Survey for the abundance of harbour porpoises (*Phocoena phocoena*) in the Western Baltic, Belt Sea and Kattegat ('Gap-Area')

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ABSTRACT

In July 2012 a ship board double-platform line-transect survey was conducted in the Kattegat, the Belt Seas and the Western Baltic to assess harbour porpoise (*Phocoena phocoena*) abundance in the so called 'GAP area' between the North Sea and the Baltic Proper. A total of 826 km of track lines were surveyed between the 2nd and 21st of July 2012 and 169 observations were made by the primary observers, comprising a total of 230 porpoises. 57 observations were identified as duplicates by the tracker observers and were used to correct for availability and perception bias of the primary detections. Using Mark-Recapture Distance Sampling analysis, we produced a model using the half normal key function and including sightability as the only covariate to estimate the density and abundance of harbour porpoise within the 51,511 km² survey area. G(0) was estimated at 0.571 (± 0.074; CV = 0.130). The abundance of harbour porpoises within the survey area was estimated at 40,475 animals (95%CI: 25,614 – 65,041, CV = 0.235) with an associated density of 0.786 animals/km² (95%CI: 0.498 – 1.242, CV = 0.235) and an average group size of 1.488 animals.

INTRODUCTION

At least three genetically and morphologically distinct populations of harbour porpoises *(Phocoena phocoena)* have been identified to occur in the waters of the Baltic Sea: a North Sea population inhabiting the North Sea, Skagerrak and the northern parts of the Kattegat, a population inhabiting the Western Baltic, the Belt Sea and the Kattegat, and a third population in the Baltic Proper (Tiedemann *et al.* 1996; Andersen *et al.* 1997; Börjesson and Berggren 1997; Huggenberger *et al.* 2002; Galatius *et al.* 2010; Wiemann *et al.* 2010, Teilmann *et al.* 2011). Morphological and satellite tracking studies show some overlap of these populations in the transition zones (Galatius *et al.* 2010; Teilmann *et al.* 2011).

The harbour porpoise population inhabiting the Baltic Proper has been classified by the IUCN as 'critically endangered', justified by the consideration that the current population size is likely to be fewer than 250 mature individuals and continues to decline (IUCN Red List, Hammond *et al.* 2008). In 2002, ASCOBANS issued the Recovery Plan for the Baltic Harbour Porpoises (Jastarnia Plan) for the conservation of the harbour porpoise population of the Baltic Proper, east of the Darß and Limhamn underwater ridges. In 2009, the Conservation Plan for Harbour Porpoises in the North Sea was adopted by ASCOBANS, covering the range of the North Sea harbour porpoise population, including the Skagerrak. Porpoises inhabiting the western Baltic, the Belt Sea and the Kattegat were not covered by either plan and the area was consequently referred to as the 'GAP-Area' (figure1). In October 2012, ASCOBANS adopted a new Conservation Plan for the Harbour Porpoise Population in the Western Baltic, the Belt Seas and the Kattegat, thus filling the gap between the areas covered by the two already existing conservation plans (ASCOBANS 2012).

