Summer distribution of harbour porpoise (*Phocoena phocoena*) in the German North Sea and Baltic Sea

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ABSTRACT

Current plans to utilise German offshore waters as sites for windmill parks as well as ongoing investigation of potential areas to implement Natura 2000 have led to an increased research effort on local marine mammal populations. The aim of this study was to determine the spatial distribution of harbour porpoises in the German part of the North Sea and Baltic Sea. Aerial surveys were conducted from May to August 2002 using standard line-transect methodology. A total of 21 days of aerial surveying covered 8,072km tracks on effort; 4,908km were conducted in conditions of good visibility. A total of 785 harbour porpoises (488 sightings) were seen; 597 animals (427 sightings) were detected in conditions of good visibility. The study area was divided into a grid of 3 minute latitude by 6 minute longitude squares. Porpoise relative abundance and distribution were estimated as the number of animals per km on effort in each square. The results showed that in the North Sea, the highest number of porpoises per km was observed in the northeastern part of the surveyed area, close to the Danish border and in the area of Amrum Outerbank. In the Baltic Sea, the highest relative abundance of porpoises was seen in the Pomeranian Bight between the island of Rügen and the Polish border. Pod size in the Baltic was larger than in the North Sea. The aerial surveys were continued in 2003 in order to collect more information on temporal and spatial distribution of harbour porpoise and its intra and inter-annual variability in German waters. These data will serve as a baseline for management decisions.

KEYWORDS: HARBOUR PORPOISE; DISTRIBUTION; SURVEY-AERIAL; INDEX OF ABUNDANCE; CONSERVATION; BALTIC SEA; NORTH SEA

INTRODUCTION

The harbour porpoise (*Phocoena phocoena*) is protected by a variety of national and international agreements. This includes Appendix II of the Convention on Migratory Species (CMS; *www.cms.int*), the Habitat Directive of the European Commission (*www.europa.eu.int/comm/environment/nature*) as well as the Red List of Endangered Species (*www.redlist.org*) of Germany, which is currently under revision.

A focus of recent attention has been the endangered status of harbour porpoises and the management of marine mammals in general in the German part of the North Sea and Baltic Sea. This has been fuelled by the necessity to propose areas of offshore German waters, which need to be incorporated into Natura 2000 (*www.europa.eu.int/comm/environment/nature*). Potential sites for windmill parks off the German coast and plans for the establishment of the first park ('Butendiek') have recently been accepted by the German government. The ongoing search for additional sites and future construction campaigns may interfere with marine mammals and risk habitat degradation.

Few data exist on the distribution of harbour porpoises in German waters. Current information for the German North and Baltic Seas is mostly based on results of the SCANS survey of 1994 (Hammond *et al.*, 2002). However, the coverage during SCANS left out some areas of the German EEZ (exclusive economic zone), such as the region east of the island of Rügen close to the Polish border in the Baltic, and some parts of the Eastern Friesian Islands between the estuary of the river Elbe and the Dutch border in the North Sea. However, strandings data submitted to the IWC on an annual basis since 1990 suggest that harbour porpoises regularly occur in these areas, albeit in small numbers (e.g. see *www.iwcoffice.org/commission/sci_com/scprogress.htm*). Heide-Jørgensen *et al.* (1993) and Sonntag *et al.* (1999) surveyed some parts of the German North and Baltic Seas, but the areas were too small to draw conclusions about the general distribution of porpoises. In this paper results of aerial surveys conducted from May to August 2002 in all German waters are presented.

MATERIALS AND METHODS

Study area

The study area included the German EEZ in the North Sea and the Baltic Sea, as well as the 12 n.mile zone in front of the coastline (Fig. 1). The area was extended into Danish waters in the Baltic and the Danish Isles were chosen as a northern boundary of the study area (Fig. 1). The study area in the North Sea was divided into four different regions (A to D). The Baltic was separated into three blocks (E to G). Regions were separated according to differences in bathymetry and maximum endurance of the survey plane. One region (block) was typically surveyed within one day (between 3 to 9 flying hours). Consideration was also given to the putative stock boundary at the Darss and Limhamn Ridges, separating the central Baltic stock from the Kattegat-Belt Sea-Western Baltic stock (Koschinski, 2002).

