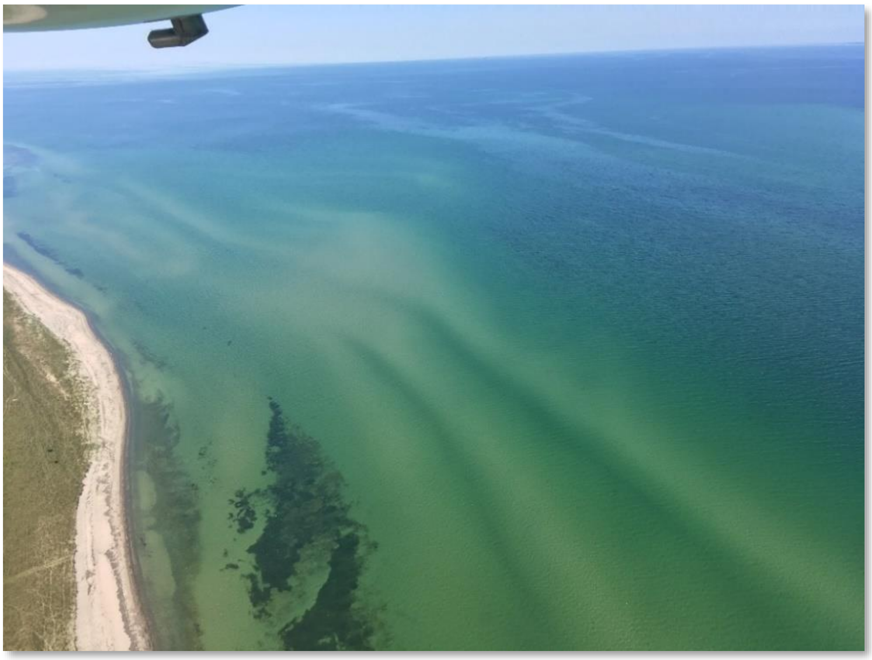
MiniSCANS-II: Aerial survey for harbour porpoises in the western Baltic Sea, Belt Sea, the Sound and Kattegat in 2020



Bianca Unger[1], Dominik Nachtsheim[1], Nadya Ramírez Martínez[1], Ursula Siebert[1], Signe Sveegaard[2], Line Anker Kyhn[2], Jeppe Dalgaard Balle[2], Jonas Teilmann[2], Julia Carlström[3], Kylie Owen[3], Anita Gilles[1]

[1] Institute for Terrestrial and Aquatic Wildlife Research (ITAW), University of Veterinary Medicine Hannover, Foundation, Werftstraße 6, 25761 Büsum, Germany

[2] Centre for Environment and Energy, Aarhus University, Frederiksborgvej 399, 4000 Roskilde, Denmark

[3] Naturhistoriska Riksmuseet, Frescativägen 40, 104 05 Stockholm, Sweden

Suggested citation: Unger, B., Nachtsheim, D., Ramírez Martínez, N., Siebert, U., Sveegaard, S., Kyhn, L., Balle, J.D., Teilmann, J., Carlström, J., Owen, K., Gilles, A. 2021. MiniSCANS-II: Aerial survey for harbour porpoises in the western Baltic Sea, Belt Sea, the Sound and Kattegat in 2020. Joint survey by Denmark, Germany and Sweden. Final report to Danish Environmental Protection Agency, German Federal Agency for Nature Conservation and Swedish Agency for Marine and Water Management. 28 pp. URL: https://www.tiho-hannover.de/fileadmin/57_79_terr_aqua_Wildtierforschung/79_Buesum/downloads/Berichte/20210913_Report_MiniSCANSII_2020_revised.pdf

Table of Contents

Summary

The Marine Strategy Framework Directive (MSFD) (Directive 2008/56/EC) emphasises the need for cross-border monitoring of wide-ranging species, such as the harbour porpoise (*Phocoena phocoena*), the most abundant cetacean species occurring year-round in the Baltic Sea. In June and July 2020, Germany, Denmark, and Sweden conducted a dedicated large-scale aerial survey (called MiniSCANS-II) for harbour porpoises in the management area of the Belt Sea population, i.e., between an east-west line between Denmark and Sweden at 56.95°N in the Kattegat Sea, and a north-south line between Sweden and Germany at 13.5°E in the southern Baltic Sea. This survey followed line-transect distance sampling methodology according to the SCANS protocol to derive an unbiased absolute abundance estimate. With a realised effort of 4,533 km in nine strata, the observers recorded a total of 202 sightings (251 individuals, of these 16 were calves). The large majority of survey effort (91.2%) was conducted in either good or moderate sighting conditions. The abundance of the Belt Sea population was estimated to be 17,301 harbour porpoises (95% CI = 11,695-25,688; CV = 0.20), with an average density of 0.41 individuals/km² (95% CI = 0.28-0.61). This is the lowest abundance estimate since the first (SCANS) survey was conducted in 1994. However, the variance (especially of the earlier abundance estimates) is high, and a dedicated trend analysis needs to be conducted to determine if there has been a decline in the population abundance over time. The results should raise some concern about the status of the population and emphasise the importance of repeated surveys in the near future to increase the time series of robust abundance estimates available. Such time series are essential for monitoring the progress of the population towards achieving favourable conservation status under the Habitats Directive and good environmental status (GES) as demanded by the MSFD.