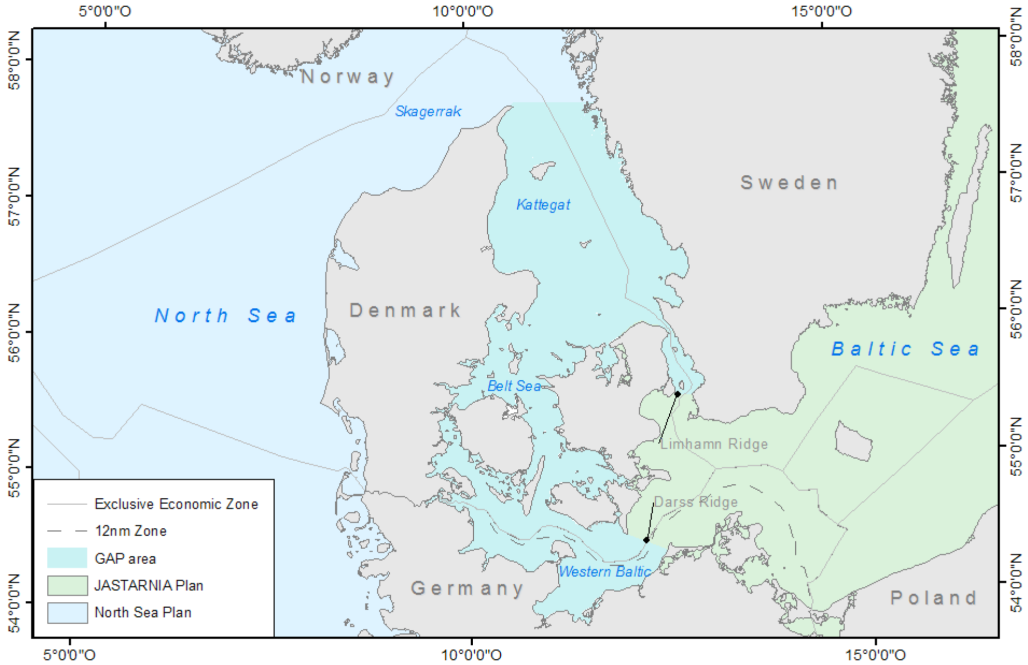

Figure 1: The GAP area as defined by ASCOBANS (ASCOBANS 2012).

While harbour porpoise numbers in the Baltic Sea were assessed during the pan-European surveys SCANS (1994, Hammond *et al.* 2002) and SCANS II (2005, Hammond *et al.*, accepted), abundance estimates are only available for the strata designed specifically for the SCANS surveys that do not reflect the extent of the 'GAP area' as defined by ASCOBANS. There have, however been indications arising from the SCANS II survey for a potential decline in population numbers for the comparable area between 1994 and 2005 in the Belt Seas and adjacent waters (Teilmann *et al.* 2011), though the decline may not be statistically significant due to the methods' inherent large confidence intervals.

A regular monitoring programme has been providing abundance estimates for harbour porpoises in the Western German Baltic Sea and the bordering Danish waters since 2002, representing the southern part of the 'GAP area' (Gilles *et al.* 2008; 2011; Scheidat *et al.* 2008). Moreover, stranded carcasses are collected along the German Baltic coastline (Siebert *et al.* 2001; 2006; 2010). An observed though not significant decrease in densities in the German Baltic (Gilles *et al.* 2011) as well as an increase in stranding numbers, potentially due to bycatch casualties along the German coasts (ICES 2009) further increased the demand for an assessment of the population status of harbour porpoises in the 'GAP' Area. There is a heavy anthropogenic impact on porpoises in the Baltic Sea that can to a large part be attributed to bycatch, especially due to the extensive use of set nets, but also to noise pollution, chemical pollution, heavy sea traffic, offshore constructions and other human activities (Benke *et al.* 1998; Berggren *et al.* 2002; Koschinski 2002; Carstensen *et al.* 2006; Siebert *et al.* 2006; Herr 2009).

Great concern for the harbour porpoises of the 'GAP area' had already been vocalized by the ICES Working Group for Marine Mammal Ecology in 2011. Moreover, in 2011 new studies were encouraged during the Jastarnia group meeting (ASCOBANS meeting in Copenhagen 2011), including the drafting of the Conservation Plan for the 'GAP area' as well as an abundance assessment. The scientific committee of the IWC also emphasized the importance and necessity of such a survey in order to gather information on the population in the 'GAP area' (IWC, Panama City, 2012). Subsequently a ship board survey to estimate the abundance of harbour porpoise of the western Baltic, Belt Sea and Kattegat was conducted in cooperation between Danish, Swedish and German institutes under Danish management and execution. Here we present the results of this survey.

MATERIALS AND METHODS

As definite population borders between the harbour porpoise population of the North Sea and the 'GAP area' population as well as for the eastern Baltic population and the 'GAP area' are not known (Tiedemann *et al.* 1996; Andersen *et al.* 1997; Huggenberger *et al.* 2002; Galatius *et al.* 2010; Wiemann *et al.* 2010; Teilmann *et al.*

2011), it was decided to expand the survey outside the 'GAP area' to the north and east to cover the potential transition zones between the three subpopulations of the North Sea and Baltic Sea. The total survey area of 51,512 km^2, which is considerably larger than the 41,280 km² of the 'GAP area' (figure 2).