Survey design and data acquisition

The surveys were conducted from May to August 2002 following standard line-transect methodology for aerial surveys (Hiby and Hammond, 1989; Buckland *et al.*, 1993). A total of 8,190km of tracklines were conducted on effort following a parallel track design for a high-winged twin-engine aircraft (*Partenavia*) flying at an altitude of 182m (600ft) and a speed of 167-186km/hr (90-100kts). The direction of tracks was north-south in areas D-G, and east-west in areas A-C to follow gradients of depth (Fig. 1). Some smaller regions within the blocks A, C and D in the North Sea as well as F and G in the Baltic received a higher

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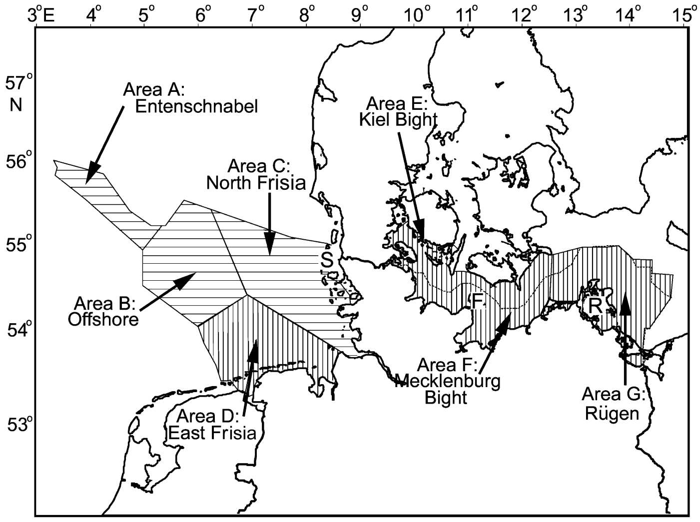

Fig. 1. Study areas and transect lines of the aerial surveys in the Baltic and the North Sea. The dashed line in the Baltic indicates the German EEZ (Exclusive Economic Zone). The main islands are marked as: S-Sylt, F-Fehmarn and R-Rügen.

survey effort. These regions are likely to host windmill parks in the future or are potential or designated Natura 2000 areas.

Data collection was based on the VOR software designed by Lex Hiby and Phil Lovell and described in Hammond *et al.* (1995). Every four seconds, the aircraft position was recorded automatically onto a laptop computer connected to a GPS. Additionally, the position was stored whenever a sighting was made. Sea state (Beaufort scale), glare, observer positions, turbidity (judged visually: 0 = clear water with several meters of visibility to 2 = very turbid water with no visibility under the surface) and cloud cover (parts of eight) were entered at the beginning of each transect and whenever environmental conditions changed. Additionally the observers used all above parameters to subjectively decide on the sightability of a harbour porpoise. The scale for these 'subjective' conditions ranged from G for good, over M for moderate, P for poor and X for conditions too bad to survey. All observers on board discussed the visibility during each flight and agreed on one condition. The observer team (consisting of six observers) did not change over the study period, and therefore the resulting conditions can be considered consistent for this team of observers. Sightings data were acquired by two observers located at each bubble window of the aircraft. These windows enabled the observers to look straight down onto the survey track. Data were entered into the computer by the recorder located in the co-pilot's position. Sightings data included species, group size, presence of calves, behaviour, swimming direction, cue, reaction to the survey plane, position (at surface or under water) and clinometer angle measured from the aircraft to the porpoise group when it passed abeam of the aircraft.

Data analysis

Data collected from sightings were summarised every four seconds, which corresponds to a distance flown of about 200m. For each of these four second intervals the exact distance flown was determined. Using the number of animals seen, the relative density of animals per km survey was calculated for each interval.

Only data obtained in conditions considered 'good' by the observers were used for the distribution analysis. This category did not include sightings obtained in sea state of more than 2 or turbidity of more than 1. Observations collected in the region of the 'Entenschnabel' (furthest out in the North Sea, see Fig. 1) have not been included. Conditions encountered in this region were only moderate during the one flight conducted there.

Geographic cells, measuring 3 minutes latitude by 6 minutes longitude, were defined throughout the study area in order to obtain information on distribution and relative abundance of harbour porpoises. This was computed as sighting rates (animals/km) for each cell. The data were analysed using GIS software (ArcView). Empty cells were those cells where no effort (under good conditions) was conducted. All maps are shown in UTM (Universal Transverse Mercator).

RESULTS

Survey effort

Environmental conditions varied between survey days and sometimes during a single flight. Table 1 shows the survey effort covered under different environmental conditions, sea state and turbidity.

Table 1

Environmental conditions during aerial surveys from May to August 2002.

