western part, namely in the *Kiel Bight* and *Flensburg Fjord*, and in the eastern part close to the border of Poland. But all sightings east of the island of Rügen were only made in 2002. Thus, there is an enormous change in the use of this area between the years. Limited coverage in the western region in 2002 (namely area E) prohibited a direct comparison. Sighting rates were lowest in survey area F. Mean summer density in area E was 0.26 porpoises per km^2 in 2003. This is higher than the density obtained during SCANS in July 1994 in area X (an area very similar in size and location to area E) with a density of 0.10 porpoises per km^2 (Hammond et al. 2002). Further information is provided by Scheidat et al. (2004).

3.3 Density estimates for the study areas

In figure 4a the mean summer (May to August) density of harbour porpoises in the three study areas in the **North Sea** is plotted. The highest density in both years was found in area 3 (*Sylt Outer Reef*) with 2.27 animals per km^2 in 2002, and 2.36 animals per km^2 in 2003. Lowest densities (0.27 in 2002, and 0.41 in 2003) were calculated for area 2 (*Borkum Reef Ground*). Area 1 (*Doggerbank*) showed a summer density of 0.73 in 2002 and of 0.97 in 2003. 95% confidence limits on these estimates are indicated in figure 4a. They show that the mean density did not differ significantly between years in the same respective area. However, density differed significantly between area 3 and areas 1 and 2, respectively; whereas density difference between areas 1 and 2 was not significant.

The results for the three study areas in the German **Baltic Sea** (figure 4b) are more difficult to interpret. Especially the mean summer density for area 6 (*Pommeranian Bay*) differed strongly between 2002 and 2003. In summer 2002 the density was very high, precisely 0.81 (CL: 0.06–2.04) animals per km^2, whereas in 2003 no single porpoise was sighted despite high effort. Mean density in area 4 (*Fehmarn Belt*) turned out to be significantly higher in 2002 (0.43) than in 2003 (0.10). In 2002 no harbour porpoise was sighted in area 5 (*Kadet Trench*), whereas in 2003 a mean density of 0.05 was achieved. As the corresponding 95% confidence level span from 0.0 to 0.14 no significant difference was detected between 2002 and 2003 in area 5. The analysis of inter-area specific variation resulted in a significant difference between areas 4 and 5 as well as between areas 5 and 6. No difference could be statistically detected between areas 4 and 6 as confidence levels are very large.

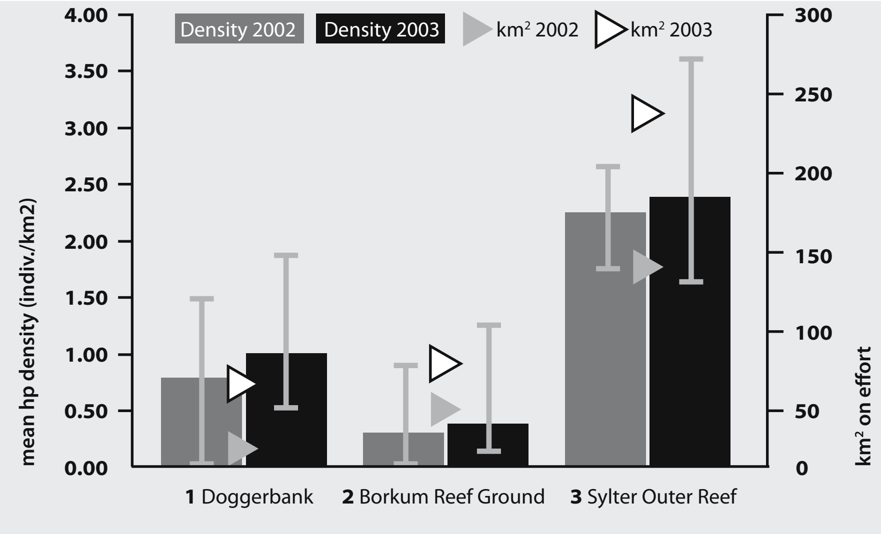


Figure 4a. Mean summer density (left scale) of harbour porpoises in the pSCI study areas of the North Sea (see figure 1b for abbreviations)