Resumé

Havstrategirammedirektivet (2008/56/EF) understreger behovet for grænseoverskridende overvågning af grænsekrydsende arter, såsom marsvin (*Phocoena phocoena*), den mest almindelige hvalart, der forekommer året rundt i Østersøen. I juni og juli 2020 gennemførte Tyskland, Danmark og Sverige en dedikeret stor-skala flyoptælling (kaldet MiniSCANS-II) for marsvin i forvaltningsområdet for Bælthavspopulationen af marsvin. Det vil sige området mellem en øst-vest-linje mellem Danmark og Sverige ved 56,95°N i Kattegat og en nord-syd-linje mellem Sverige og Tyskland ved 13,5°Ø i den sydlige Østersø. Optællingen benyttede metoden for linjetransekt distance sampling og fulgte SCANS-protokollen til at udregne et absolut populationsantal. Med en realiseret effort på 4.533 km fordelt på ni observationsområder havde observatørerne i alt 202 observationer (251 individer, heraf 16 kalve). Langt størstedelen af optællingerne (91,2%) blev udført under enten gode (g) eller moderate (m) observationsforhold. Antallet af marsvin i Bælthavspopulationen blev estimeret til 17,301 marsvin (95% konfidensinterval = 11,695-25,688; CV = 0,20) med en gennemsnitlig tæthed på 0,41 individer/km² (95% konfidensinterval = 0,28-0,61). Dette er det laveste bestandsestimat siden den første (SCANS) undersøgelse blev udført i 1994. Konfidensintervallet er stort (især de tidligere optællinger), og for at afgøre, om der har været et fald i bestandsantal over tid, skal der udføres en dedikeret trendanalyse. Resultaterne giver anledning til bekymring over populationens status og understreger vigtigheden af at gentage

optællingen i den nærmeste fremtid for at øge tidsserien af robuste bestandsestimater. Sådanne tidsserier er afgørende for at overvåge populationens fremskridt i retning af at opnå gunstig bevaringsstatus i henhold til habitatdirektivet og god miljøstatus (GES) som krævet af havstrategirammedirektivet.

Zusammenfassung

Die Meeresstrategie-Rahmenrichtlinie (MSRL) (Richtlinie 2008/56/EG) unterstreicht die Notwendigkeit einer regelmäßig durchgeführten, grenzüberschreitenden Erfassung weit verbreiteter Arten, wie des Schweinswals (*Phocoena phocoena*). Der Schweinswal ist die am häufigsten vorkommende Walart in der Ostsee und ist dort ganzjährig anzutreffen. Im Juni und Juli 2020 führten Deutschland, Dänemark und Schweden eine groß angelegte Bestandsaufnahme aus der Luft durch („MiniSCANS-II“ genannt) mit dem Ziel, die Verteilung und Abundanz der Schweinwale der Beltsee-Population zu ermitteln. Dabei stand besonders das bereits etablierte Managementgebiet der Population im Fokus. Das Gebiet wird abgegrenzt durch eine Ost-West-Linie zwischen Dänemark und Schweden bei 56,95°N im Kattegat und eine Nord-Süd-Linie zwischen Schweden und Deutschland bei 13,5°O in der südlichen Ostsee. Die Erhebung erfolgte unter Einhaltung des SCANS-Protokolls mit Hilfe der sogenannten Linientransektmethode nach distance sampling, bei der vorher festgelegte Transekte im Untersuchungsgebiet systematisch abgeflogen werden. Dies ermöglicht eine Schätzung der absoluten Abundanz der Schweinswale. Bei einem realisierten Aufwand von 4.533 km in neun Teilgebieten wurden insgesamt 202 Sichtungen (251 Individuen, davon 16 Kälber) registriert. Der größte Teil der Surveys (91,2%) wurde unter guten oder moderaten Sichtungsbedingungen durchgeführt. Die Abundanz der Population in der Beltsee wurde auf 17.301 Schweinswale (95% KI = 11.695 - 25.688; VK = 0,20) geschätzt, mit einer durchschnittlichen Dichte von 0,41 Individuen/km² (95% KI = 0,28 - 0,61). Dies ist die niedrigste Abundanzschätzung seit der ersten Erhebung (SCANS) im Jahr 1994. Allerdings ist die Varianz (insbesondere bei den früheren Bestandsschätzungen) hoch. Eine Trendanalyse wird zeigen, ob der Bestand im Laufe der Zeit tatsächlich zurückgegangen ist. Die Ergebnisse geben Anlass zur Sorge über den Zustand der Population und verdeutlichen, wie wichtig wiederholte Erhebungen in naher Zukunft sind, um die bereits verfügbaren Zeitreihen zuverlässiger Abundanzschätzungen zu erweitern. Solche Zeitreihen sind für die Überwachung der Population auf dem Weg zum Erreichen eines günstigen Erhaltungszustands gemäß der Flora-Fauna-Habitat-Richtlinie (FFH) und eines guten Umweltzustands (GES), wie er in der MSRL gefordert wird, unerlässlich.

Sammanfattning

Havsmiljödirektivet (Europaparlamentets och rådets direktiv 2008/56/EC) betonar vikten av gränsöverskridande övervakning av arter med gränsöverskridande utbredningsområden, som till exempel tumlare (*Phocoena phocoena*), den enda valart som finns året runt i Östersjön. Under juni och juli 2020 genomförde Tyskland, Danmark och Sverige en storskalig flyginventering (kallad MiniSCANS-II) av tumlare inom Bälthavspopulationens förvaltningsområde. Området sträcker sig mellan en öst-västlig linje mellan Danmark och Sverige längs 56,95°N i Kattegatt och en nord-sydlig linje mellan Sverige och Tyskland längs 13,5°E i södra Östersjön. Inventeringen genomfördes som en avståndsinventering med

linjetransekter enligt metoder utarbetade vid tidigare SCANS-inventeringar för beräkning av absolut abundans. Sammanlagt observerades totalt 202 tumlargrupper (251 individer, varav 16 kalvar) längs 4,533 km i nio strata. Inventeringsförhållandena var goda eller måttliga under merparten av den inventerade sträckan (91,2%). Bälthavspopulationens abundans beräknades till 17 301 individer (95% CI = 11 695–25 688; CV = 0.20) och den genomsnittliga densiteten till 0,41 individer/km² (95% CI = 0,28–0,61). Detta är den lägsta abundansskattningen sedan den första SCANS-inventeringen genomfördes år 1994. Eftersom variansen i framförallt de tidigare abundansskattningarna är hög krävs det en dedikerad trendanalys för att fastställa om populationen har minskat över tid. Resultaten väcker viss oro om populationens status och visar på vikten av regelbundna och frekventa inventeringar för att öka tidserien av robusta abundansskattningar. Tidsserien ger grundläggande information om populationens utveckling mot att uppnå gynnsam bevarandestatus enligt art- och habitatdirektivet och god miljöstatus enligt havsmiljödirektivet.