Conditions	% Effort	Sea state	% Effort	Turbidity	% Effort
Good	23.9	0	9.4	0	19.0
Moderate	36.6	1	38.0	1	67.3
Poor	39.5	2	34.3	2	13.5
		3	17.4	3	0.2
		4	0.9		

Regions A and E received substantially less coverage in terms of survey effort than planned (Table 2). Region A (Entenschnabel) was only covered once during moderate conditions. Region E (Kiel Bight) could not be covered to the extent intended due to military activities in that area during weekdays.

Sighting rates in good conditions were always higher than in the data collected in moderate and poor conditions. This difference was significant when comparing all regions

(Mann-Whitney U-Test, $p<0.05$, two-tailed). An example from region F demonstrates how dependable sighting rates were on weather conditions where a substantially increased effort (1,030km versus 572km) under less favourable sighting conditions only led to an increase in sighting rate from 0.002 to 0.017 (Table 2). When comparing animals per km from regions A through G in good conditions versus moderate and poor conditions the difference was not significant.

Pod size was consistently larger when comparing sightings data obtained under moderate and poor conditions than pod sizes obtained from sightings data made only in good conditions (Table 2). When testing this difference (U-Test, two-tailed) the resulting p value is less than 0.1. Maximum pod size of porpoises in the North Sea and Baltic Sea was 5 and 10 respectively. Mean pod size was 1.30 in the North Sea and 2.16 in the Baltic under good conditions (Table 2). In the North Sea, almost 78% of the sightings were of individual porpoises compared to only 57% in the Baltic (Fig. 2).

Fig. 3 shows all the tracklines flown on effort during the aerial survey in the German North Sea as well as the number of sighted porpoises and their pod sizes. A higher number of tracks was flown in areas C and D (Fig. 3).

Fig. 4 shows all the tracklines flown in the Baltic and the sightings of harbour porpoises. In the Baltic a larger number of tracks was flown around the island of Fehmarn (Area F) and in the Kadet fairway (Area F) as well as in the area Rügen/Pomeranian Bight (Area G). Larger pod sizes of up to 10 animals were only seen in the eastern part of the Baltic. This area includes the Oderbank, a shallow bank (about 8m deep) in the centre of the Pomeranian Bight (Fig. 4).

The study area was separated into 3 minute latitude by 6 minute longitude grids (about 3 n.miles × 3.5 n.miles). For each cell the number of porpoises per km survey effort collected in good visibility was calculated. A dash indicates those cells in which no sightings were made. No dash or circle shows that no survey effort in good conditions was made in that part of the area (Figs 5 and 6). In the North Sea, the highest number of animals per km was seen in Area C. In the Baltic, the highest encounter rate was in Area G, east of the island of Rügen.

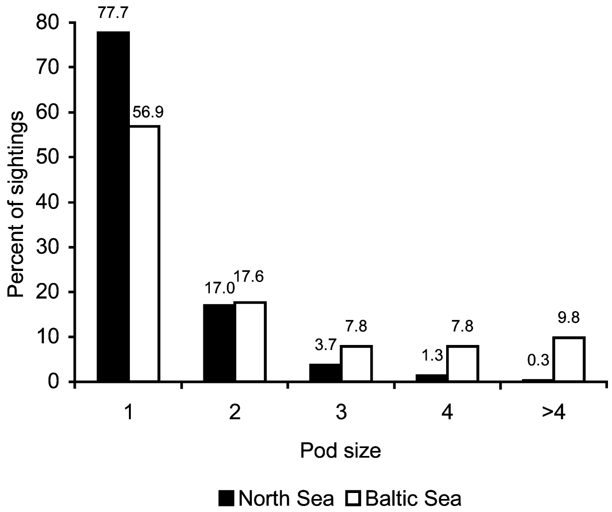

Fig. 2. Distribution of pod sizes of harbour porpoise sightings in the North Sea and Baltic (only sightings in good conditions were considered).

DISCUSSION

Survey methodology

The sightability of cetaceans during surveys is influenced directly by environmental parameters (Buckland *et al.*, 1993). During shipboard surveys, an increase in Beaufort Sea state conditions led to a decrease in sighting rates of harbour porpoises (e.g. Palka, 1996; Teilmann, 2003). Similarly, during aerial surveys for white whales (*Delphinapterus leucas*), deMaster *et al.* (2000) showed that an increase in sea state also led to a reduction in the sighting rate. When surveying from a plane, animals are also sighted in the water column and therefore the sea state as well as the turbidity of the water affects the number of porpoises detected. Gunnlaugsson *et al.* (1988) also found an apparent relationship for sightings rate of harbour porpoises from

Table 2

Survey effort, sighting rates (animals and sightings per km) and group sizes in the North Sea and the Baltic study area (May to August 2002). Data are provided for total survey effort, survey effort in moderate (M) and poor (P) conditions and for survey effort in good (G) conditions only.