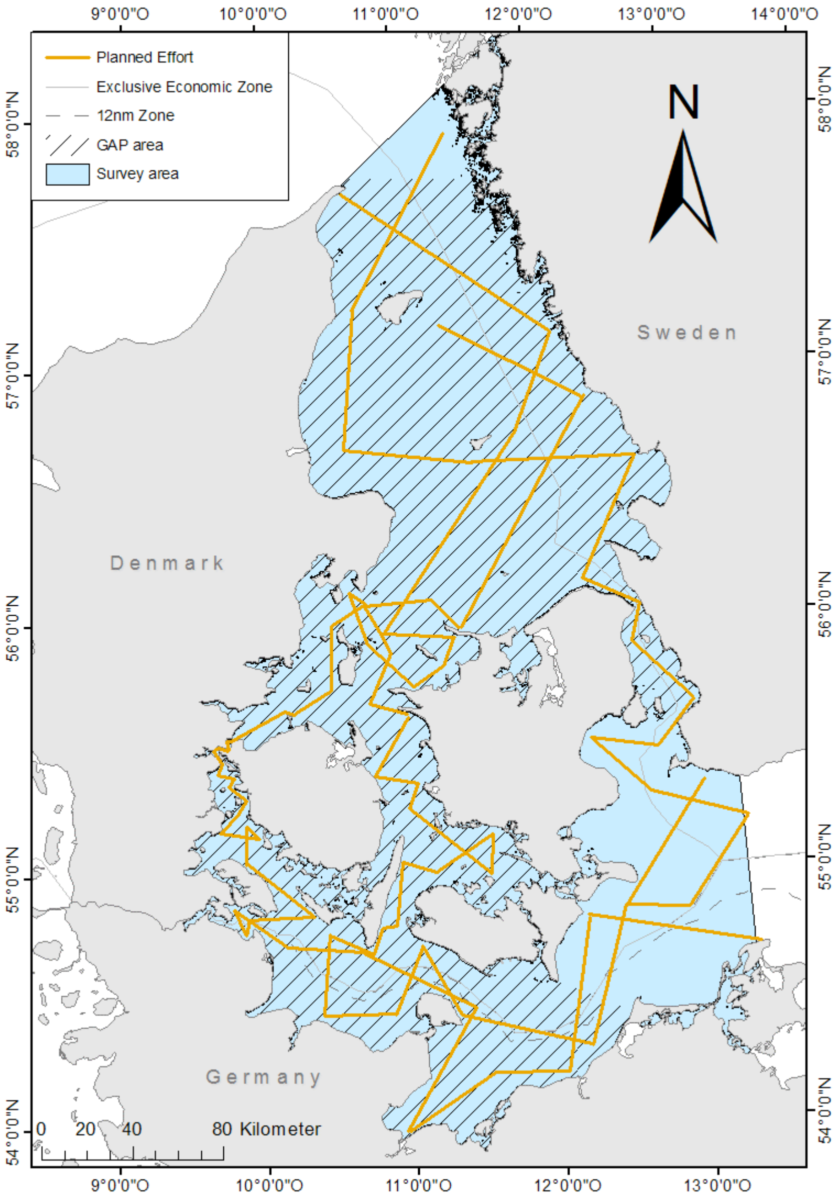

Figure 2: Survey area in blue while dashed lines represent the GAP area; amber solid lines indicate planned transects.

The survey was conducted in July 2012 in accordance with the double platform line-transect distance sampling approach (Buckland *et al.* 2001; 2004), also used in SCANS II (Hammond *et al.* accepted). In contrast to single platform techniques, in which the probability of detections on the transect line g(0) is assumed to be 1, the double platform approach allows for the estimation of the proportion of animals missed by the primary observers, due to availability as well as perception bias, through Mark-Recapture Distance Sampling (MRDS, Buckland *et al.* 2004; Thomas *et al.* 2010). The detection function for the primary observers is adjusted by the MRDS based estimate of g(0) which is derived from the number of tracker sightings that were missed by the primary observers, by comparing the tracker detection function with the primary detection function (for details, see Buckland *et al.* 2004) and assessing the duplicates.

A zig zag design was preferred over regular parallel transect placement due to the complexity and fragmentation within parts of the survey area. Transects designed for SCANS II stratum 'S' (SCANS II 2008) were used and modified for this survey (figure 2). The *R/V Skagerak*, a research vessel owned by the University of Gothenburg, was used throughout the survey (figure 3). The primary platform in the bow section of the ship was raised 6m above sea level, while the tracker platform was at 10m above sea level, atop the bridge section. Primaries searched the area with naked eyes, but were equipped with binoculars for confirmation of sightings, angle boards and an distance estimation stick made for the eyeheight of each observer. The two trackers used 7x50 binoculars and big eye binoculars, with angle and reticles for distance estimation.