Background and aim

The harbour porpoise (*Phocoena phocoena*) is the most abundant cetacean species occurring year-round in both the North Sea and Baltic Sea. In the Baltic Sea region and the North Sea, three distinct populations of harbour porpoises are recognised: (1) the Baltic Proper population in the inner Baltic Sea, (2) the Belt Sea population in the western Baltic Sea, Belt Sea, the Sound and southern Kattegat, and (3) the North Sea population, which occurs from the northern Kattegat, through Skagerrak to the entire North Sea. The three populations are genetically and morphologically distinct (Wiemann et al., 2010; Galatius et al., 2012; Lah et al., 2016). Furthermore, satellite telemetry and passive acoustic monitoring studies have demonstrated limited exchange and geographic overlap between the North Sea and Belt Sea populations, and between the Belt Sea and the Baltic Proper populations (Sveegaard et al., 2011; Sveegaard et al., 2015; Carlén et al., 2018). These findings have led to the suggestion of defined summer management borders, which should be used when monitoring the Belt Sea population (Sveegaard et al., 2015).

In the EU, the Habitats Directive (Directive 92/43/EEC) demands that all member states protect the harbour porpoise in its entire natural range, and designate Special Areas of Conservation (SACs) as part of the Natura 2000 network (Habitats Directive, 1992). These Natura 2000 sites are areas of importance for the conservation of the population, taking into account the abundance and density at the site in relation to the population's presence within the national territory (European Commission, 2012). The Marine Strategy Framework Directive (MSFD) (Directive 2008/56/EC) emphasises the need for cross-border monitoring of a wide-ranging species, such as the harbour porpoise (Marine Strategy Framework Directive, 2008). Consequently, management programmes will have to include monitoring not only of porpoise density (and/or abundance) within the designated Natura 2000 sites, but also of the entire biological population to detect any changes in abundance and to provide robust abundance estimates. In order to assess and report on the status of the population in time with the six-year reporting cycle of the Habitats Directive, the abundance and distribution surveys should be conducted approximately every six years.

The waters inhabited by the Belt Sea population were first assessed partly in 1990 and 1991 by aerial surveys in the western Baltic Sea (Heide-Jørgensen et al., 1992; Heide-Jørgensen et al., 1993). The knowledge from these pilot surveys were used to design the first SCANS survey in 1994 (Hammond et al., 2002) that covered the complete area of the Belt Sea population as well as the Skagerrak and estimated an abundance of 51,660 porpoises (95% CI = 29,058-91,841). The estimates from SCANS-II in 2005 indicated a steep decline in abundance in this area

(27,901; 95% CI =13,387-58,149) (Hammond et al., 2013), which led to the first dedicated survey of the Belt Sea population in 2012, called MiniSCANS. In MiniSCANS, the abundance was estimated to be 40,475 animals (95% CI = 25,614-65,041; CV = 0.24) (Viquerat et al., 2014). The population was assessed again four years later during the large-scale SCANS-III survey in 2016 (Area 2). At that time, it was estimated that 42,324 (Area 2, 95%CI = 23,368-76,658) harbour porpoises inhabit the area (Hammond et al., 2021).

In 2020, Germany, Denmark and Sweden conducted a dedicated large-scale aerial survey (MiniSCANS-II) for harbour porpoises in the area of the Belt Sea population. The Institute for Terrestrial and Aquatic Wildlife Research (ITAW), University of Veterinary Medicine Hannover, Foundation (Germany), the Department of Bioscience, Aarhus University (Denmark) and the Swedish Museum of Natural History Stockholm (Sweden) were involved in the planning and realisation of the survey. The survey used the same protocol and methodology for aerial surveys as implemented in the SCANS-II and -III surveys (Hammond et al., 2021), as well as in the national monitoring surveys conducted in German, Dutch and Danish waters (Scheidat et al., 2008; Gilles et al., 2009; Gilles et al., 2016) to derive unbiased absolute abundance estimates. The results of this study allow for estimating abundance and potential trends to monitor progress in achieving favourable conservation status under the Habitats Directive and good environmental status (GES) as demanded by the MSFD.

Methodology

Survey design

The MiniSCANS-II (MS) survey area was divided into ten survey strata (MSA-MSI, plus NK - Northern Kattegat) covering 50,222 km². The strata MSA-MSI covered the management unit of the Belt Sea harbour porpoise population as suggested by Sveegaard et al. (2015), i.e. between an east-west line between Denmark and Sweden at 56.95°N in the Kattegat Sea, and a north-south line between Sweden and Germany at 13.5°E in the southern Baltic Sea. In addition, the stratum NK in the northern Kattegat covered the transition zone towards the North Sea harbour porpoise population (Figure 1, Table 1). Each stratum was covered on a single day.

The survey design was set up using the R package 'dssd' (Marshall, 2020) in R version 3.4.4 (R Core Team, 2018). Line transects were designed to provide a systematic survey with even coverage probability of the survey area, following the principles described in Buckland et al. (2001). This ensured that each point within a stratum has the same probability of being surveyed, which allows for an unbiased abundance estimation by extrapolating estimated sample density to the entire stratum. Transects were oriented perpendicular to the main depth gradient, if possible. Spacing of parallel transects was 10 km for all strata except MSD, where a zigzag-design was chosen to cover the narrow area of the Great Belt efficiently (Figure 1).

The boundaries of strata MSF-MSI were based on the current strata of the German aerial monitoring programme for harbour porpoises. The area of MSF corresponds with the area I of the German national monitoring programme, while MSG corresponds to J, MSH to K and MSI is corresponding to area L and part of M. For the MiniSCANS-II survey the national survey design was adjusted accordingly to cover Danish waters specifically in the areas MSF and MSI. Therefore, in both areas the transects were extended towards the north. For area MSI, the transects were additionally extended towards the east covering part of the area M (German monitoring), but in MSI running perpendicular to the coast instead of diagonal (Nachtsheim et al., 2020).