	North Sea survey regions					Baltic Sea survey regions				
	A	B	C	D	All North Sea regions	E	F	G	All Baltic regions	Summary total survey
Area size (km²)	3,903	11,650	13,668	11,824	41,045	4,696	7,248	10,990	22,934	63,979
Effort km all conditions	144	647	2,991	1,804	5,586	382	1,030	1,075	2,486	8,073
Sightings per km all conditions	0.014	0.045	0.124	0.018	0.078	0.013	0.011	0.034	0.021	0.061
Mean group size all conditions	2.50	1.28	1.46	2.61	1.54	1.80	1.27	2.49	2.17	1.61
No. of animals per km all conditions	0.035	0.057	0.181	0.048	0.12	0.024	0.014	0.086	0.046	0.097
Effort kilometre in M and P	144	275	1,190	672	2,281	-	458	426	883	3,165
Sightings per km in M and P	0.014	0.004	0.040	0.012	0.026	-	0.002	0.002	0.002	0.019
Mean group size in M and P	2.50	3.00	2.75	5.38	3.10	-	1	4	2.5	3.08
No. of animals per km in M + P	0.035	0.011	0.111	0.064	0.080	-	0.002	0.009	0.006	0.059
Effort km in G	-	372	1,801	1,132	3,305	382	572	649	1,603	4,908
Sightings per km in G	-	0.075	0.179	0.022	0.114	0.013	0.017	0.055	0.032	0.087
Mean group size in G	-	1.21	1.27	1.72	1.30	1.80	1.30	2.44	2.16	1.40
No. of animals per km in G	-	0.091	0.228	0.038	0.147	0.024	0.023	0.136	0.069	0.122