Figure 3: Survey vessel *R/V Skagerak* and survey platform indications (Photo: S. Sveegaard).

The 63 transects were surveyed at an average speed of 9.8 knots and all porpoise sightings recorded included group size, cue, and the perpendicular distance to the transect line, as measured by the observer. Besides GPS coordinates being stored every 4 seconds by a software setup using the software Logger, additional variables and sighting conditions were recorded and continuously updated by the data recorder. Several variables known to impact the probability of detecting porpoises were noted, including sightability, swell, seastate and glare (table 5, Appendix).

The resulting dataset was analysed in DISTANCE 6.0r2 (Thomas *et al.* 2010) using the MRDS engine and incorporating covariates within the detection function modeling stages of the analysis. Visual assessement of initial detection functions showed sparsely distributed observations at distances beyond 700 m from the transect line, which we thus discarded using a right truncation at 700 m for the sake of detection function robustness. Additionally, all sightings that occurred during poor sighting conditions (sightability > 2) were excluded from the analysis.

RESULTS

The survey took place between the 2^{nd} and the 21^{st} of July 2012. Weather conditions allowed surveying on 9 out of 21 days. The total effort was 1,068 km, of which 826 km (77.4%) were conducted during sea states ≤ 2 Beaufort (table 1, figure 4). Effort and sightings at sea states > 2 were discarded before analysis.

Table 1: Realised survey effort in seastates 0 - 4 Beaufort.

Seastate [Beaufort]	*Effort [km]*	*%*
0	55.6	5.2
1	450.0	42.1
2	320.4	30.0
3	241.4	22.6
4	0.4	0.0
Sum	1,067.9	100
≤ 2	826.0	77.4
> 2	241.9	22.4