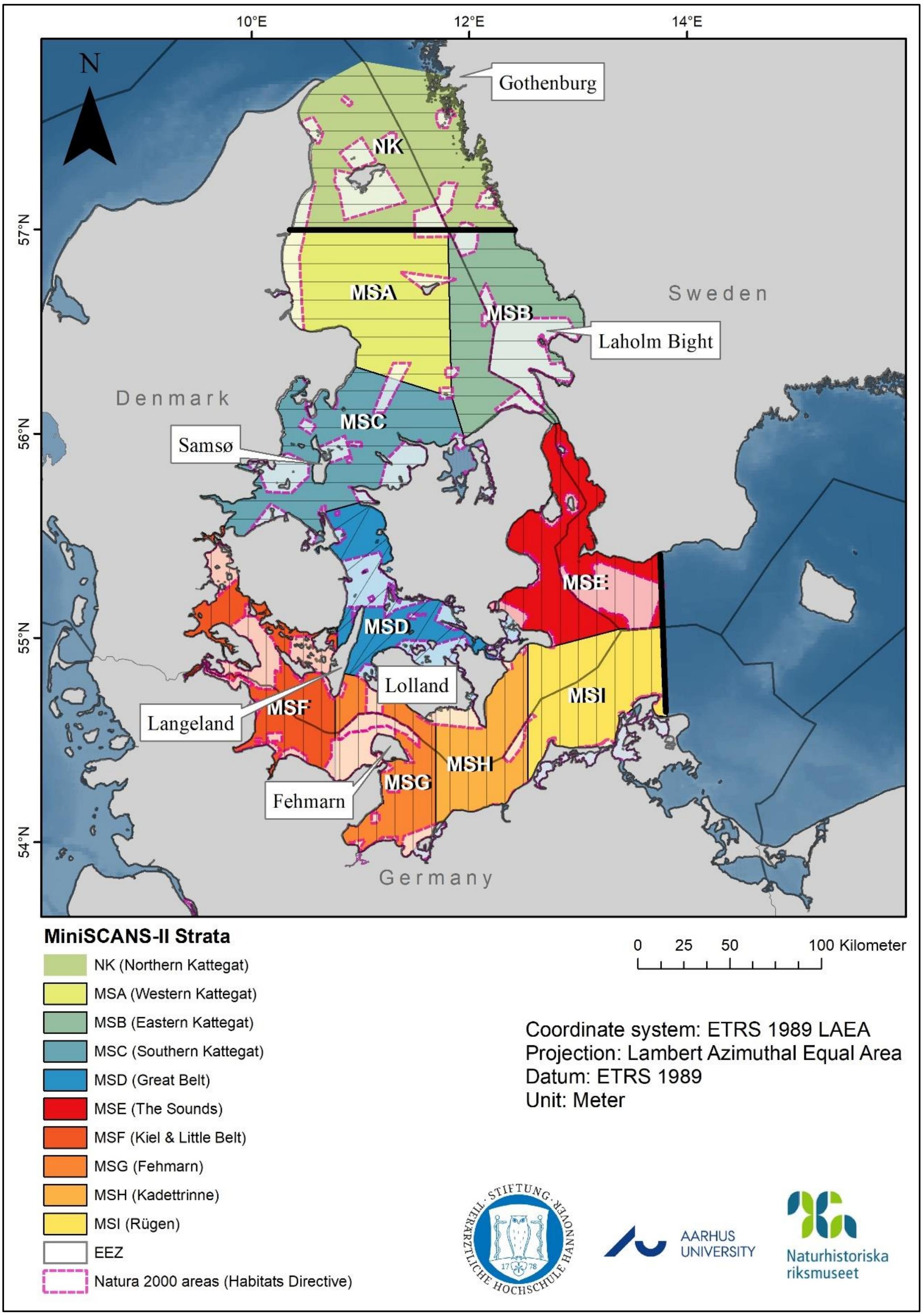


Figure 1. Survey design of MiniSCANS-II in the western Baltic Sea, Belt Sea, the Sound and Kattegat conducted in 2020 covering German, Danish and Swedish waters. The map shows all Natura 2000 areas in the study area, where the harbour porpoise is listed as protected species. The thick black lines indicate the borders of the management area of the Belt Sea population (defined in Sveegaard et al. 2015).

Table 1. Overview of MiniSCANS-II strata and planned transects lengths.

Stratum	Name	Stratum size (km^2)	Planned transect length (km)
MSA	Western Kattegat	6,177	594
MSB	Eastern Kattegat	5,842	599
MSC	Southern Kattegat	6,073	623
MSD	Great Belt	3,836	420
MSE	The Sound	5,157	512
MSF	Kiel & Little Belt	4,372	401
MSG	Fehmarn	3,592	374
MSH	Kadet Trench	3,144	322
MSI	Rügen	4,067	378
Total (MSA-MSI)		***42,260***	***4,222***
NK	Northern Kattegat	7,979	811

Data collection

The MiniSCANS-II survey followed line-transect distance sampling methodology (Buckland et al., 2001). Aerial surveys were conducted using a twin engine, high-wing aircraft (Partenavia P68), equipped with two bubble windows enabling the observers to monitor the area directly underneath the aircraft. At a constant altitude (600 ft) and speed (90-100 knots), two observers reported their observations to the data recorder (navigator) who entered sighting information into a laptop computer running dedicated data collection software (VOR, Hammond et al. (1995). The aircraft's position was stored every 2 seconds. Additionally, the start and end positions of the transect lines and the exact sighting positions were recorded. Each observer reported on harbour porpoise sightings (sighting declination angle, group size, number of calves, behaviour, etc.) and other sightings, e.g. mammals such as seals (at sea) and anthropogenic activities such as shipping and fishing. Environmental conditions such as sea state, water turbidity and cloud cover were recorded. Additionally, glare and subjective sighting conditions were recorded separately for each side of the aircraft. The subjective conditions reflect the observer's subjective view of the likelihood of sighting a harbour porpoise given the prevailing environmental conditions and could be either good, moderate, poor or unacceptable (e.g., fog). In case transects are close to land or the water is too shallow, the observer would note "over land (l)" as subjective conditions and later, during analysis, these transect parts were excluded for analysis.

Estimation of abundance

In order to collect data from which corrections could be made for animals missed on the transect line (commonly known as g(0)), the circle-back or "racetrack" method of Hiby (1999) was used. In this approach, upon detecting a group of animals, the aircraft circles back to resurvey the part of the transect where the initial (leading) sighting occurred (see Scheidat et al. (2008) for details). The same method is used in the German and Dutch aerial surveys as well as during SCANS-II and -III (Hammond et al., 2013; Hammond et al., 2021); an equivalent method developed for tandem aircrafts (Hiby et al., 1998) was used in SCANS (Hammond et al., 2002). The major advantage of this method is that it takes into account both availability and perception bias with the same data collected (Hiby et al., 1998; Hiby, 1999). Per definition of the analytical approach, the Hiby racetrack method produces estimates of total effective strip width ESW (i.e., on both sides of the aircraft) that incorporates g(0).