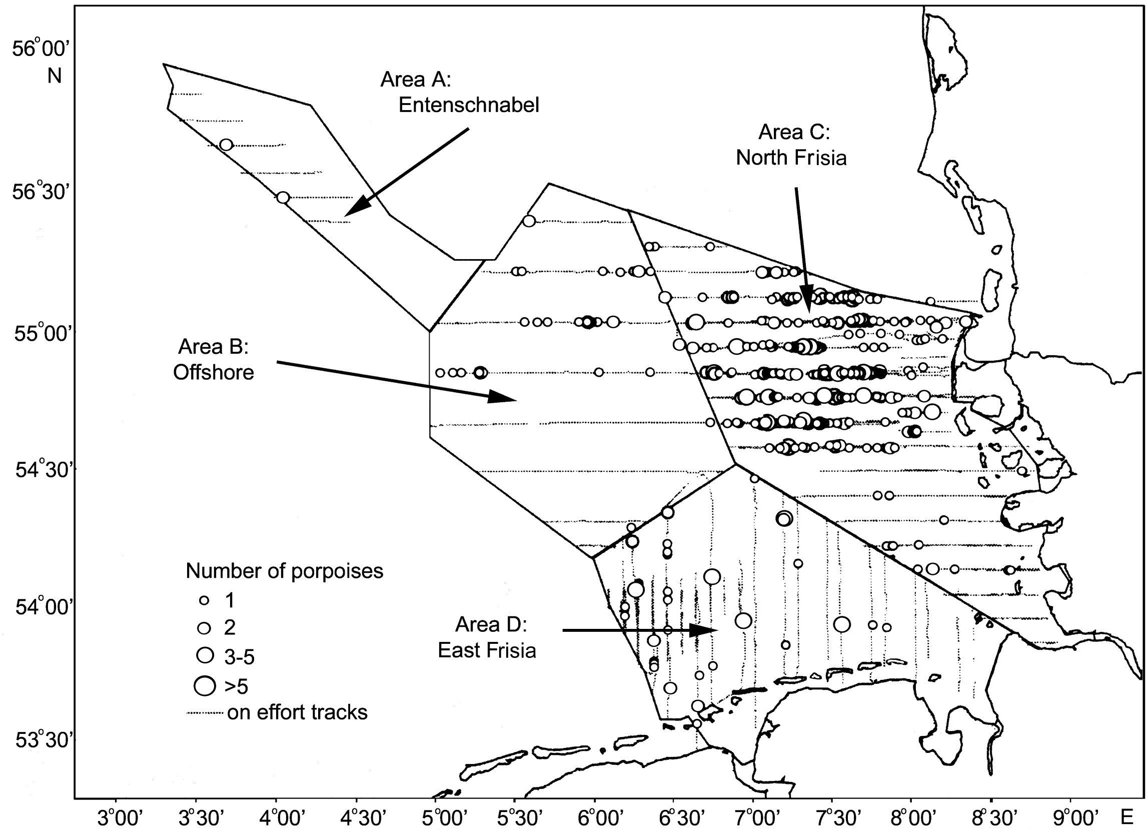

Fig. 3. All tracklines flown on effort from May to August 2002 in the German North Sea and number of porpoises in each sighting.

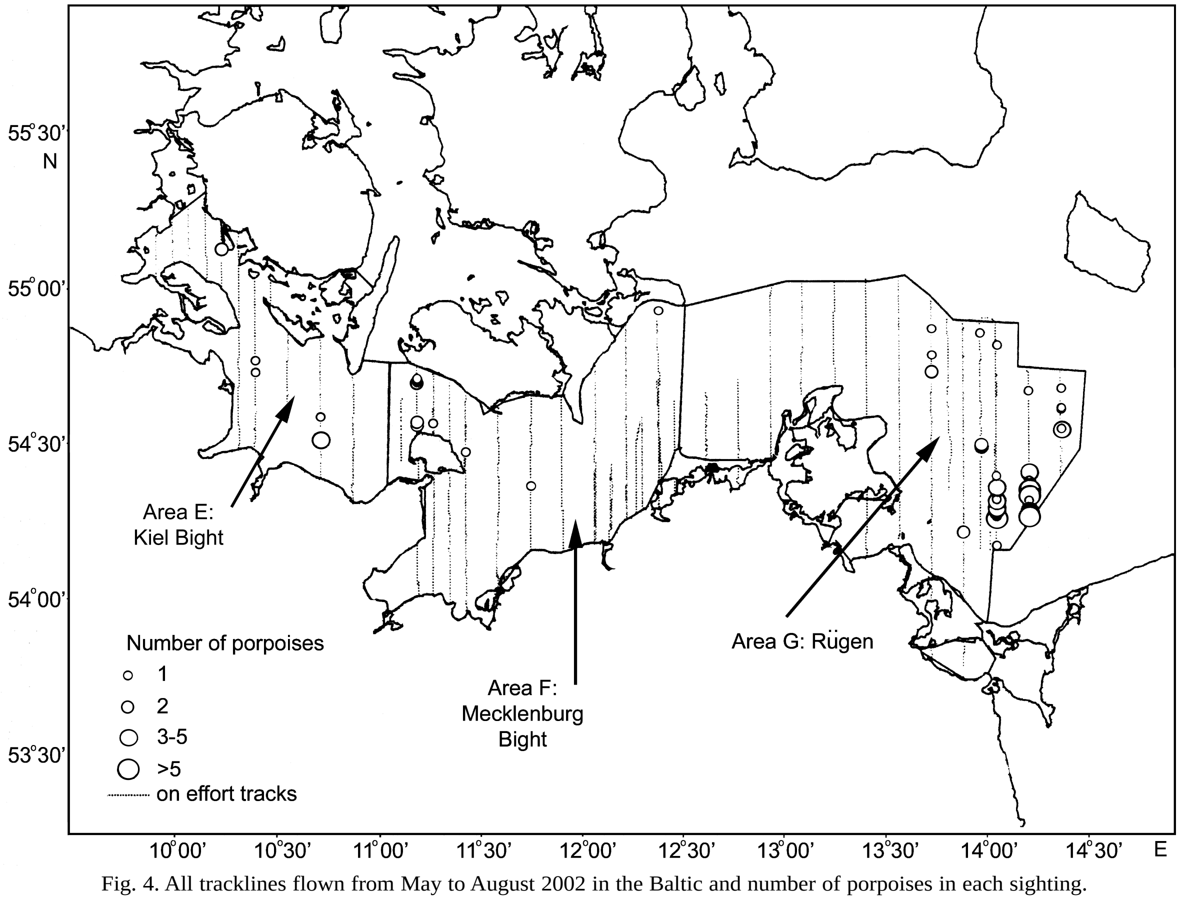

Fig. 4. All tracklines flown from May to August 2002 in the Baltic and number of porpoises in each sighting.