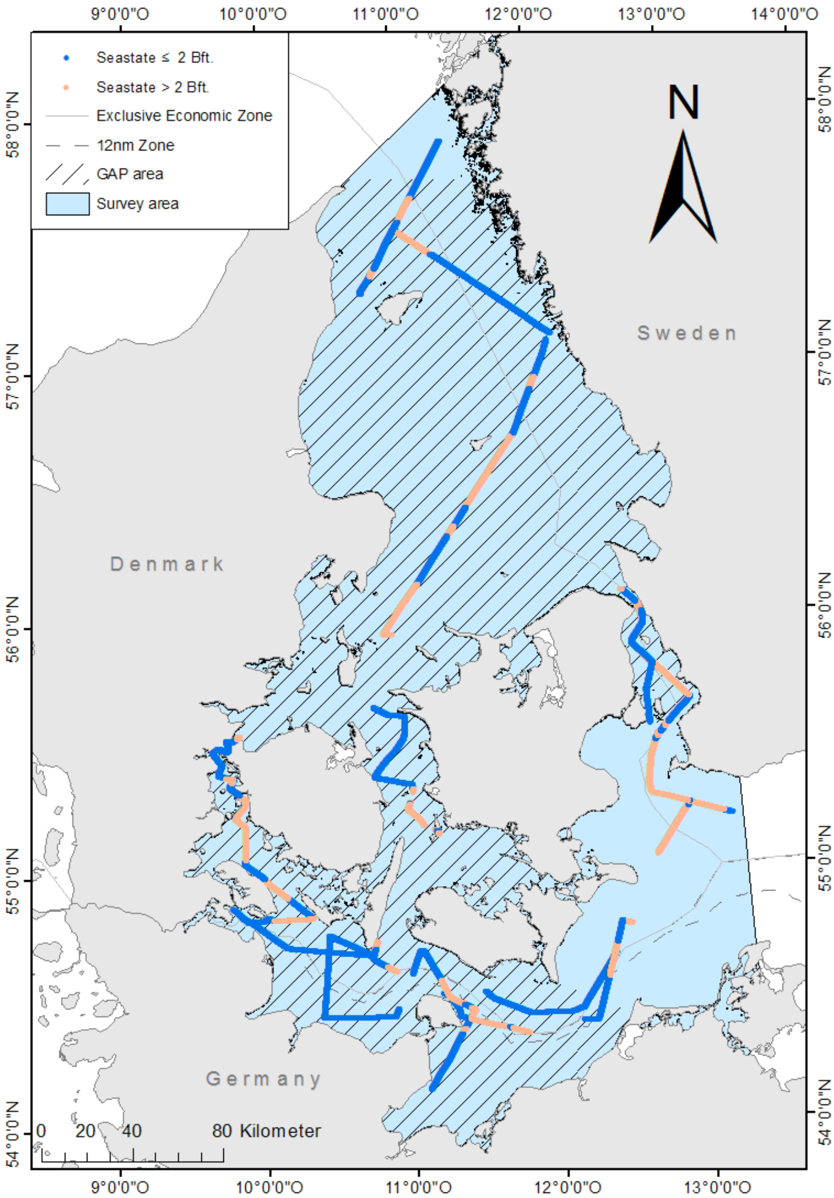

Figure 4: Realised survey effort in sea states ≤ 2 Beaufort (blue) and > 2 Beaufort (orange); survey area in blue while dashed lines represent the GAP area.

A total of 350 sightings were recorded, to which the primaries contributed 169 with a total of 230 porpoises. The trackers recorded 181 sightings comprising 256 porpoises (table 2), of which 57 observations were identified as matched duplicates. After right truncation at 700 m, primary observations were reduced to 165 observations comprising 225 porpoises while tracker sigtings were reduced to 145 observations comprising 207 animals (see also figure 5). No duplicates were discarded due to the right truncation. Modelling the primary detection function showed sightability to be the major effect on the detectability of porpoises (table 3). Model selection was based on the lowest AIC score (Akaike Information Criterion, see Akaike 1974, Bozdogan 1987, Anderson *et al.* 1994). Model g_3 was identified as best model (using a half normal key function and sightability as only covariate, figure 6). The analysis of covariates for the tracker detection function yielded model m_1 to fit the data best (sightability as base model and distance as only covariate for the tracker detection function, table 4). Applying the information from the MRDS engine, the detection function of the primary observers was corrected by the tracker detection function of model m_1, yielding a g(0) of 0.571 (± 0.074; CV = 0.130), resulting in a corrected detection function as displayed in figure 7. A correction factor of 1.084 for group size was applied, accounting for slightly larger group sizes estimated by the trackers than the primaries in the event of duplicate sightings. The abundance estimate resulting from the MRDS analysis was therefore multiplied with this factor post analysis.

We thus estimated the abundance of harbour porpoises within the survey area of 51,511 km² at 40,475 animals (95% CI: 25,614 – 65,041, CV = 0.235), the associated density at 0.786 animals/km² (95% CI: 0.498 – 1.242, CV = 0.235) and the expected group size to be 1.488 animals/group.

Table 2: Realised survey effort, number of porpoise sightings and encounter rate of both survey platforms

Observer	*Effort [km]*	*Group count*	*Individual count*	*Calves*	*Average group size*	*Encounter rates [Encounters/km]*
Primary	826	169	230	13	1.36	0.20
Tracker	740	181	256	25	1.41	0.24

Table 3: Model selection based on the key function used within Distance 6.0r2 using AIC; g3 (half-normal key function, sightability as covariate) was identified as best model; Key = key function of the detection function, Variable = covariate used in the modelling process, AIC = Akaike Information Criterion, ΔAIC = difference in AIC compared to the lowest AIC score

Model	*Key*	*Variable*	*AIC*	*ΔAIC*
g_1	Half normal	-	2,084.48	9.13
g_2	Hazard rate	-	2,086.15	10.81
g_3	Half normal	sightability	2,075.35	0.00
g_4	Hazard rate	sightability	2,081.59	6.25
g_5	Half normal	beaufort	2,084.69	9.35
g_6	Hazard rate	beaufort	2,086.71	11.36
g_7	Half normal	swell	2,084.96	9.61
g_8	Hazard rate	swell	2,086.13	10.79
g_9	Half normal	glare	2,089.02	13.67
g_{10}	Hazard rate	glare	2,090.00	14.65