Animal abundance in stratum v was estimated as:

$$\hat{N}_v = \frac{A_v}{L_v}\left(\frac{n_{gsv}}{\hat{\mu}_g} + \frac{n_{msv}}{\hat{\mu}_m}\right)\bar{s}_v$$

Where A_v is the area of the stratum, L_v is the length of transect line covered on-effort in good or moderate conditions, n_{gsv} and n_{msv} are the number of sightings collected in good conditions and moderate conditions respectively, $\hat{u}_g$ is the estimated ESW in good conditions, $\hat{u}_m$ is the estimated ESW in moderate conditions and $\bar{s}_v$ is the mean observed group size in the stratum. Coefficients of variation (CVs) and 95% confidence intervals (CIs) were estimated by bootstrapping (999 replicates) within strata, using transects as the sampling units.

More details on survey method and abundance estimation are described in Scheidat et al. (2008), Gilles et al. (2009), Hammond et al. (2013) and Nachtsheim et al. (2021).

Results

Survey effort and sightings

Between 24 June 2020 and 10 July 2020 all survey strata were covered by two German and one Danish aerial survey team. During the ten surveys, the realised effort was 5,358 km (Figure 2, Table 2). The large majority of survey effort (91.2%) was conducted in either good (g) or moderate (m) conditions (Figure 2). Survey effort collected under poor (p) or unacceptable (x) conditions or over land (l) were excluded from the analysis. The proportion of survey effort in Beaufort sea state (BSS) was reported to be 4.2% BSS 0, 78.4% BSS 1, 17% BSS 2, and 0.4% in BSS 3. In total, 224 harbour porpoise groups, with a total of 278 individuals, including 20 calves, were sighted (Table 2, Figure 3).

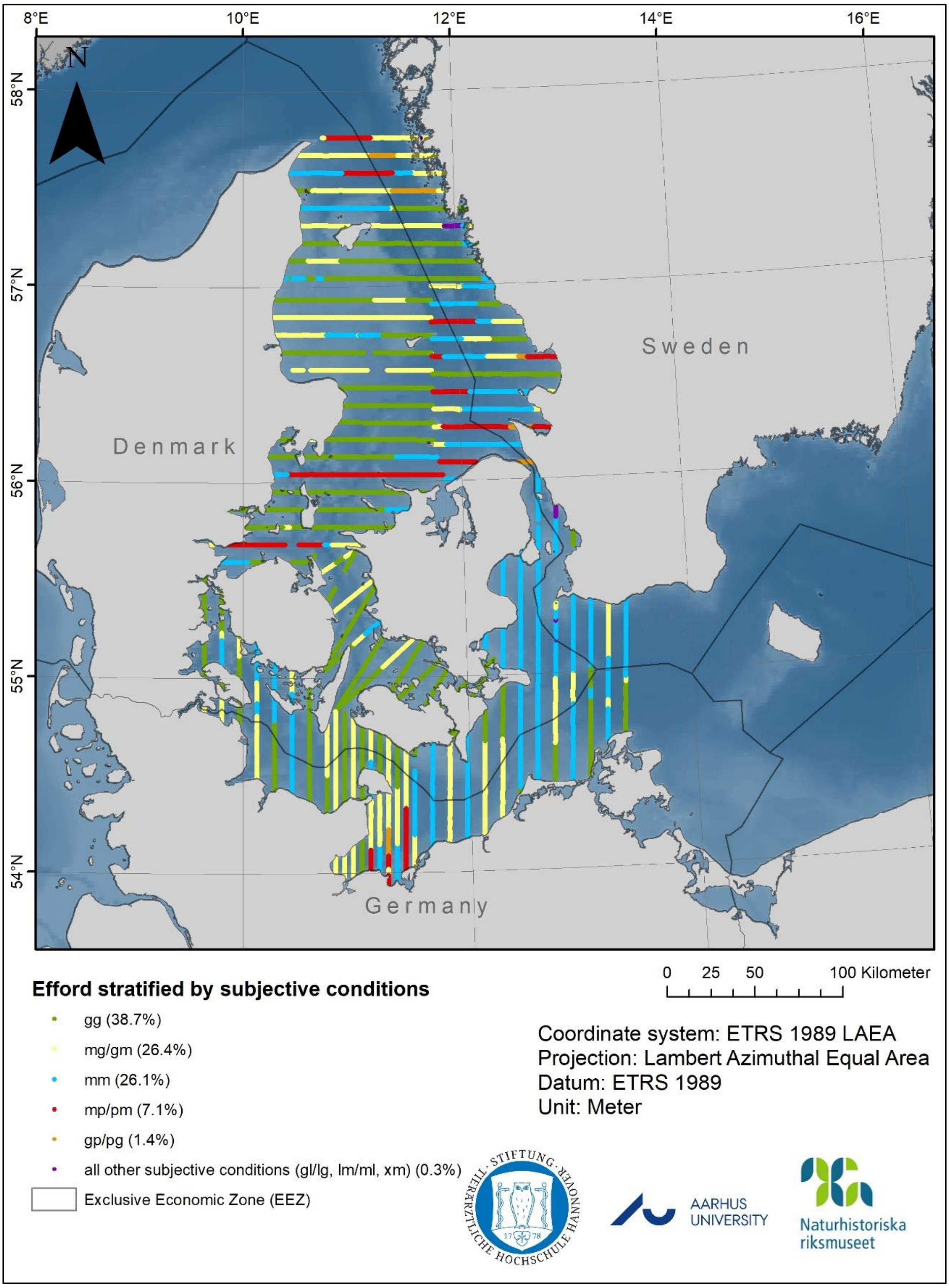


Figure 2. Spatial overview of the observers' subjective categorization of conditions during the MiniSCANS-II survey. Conditions are defined as either being good (g), moderate (m), poor (p), unacceptable (x) or over land (l). These could differ between each side of the plane and are, therefore, noted with two letters (e.g., "mg" means moderate subjective condition on the left side and good conditions on the right side). The combined percentage of each category during the survey is shown in brackets.