aerial surveys with cloud cover. When using line-transect distance sampling, the effective strip width changes with environmental conditions and therefore densities can be calculated even if conditions change from good to moderate. However, when using sighting rate, the comparison between detection rates observed during different environmental conditions can lead to misinterpretation of the observed patterns of distribution. Data in this paper reiterated that the

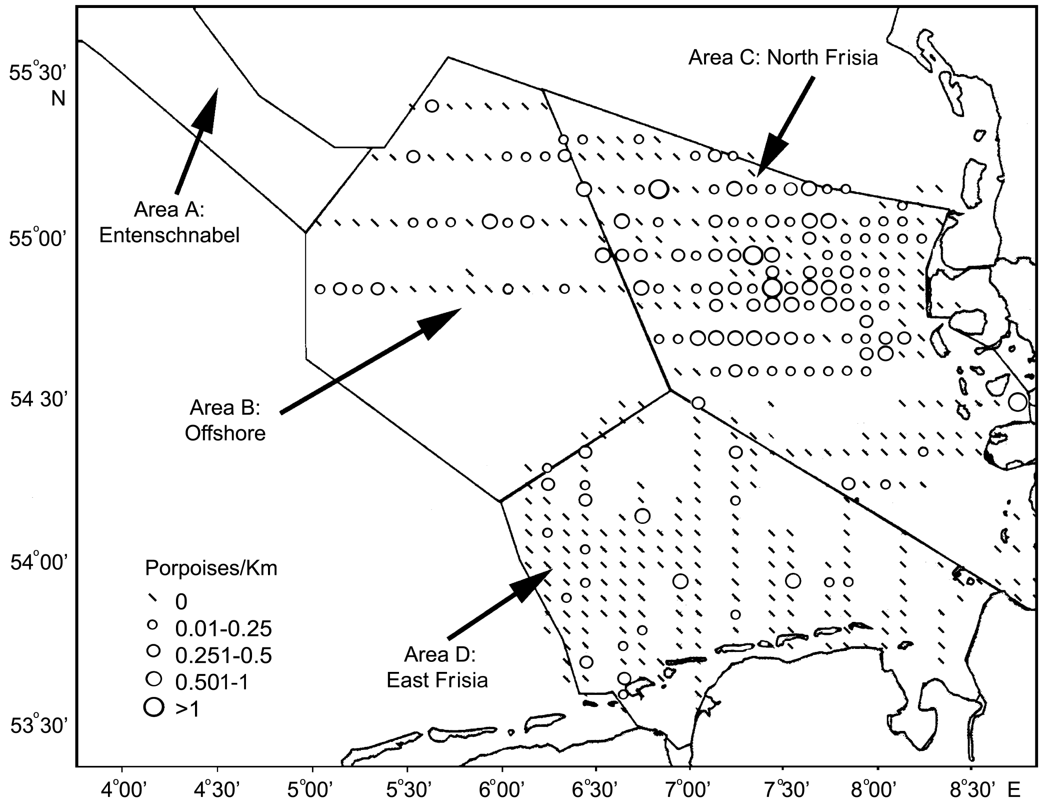

Fig. 5. Distribution of harbour porpoises in the German part of the North Sea (May to August 2002). Each circle or dash represents a cell of 3' latitude by 6' longitude (3 n.miles × 3.5 n.miles). For each cell the number of porpoises per km survey is shown. Only data obtained in good survey conditions are shown.