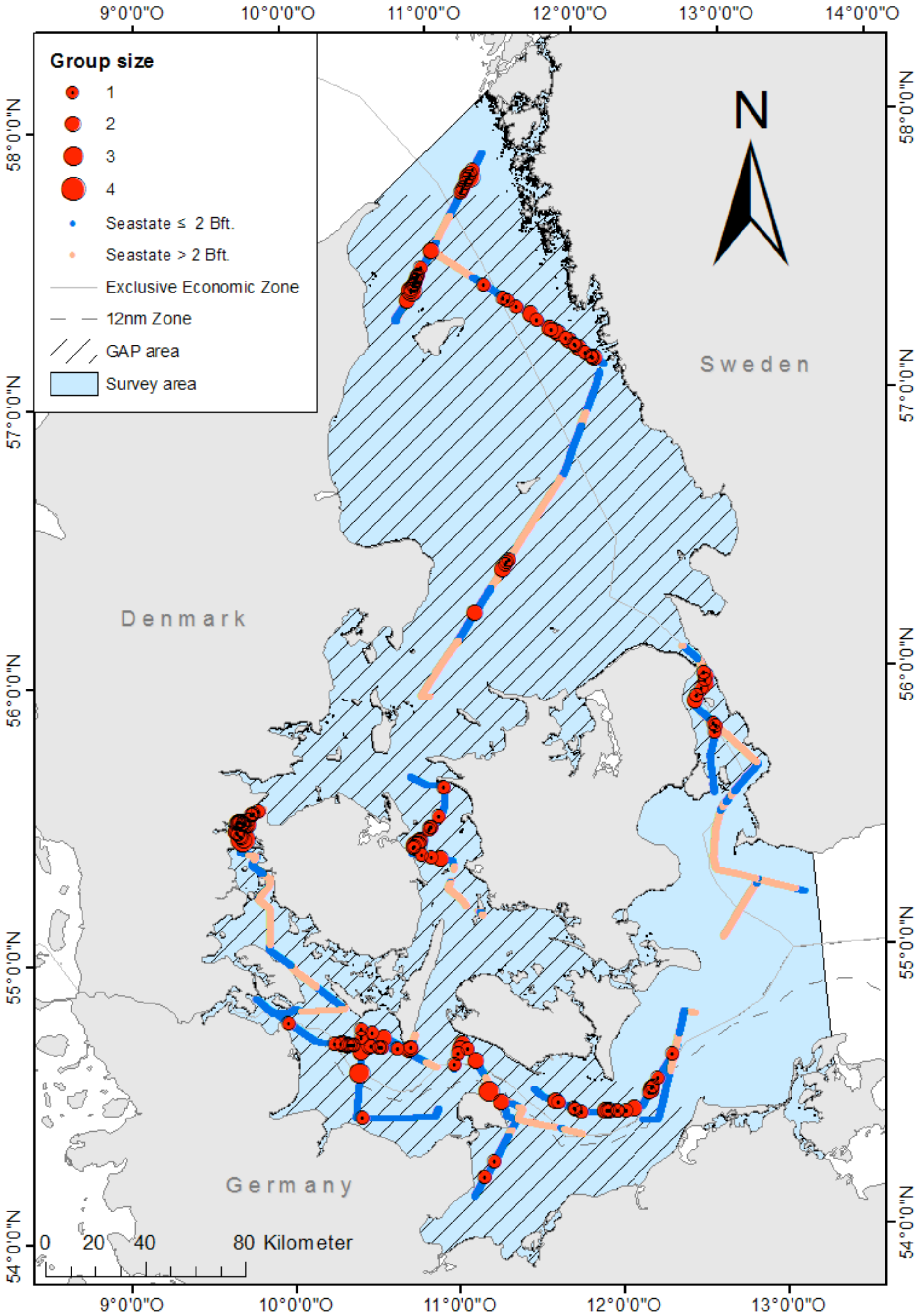

Figure 5: Realised survey effort in sea states ≤ 2 Beaufort (blue) and > 2 Beaufort (orange); the sightings are based on the data used in the analysis (right truncation at 700m, sightability < 2); the group size of porpoise sightings is marked in red circles, the diameter of these circles indicates the group size; survey area in blue while dashed lines represent the GAP area.

Table 4: Model selection of the tracker detection function based on the primary detection function g3; dsmodel shows the covariate used in the primary detection function; mrmodel displays the covariate used in the detection function modeling of the tracker, a ~1 indicates the lack of a covariate, i.e. it assumes a constant value of the detection function; AIC = Akaike Information Criterion, ΔAIC = difference in AIC compared to the lowest AIC score; g(0) = corrected detection function parameter

Model	*dsmodel*	*mrmodel*	*AIC*	*ΔAIC*	*g(0)*
m_1	sightability	distance	2,265.36	0.00	0.571
m_2	sightability	distance + beaufort	2,264.77	0.40	0.570
m_3	sightability	distance + sightability	2,265.82	0.45	0.572
m_4	sightability	distance + swell	2,266.62	1.25	0.587
m_5	sightability	distance + swell + sightability	2,267.55	2.18	0.591
m_6	sightability	glare	2,270.12	4.76	0.570
m_7	sightability	~1	2,271.70	6.33	0.393
m_0	-	~1	2,280.81	15.45	0.393