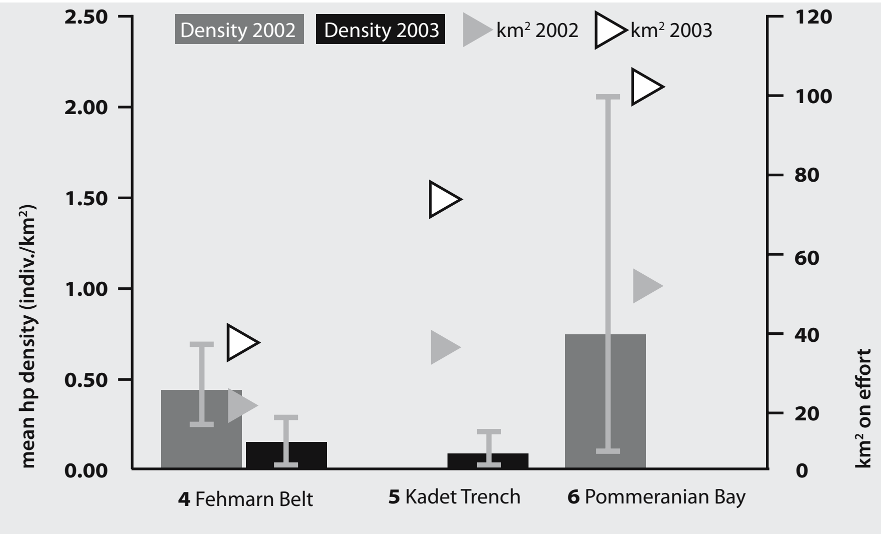


Figure 4b. Mean summer density (left scale) of harbour porpoises in the pSCI study areas of the Baltic Sea (see figure 1b for abbreviations).
Flights conducted in the period May–August 2002 and May–August 2003 were pooled. The upper and lower confidence levels are indicated by the grey line. The tinted and outlined arrowheads show the corresponding effort (right scale, in km²) in 2002 and 2003

4 Discussion

4.1 Distribution patterns and comparison of selected areas

North Sea

The highest number of harbour porpoises was observed in the northern part of the German EEZ. In the remainder of the study area, harbour porpoises were more evenly distributed and no cells with particularly high densities were found. However, coverage under good or moderate conditions was low in the southwestern offshore area, which stresses the importance of conducting further surveys in this area. The high density in the area *Sylt Outer Reef* during the summer survey might be especially related to observed aggregations of animals (i.e., high local sighting rates) in May and June. This seasonal pattern has been observed in both study years around the same time (precisely in 27 and 28 May 2002 and 27 May 2003). The breeding and mating season starts in May (Read 1990, Kinze 1994, Benke et al. 1998). Harbour porpoises might be more gregarious at this time than in other times of the year. The reproductive period is also a life-cycle stage where energy demand is highest (Read 2001). This is especially important for female porpoises as many are simultaneously pregnant and lactating (Read and Hohn 1995, Lockyer et al. 2001). It would therefore be advantageous if lactation occurred when food is abundant and/or of high quality (Börjesson and Read 2003). Pelagic fish, like herring or sprat, have a very high energy content in the summer (Hislop et al. 1991). Swarms of these species might have occurred in the area. Other potential prey species of harbour porpoises are sandeels (*Ammodytes marinus*) which often burrow in the seafloor from October to early April (Wright and Begg 1997, Wright et al. 2000). During late spring and summer they emerge from the seafloor and form dense swarms to feed in the water column (Wright et al. 2000). Distributed in the water column, they are more easily available for predators. Thus, they might be an important food source for porpoises in the North Atlantic (Evans 1990). Analyses of stomach content of porpoises from German waters (1992/1993) showed that 37% of the fish found in the stomachs (by weight) were sandeel. Dab (*Limanda limanda*) and common sole (*Solea vulgaris*) made up 38% and whiting (*Merlangius merlangus*) and cod (*Gadus morhua*) 15% of prey (Benke et al. 1998). If aggregations of harbour porpoise occur due to prey concentrations in certain areas they would most likely occur in late spring and early summer. Similarly, if aggregations occur due to reproductive behaviour these would be expected to be observed in the same time period. A combination of both scenarios is very likely.