Table 2. MiniSCANS-II aerial survey. Effectively covered transects (survey effort), number of harbour porpoise groups and individuals sighted under good or moderate conditions (on at least one side of the plane). The number of calves is included in the no. of individuals. Mean group size = individuals / sightings of harbour porpoise groups within each stratum, total mean calculated as the mean of all strata. Note that three aircrafts conducted surveys on 24 June 2020 and 03 July 2020 and two aircrafts on 25 June 2020. The sum is made for all strata within the Belt Sea management area (Sveegaard et al., 2015). The NK=Northern Kattegat is included but not as part of the Belt Sea area.

Date	Stratum	Team	Survey effort (km)	No. of groups	No. of individuals	No. of calves	Mean group size
24 June 2020	MSG	DE	705	33	46	5	1.39
24 June 2020	MSH	DE	325	20	22	0	1.10
24 June 2020	MSC	DK	630	35	42	0	1.15
25 June 2020	MSA	DK	607	34	43	3	1.26
25 June 2020	MSB	DE	606	67	85	8	1.27
27 June 2020	MSF	DE	402	8	8	0	1.00
03 July 2020	MSE	DE	485	2	2	0	1.00
03 July 2020	MSI	DE	375	0	0	0	-
03 July 2020	MSD	DK	398	3	3	0	1.00
Σ Total Belt Sea population			***4,533***	***202***	***251***	***16***	***1.22***
07 July 2020	NK	DE	825	22	27	4	1.23

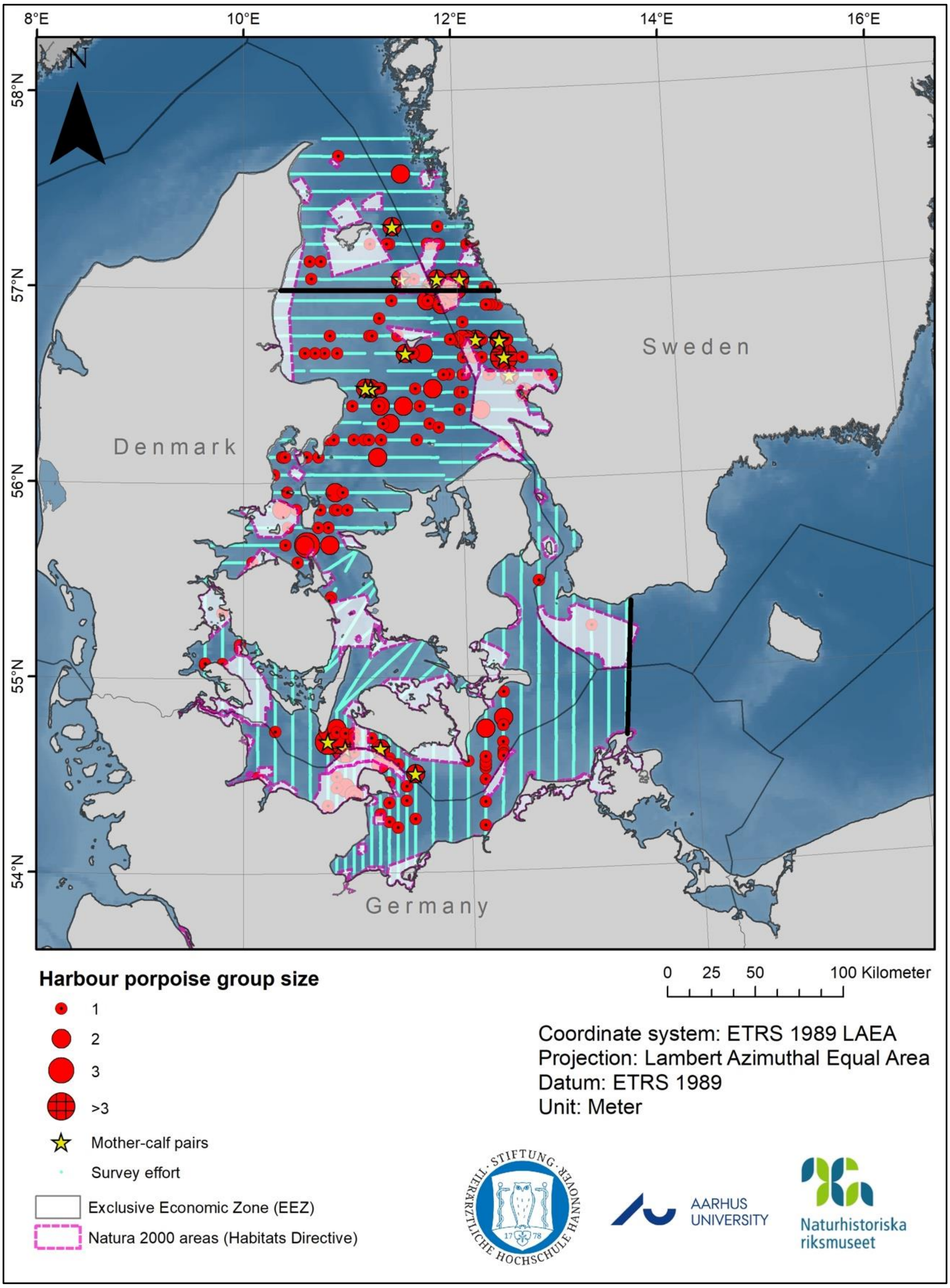


Figure 3. Survey effort and distribution of harbour porpoise sightings during aerial surveys (under good or moderate conditions) in the strata MSA-MSI and NK during the MiniSCANS-II survey. The map shows all Natura 2000 areas in the study area, where the harbour porpoise is listed as protected species. The thick black lines indicate the borders of the management area of the Belt Sea population (defined in Sveegaard et al., 2015).

Design-based abundance and density estimates

A total of 38 racetracks were conducted. However, the number of re-sightings was too low to estimate a robust ESW from the data collected. In order to estimate capture probability reliably, the collection of a large number of “re-captures” from racetracks is needed. During MiniSCANS-II, the same type of aircraft was used as in surveys in Germany as during SCANS, and all of the observers were trained and experienced in data collection and defining subjective sighting conditions in a comparable manner. Therefore, we decided to apply the ESWs, incorporating g(0) values of 0.42 and 0.21 for good and moderate conditions respectively, as estimated from German and SCANS aerial surveys to provide an unbiased corrected absolute abundance estimate.