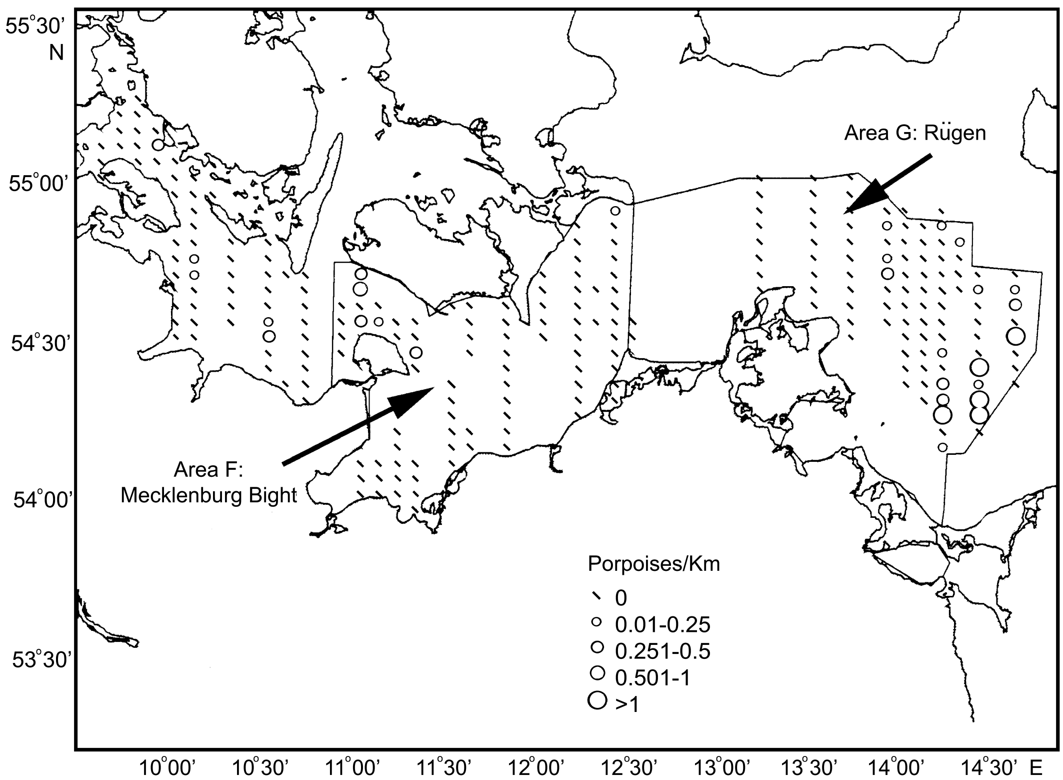

Fig. 6. Distribution of harbour porpoises in the Baltic Sea study area (May to August 2002). Each circle or dash represents a cell of 3' latitude by 6' longitude. For each cell the number of porpoises per km survey are shown. Only data obtained in good survey conditions is shown.

sighting rate, both for animals per km and sightings per km, decreased noticeably when all flights on effort (including those under deteriorating weather conditions) were included in the analysis. Mean pod size also increased when all flights were taken into consideration. This indicates that the probability of seeing single animals or small groups decreases with deteriorating weather conditions compared to larger groups. Due to the difficulty in sighting porpoises when the water is very turbid, certain areas (such as the river estuaries of Elbe and Weser) will probably always have worse sighting conditions than others. When surveys are conducted, e.g. for environmental impact studies, it is crucial that sighting conditions are described in detail. This is especially true if the data are compared to other studies conducted on the same or other temporal and/or spatial scales. In the following discussion only the results from the surveys conducted in good conditions are used.

North Sea

Highest aggregations of harbour porpoises were observed in the northern part of the German EEZ and close to the Danish border (Area C). This area also includes the German cetacean sanctuary off the island of Sylt. In the remainder of the study area harbour porpoises were more evenly distributed and no particular aggregations were found. The sighting rates of 0.18 sightings per km in Area C were substantially higher than those obtained during two preceding surveys in the same region in 1992 (0.06 sightings per km; Heide-Jørgensen *et al.*, 1993) and 1994 (0.05 and 0.04 sightings per km; Hammond *et al.*, 2002) using the same aircraft type and methodology. The higher sighting rate here can in part be due to the fact that the survey covered several months. May is the beginning of the mating and breeding season when harbour porpoises might be more gregarious than at other times of the year (Read and Hohn, 1995). It is also possible that these aggregations were caused by food availability. Swarm fish, such as herring or sprat, might have been present in the area. Other potential prey species were sand eels (*Ammodytes marinus*), which often burrow in the seabed from October to early April and are important to many marine predators (Wright and Begg, 1997). During April and May they emerge from the seabed to feed in the water column (Evans, 1990). At this time they aggregate in the water column and are available to predators. Analyses of stomach contents of porpoises from the German North Sea (1992/1993) showed that 37% of the fish found in the stomachs (by weight) were sand eel. Dab (*Limanda limanda*) and common sole (*Solea vulgaris*) made up 38%, and whiting (*Merlangius merlangus*) and cod (*Gadus morhua*) 15.1% of prey (Benke *et al.*, 1998). If aggregations of harbour porpoises occur due to prey concentrating in certain areas, they would most likely occur in spring. Similarly, if aggregations occur due to reproductive behaviour we would expect to observe this in May and June when calving and mating occur (Read, 1990; Sørensen and Kinze, 1994). However, most previous aerial and ship surveys in this area took place in July and August and therefore might have observed a more even distribution over a large area.