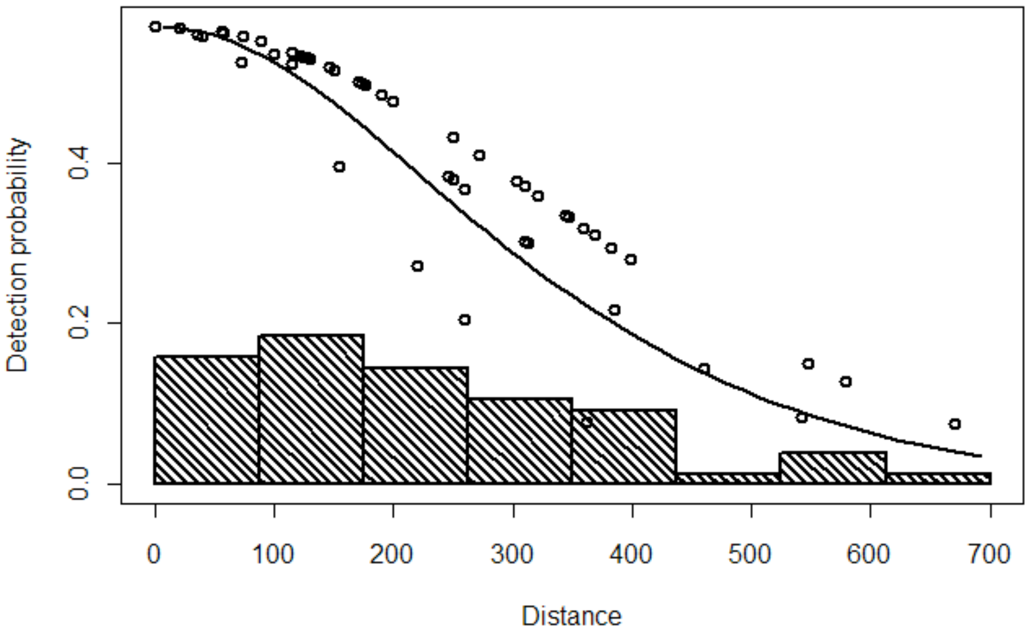

Figure 6: Mean detection function of the primary observer (solid line) and the individual levels of the associated covariate visibility (points).