The abundance of the Belt Sea population, i.e., the abundance of all surveyed strata except NK, was estimated to 17,301 harbour porpoises (95% CI = 11,695-25,688; CV = 0.20). The average density of the population was 0.41 individuals/km² (95% CI = 0.28-0.61). The highest density was estimated for stratum MSB in the eastern Kattegat whereas in stratum MSI (Rügen) no harbour porpoises were sighted and, consequently, no abundance could be estimated. Densities in MSD (Great Belt) and MSE (The Sound) were estimated to be very low, however associated with high CVs (Table 3, Figure 4).

Table 3. Summary of abundance and density estimates of harbour porpoises during the MiniSCANS-II survey. Density (ind./km^2) and abundance estimates are given with respective 95% confidence intervals (95% CI) and coefficients of variation (CV). The total abundance for Belt Sea management area is shown separately from northern Kattegat (NK).

Stratum	Name	Abundance (95% CI)	Density (95% CI)	CV
MSA	Western Kattegat	2,869 (1,389-5,001)	0.46 (0.22-0.81)	0.30
MSB	Eastern Kattegat	7,316 (3,768-12,861)	1.25 (0.64-2.20)	0.32
MSC	Southern Kattegat	2,529 (1,594-3,671)	0.42 (0.26-0.60)	0.22
MSD	Great Belt	174 (0-628)	0.05 (0-0.16)	1.05
MSE	The Sound	267 (0-626)	0.05 (0-0.12)	0.61
MSF	Kiel & Little Belt	596 (216-1,228)	0.14 (0.05-0.28)	0.40
MSG	Fehmarn	1,883 (1,190-2,847)	0.53 (0.33-0.80)	0.22
MSH	Kadet Trench	1,667 (170-3,282)	0.53 (0.05-1.04)	0.47
MSI	Rügen	0	-	-
Σ Belt Sea population		**17,301 (11,695-25,688)**	**0.41 (0.28-0.61)**	**0.20**
NK	Northern Kattegat	1,892 (625-3,388)	0.24 (0.08-0.42)	0.38

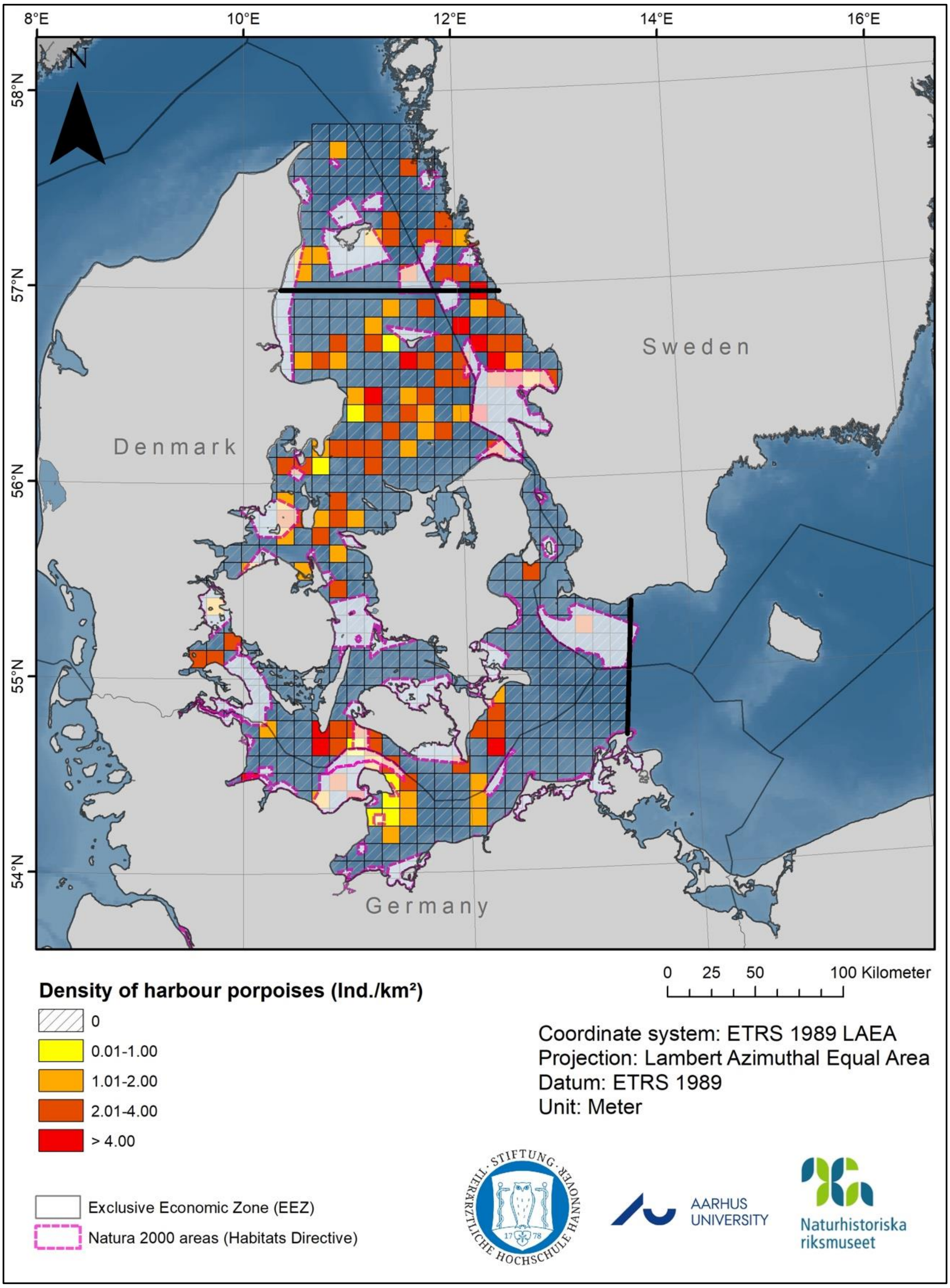


Figure 4. Estimated mean harbour porpoise density (ind./km²) per grid cell (here: 10x10 km) during the MiniSCANS-II survey in 2020. The map shows all Natura 2000 areas in the study area, where the harbour porpoise is listed as protected species. The thick black lines indicate the borders of the management area of the Belt Sea population (defined in Sveegaard et al., 2015).