Mean group sizes of 1.27 porpoises in Area C and 1.72 in Area D were comparable to those found during the SCANS survey with a mean pod size of 1.45 in area Y and 1.62 in area L (Hammond *et al.*, 2002). Heide-Jørgensen *et al.* (1993) surveyed only a small part of Area C directly off the island of Sylt in 1992 and found a lower mean group size of 1.03 porpoises. Again, seasonal changes in behaviour during the spring and summer months might be responsible for changing group sizes but little is known about temporal changes of group sizes in the North Sea.

Baltic Sea

In the Baltic Sea, harbour porpoises were only seen in Kiel Bight, around the island of Fehmarn (Fig. 4) and east of Rügen. Sighting rates in the Baltic were lowest in the two western areas: the Kiel and Mecklenburg Bight (E and F), with 0.013 and 0.017 sightings per km survey effort. During the SCANS survey the sighting rate in area X (south of the islands of Fyn and Lolland, covering the Area E from this study) was 0.008 sightings per km (Hammond *et al.*, 2002) and during the survey flights conducted by Heide-Jørgensen *et al.* (1993) 0.004 sightings per km were recorded. For the Kiel and Mecklenburg Bight the mean group size was 1.8 and 1.3 animals respectively. Comparable values of 1.5 were found during the SCANS survey (Hammond *et al.*, 2002). Heide-Jørgensen *et al.* (1993) recorded a lower mean group size of 1.13 porpoises in 1992.

An unexpected observation was made during flights between the island of Rügen and the Polish border (Area G, Fig. 1) in May and July 2002. The highest sighting rates for the Baltic Sea, highest maximum pod size (10 porpoises) and the highest number of porpoises per sampling unit (4 seconds survey) for both the Baltic and North Sea were found in this area (Fig. 6). However, the subsequent flights in August, September and December 2002 in the same area did not locate a single porpoise. This demonstrated a dramatic change in seasonal density of porpoises between the island of Rügen and the Polish border.

The population east of the Darss and Limhamn Ridges is considered a different population from the rest of the Baltic/Belt Sea (Tiedemann *et al.*, 1996; Börjesson and Berggren, 1997; Huggenberger *et al.*, 2002). Both ASCOBANS and the IWC have underlined the precarious situation of this stock (IWC, 2003). With the exception of our observations during flights in May and August, sighting rates are extremely low. Two cruises of the IFAW sailing boat *Song of the Whale* between Darss ridge and the Bay of Gdansk in Poland in July/August 2001 and 2002 have revealed only single sightings or acoustic detections in the area (Gillespie *et al.*, 2003). In 1995 the stock was estimated to be 599 animals (CV=0.57). Recent observations in Puck Bay (inner Bay of Gdansk) found very few animals (Berggren, pers. comm.). Bycatches of harbour porpoises in Puck Bay are on average 2.2 a year (a total of 22 animals from 1990-1999) and occur mostly in the winter months (Kuklik and Skóra, 2003).

The most likely explanation for the observed aggregation of porpoises in the Pomeranian Bight in May and July (2002) seems to be the availability of food. 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). If prey is only available for a short period of time, as are for example spawning shoals of herring or sprat, these aggregations might be difficult to encounter using widely spaced transects. In addition, the aggregations were on the Oderbank, an area east of the island of Rügen on the border between Poland and Germany. It is characterised by shallow waters of around 8m depth. Most ship surveys avoid such shallow areas. The Swedish aerial surveys from 2002 included the area east of Rügen but were conducted in July and August, therefore possibly missing an event that only lasted a few months. Another scenario is that porpoises from the Belt Sea followed their prey into the area of the Pomeranian Bight. The presence of swarm fish such as herring could also explain the relatively large group sizes. In contrast to the German North Sea, herring are available in the Baltic year-round. Stomach analyses of harbour porpoises from the German coast of the Baltic showed that 22.8% of the fish found (by weight) was herring, 52.7% goby (*Pomatoschistus* spec.) and 14.8% cod (Benke *et al.*, 1998). However, these results should be viewed with some caution because they were integrated over whole years and areas and may therefore mask seasonal and geographical variation in the diet.

The aerial surveys in German waters over the course of the 2002 summer yielded new information on distribution of porpoises that was in some ways unexpected. The main results were large aggregations and high densities of porpoises found in Area C in the North Sea and in Area G in the Baltic Sea. Information on abundance, distribution and stock identity at a greater scale are necessary to put the observations from this study into a broader management context.

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