Baltic Sea

The population east of the underwater *Darss Sill* (*Darsser Schwelle*) is considered to belong to a different subpopulation than the rest of the Baltic/Belt Sea (e.g., Tiedemann et al. 1996, Börjesson and Berggren 1997, Huggenberger et al. 2002). Joint activities of ASCOBANS and the IWC (International Whaling Commission) have underlined the precarious situation in which this stock seems to be. It seems unlikely that the stock is much larger than 599 animals (CV = 0.57) estimated from a survey in 1995 (Berggren 1995). Therefore, the high densities of porpoises observed in the area *Pommeranian Bay* during the flights in May and June 2002 were quite unexpected. During all other flights sighting rates were extremely low (check areas 6 and G in table 2). Two cruises of the IFAW sailing boat *Song of the Whale*, conducted between Darss ridge and the Bay of Gdansk in Poland in July/August 2001 and 2002 (2,946 km surveyed), have revealed no visual sighting and only three acoustic detections in the area (Gillespie et al. 2002). The most likely explanation for the observed 'hot spots' of porpoises in areas 6 and G in May and July 2002 might be an unusual availability of food. A possible scenario is that porpoises from the Belt Sea, which are part of the subpopulation 'western Baltic' (including Kattegat, Belt Seas, Øresund, *Kiel Bight* and *Fehmarn Belt*), followed their prey into the area of the *Pommeranian Bay*. Again the presence of swarm fish such as herring could also explain the relatively large group sizes. Stomach analyses of stranded harbour porpoises along the German coast of the Baltic showed that 22.8% of the fish found (by weight) was herring, 52.7% goby and 14.8% cod (Benke et al. 1998). Large aggregations of up to several hundred harbour porpoises have been observed in other areas of the world, probably related to good feeding grounds (Rae 1965, Evans 1990). If valuable prey is only available for a short period of time, such as spawning shoals of herring or sprat, these aggregations of harbour porpoises might be difficult to encounter using standard line-transect methodology in such a low density area like the eastern Baltic Sea.

A general west–east gradient in harbour porpoise densities is very likely. The high density in area E and the gradual decline in density while moving to the east (e.g., areas F: 0.06 in 2003 and G: 0 porpoises per km^2 in 2003) underline that theory. A robust analysis of the results for the study areas *Fehmarn Belt* and *Kadet Trench* is difficult as these survey areas were very small in size. Thus, detecting a sufficient number of sightings for robust statistics was impossible. The mean length of the six transects in area 4, for example, was only 14 km. An aircraft flying at 100 knots covers this distance in 4 to 5 minutes.

5 Conclusion

The 2002 and 2003 aerial surveys in German waters revealed new and, in some respects, unexpected information on distribution of porpoises. The results allowed us to answer the main question of this study.

• Are porpoises evenly distributed within the study area or can we identify areas of lower or higher density?

The main results showed large aggregations and high densities of porpoises in the north-eastern part of the German EEZ in the North Sea. Especially the areas off the North Friesian islands of Sylt and Amrum revealed a great abundance of harbour porpoises in the summer months. There seems to be a sharp gradient of density running from north to south. In the eastern part of the Baltic Sea high densities were observed in summer 2002. As subsequent surveys did not yield a single sighting, an explanation for this phenomenon remains speculative. Besides that, a clear west–east gradient in harbour porpoise density was ascertained. Further large scale information on abundance, distribution and stock identities are necessary to put into a broader context the observations from this study.

• How are the pSCI (proposed Sites of Community Importance) used by porpoises?

The sites were used differently by harbour porpoises. Within the North Sea the highest density was found in the area *Sylt Outer Reef*. This was consistent during the two survey years. Our results clearly indicate that this site is very important during the sensitive reproductive period. The offshore area *Doggerbank* was only covered twice by flights due to logistical difficulties associated with flying in offshore areas. The densities estimated for this site were fairly high indicating an important area for porpoises. The lowest densities in the study areas of the North Sea were found in the area *Borkum Reef Ground*. Generally the high confidence limits of the density estimates of both *Doggerbank* and *Borkum* are related to the smaller size of the areas and the lower sighting rate, thus making it difficult to evaluate their importance.

In the Baltic Sea highest densities were found in the area *Pommeranian Bay* in 2002. However, no sightings were made in this area in 2003. Continuing surveys are carried out to determine how regularly this area is used by harbour porpoises and again in early summer 2005 some individuals were sighted. The aerial surveys show that the remaining two study areas *Fehmarn Belt* and *Kadet Trench* are used by porpoises, especially the area around the island of Fehmarn. For a detailed monitoring of how porpoises use those fairly small areas the use of stationary acoustics (see chapter 12) are applied as well.

Acknowledgements

This work was made possible due to two projects which investigate the distribution and abundance of marine mammals in German waters. The German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) is funding within the Investment-in-future program (ZIP), the project MINOS (Marine Warmblüter in Nord- und Ostsee), and the project EMSON (Erfassung von Meeressäugetieren und Seevögeln in der deutschen AWZ der Nord- und Ostsee), the latter being under the management of the Federal Agency for Nature Conservation (BfN). We would like to thank Lex Hiby and Phil Lovell for the calculation of strip-width and g(0). Our special thanks go to the pilots of the survey planes, especially Peter Siemiatkowski from Sylt Air and Leif Petersen from the Danish Air Survey. The completion of the surveys was only possible through the dedication of the observers Jörg Adams, Patrik Börjesson, Helena Herr, Iwona Kuklik, Kristina Lehnert, Maik Marahrens and Carsten Rocholl. Data analyses were only possible due to the help of Hauke Giewat, Ulrike Kleeberg and Roger Mundry.

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