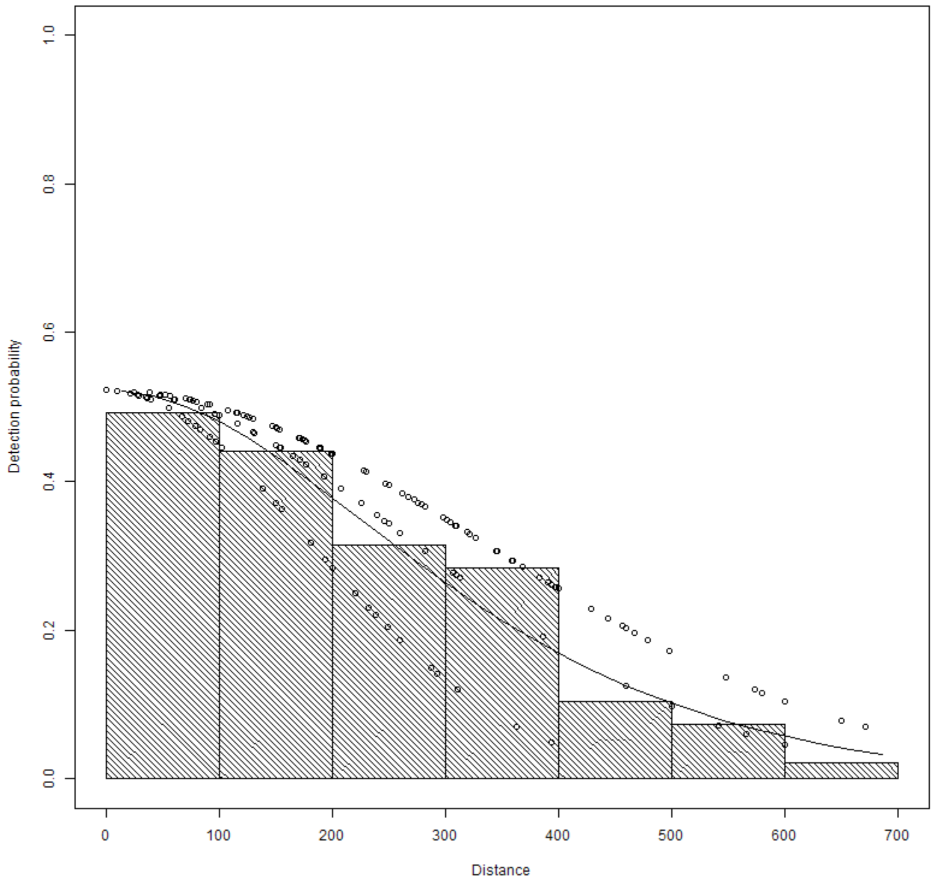

Figure 7: Mean detection function of the primary observer using corrections derived from the tracker observations (solid line) and the individual levels of the associated covariate visibility (points).

DISCUSSION

The obtained abundance estimate is the first for this survey area and can not be directly compared with abundance estimates from previous surveys, due to different survey and strata boundaries. However, during SCANS in 1994, three strata (strata I, I' and X) partly represented the 'GAP area' and adjacent waters. Densities estimated for these areas in 1994 were 0.725 animals/km² for area I (Skagerak, Kattegat and northern part of the Belt Sea), 0.987 animals/km² for area I' (Central Belt Sea) and 0.150 animals/km² for area X (part of the western Baltic) (Hammond *et al.* 2002). In 2005 these strata were comprised in one single larger stratum (stratum S), which yielded a density of 0.280 animals/km² (CV = 0.36) (Hammond *et al.* accepted). Our estimated density of 0.786 animals/km² (95%CI: 0.498 – 1.242, CV = 0.235) lies well within range of these density estimates of previous surveys and does not indicate a drastic decline in animal densities since 1994. However, we cannot exclude the possibility of local changes in abundance as suggested by Teilmann *et al.* 2011. Densities estimated in 2005 were considerably lower than overall density estimated during the present survey. Yet, the areas covered were different between the surveys and included areas not covered by the other survey, respectively.

There is indication that the subpopulation of harbour porpoises is confined to a smaller area than the 'GAP area' (Edrén *et al.* 2010; Sveegaard *et al.* 2011; Teilmann *et al.* 2011) and thus for the possible inclusion of trans-population boundaries within the larger survey area presented here. Spatially sensitive analysis may reveal changes within subregions of the survey area. It would be of interest to additionally assess abiotic parameters that may affect the harbour porpoise distribution in the area. It would be highly beneficial to spatially assess the distribution of harbour porpoises within the fragmented area of the 'GAP area' to identify possible hot spots and to discuss the population boundaries proposed by Teilmann *et al.* (2011). In the light of the upcoming SCANS III survey proposed to take place in 2015, there is a great need to further investigation of the 'GAP area' population and to establish an a priori knowledge of the spatial distribution of the local populations in order to reevaluate the strata design for the upcoming surveys of that area. A comprehensive dataset such as assembled on this survey should be explored more thoroughly by means of spatial variables that will help to understand the distribution of the harbour porpoise within the 'GAP area'.

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APPENDIX

Table 5: Variables recorded by observers in regular intervals and on porpoise sightings

Variable	*Coding*	*Definition*
General climatic variables recorded upon change of variable and the event of observer rotation, transect start and porpoise sighting		
sightability	0:excellent, 1:good, 2:moderate, 3:poor	Subjective judgement of the potential for spotting a porpoise under the given environmental conditions
swell	0:no swell, 1:height below 1m and short wavelength, 2:height below 1m but long wavelength, 3:height below 2m and short wavelength	Height of surface gravity waves not induced by wind events
seastate	Beaufort scale	The state of the sea according to the Beaufort scale; seastates >2 are not recommended for porpoise surveys
glare	0:no glare, 1:low glare, 2:light glare, 3:heavy glare	Spread of sun glare across ocean surface
Sighting specific variables recorded on sighting events		
behaviour	FE: feeding, LO: logging, MI:milling, PO: porpoising, SW:swimming	Description of the animal behaviour during / upon sighting
cue	BL: Blow, BY: Body, FL:Flash, SB: Seabirds, SD: Sound, SP:Splash, JU: Breach/jump, AW: other associated wildlife, SL: Slick, 'footprint' or ring	The trigger for detection
calves	numeric	The number of calves seen