Discussion

The MiniSCANS-II survey was successfully completed, allowed for the estimation of absolute abundance of 17,301 harbour porpoises (95% CI = 11,695-25,688; CV = 0.20) and a density of 0.41 ind./km^2 (0.28-0.61) and, therefore, adds to the time series of population estimates for the Belt Sea population (Figure 5).

Comparison to previous assessments

The spatial extent of the five surveys carried out in the area of the Belt Sea population management area (i.e., western Baltic Sea, Belt Sea, the Sound and Kattegat) has varied and surveys also covered a larger area including the Skagerrak to varying extents (Figure 6). Consequently, comparisons of the abundance across all surveys should be made with caution and rather the mean density estimates for the study areas should be displayed (Figure 5, Table 4).

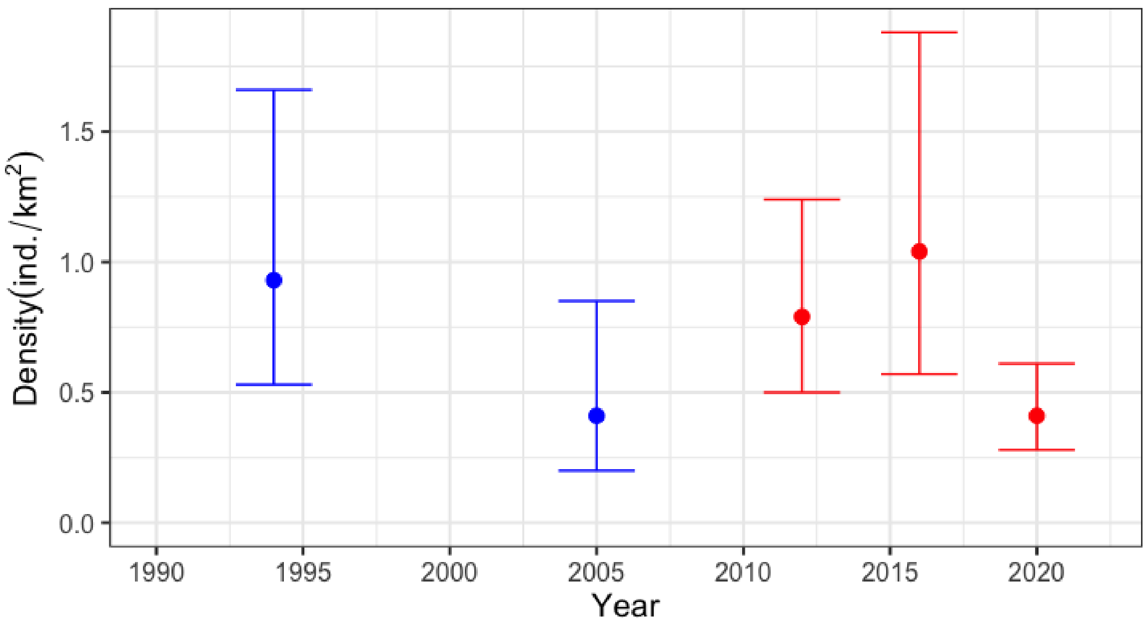


Figure 5. Time series of harbour porpoise mean density estimates for surveys in the Belt Sea population region. Surveys either covered solely the distribution range of the population (i.e., western Baltic Sea, Belt Sea, The Sound and Kattegat) (red) or covered a larger area, including the Skagerrak to different extents (blue). See Figure 6 for survey areas and Table 4 for detailed information per survey. Figure modified from Hammond et al. (2021).

MiniSCANS (2012) covered the area of the Belt Sea population as well as the northern Kattegat and the estimated abundance of harbour porpoises was 40,475 animals (95% CI = 25,614–65,041; CV = 0.24) and the density 0.79 ind./km^2 (95% CI = 0.50-1.24) (Viquerat et al., 2014). Four years later, in the SCANS-III survey, block 2 covered a smaller area and an abundance of

42,324 animals (95% CI = 23,368-76,658; CV = 0.30) was estimated, with a corresponding density of 1.04 ind./km^2 (95% CI= 0.57-1.88) (Hammond et al., 2021) (Table 4).

Table 4. Overview of harbour porpoise abundance and density (ind./km^2) estimates from SCANS and MiniSCANS surveys in the Belt Sea population region. Surveys were either conducted solely on the distribution range of the population (i.e., western Baltic Sea, Belt Sea, The Sound and Kattegat) (BS) or covered a larger area, including the Skagerrak, to different extents (S). *For ship surveys, effort refers to km in sea conditions Beaufort ≤2, and for aerial surveys, under good or moderate conditions.

Year	**1994**	**2005**	**2012**	**2016**	**2020**
Survey dates	27 June-09 July 1994	27 June-16 July 2005	02-21 July 2012	5-24 July 2016	24 June-10 July 2020
Survey	SCANS	SCANS-II	MINISCANS	SCANS-III	MiniSCANS -II
Block	I + X	S		2	MS A-I
Area	S/BS	S/BS	BS	BS	BS
Area (km^2)	55,295	68,372	51,511	40,707	42,244
Platform	ship + aerial	ship	ship	ship	aerial
Effort (km)*	2,292	1,279	826	1,028	4,533
Abundance	51,660	27,901	40,475	42,324	17,301
CV	0.30	0.39	0.24	0.30	0.20
CI low_abu	29,058	13,387	25,614	23,368	11,695
CI high_abu	91,841	58,149	65,041	76,658	25,688
Density	0.93	0.41	0.79	1.04	0.41
CI low_dens	0.53	0.20	0.50	0.57	0.28
CI high_dens	1.66	0.85	1.24	1.88	0.61
Reference	Hammond et al. (2021), revised from Hammond et al. (2002)	Hammond et al. (2021), revised from Hammond et al. (2013)	Viquerat et al. (2014)	Hammond et al. (2021)	this report

The MiniSCANS-II point estimate for harbour porpoise abundance in 2020 is lower than all previous estimates (Table 4). The second lowest estimate is from SCANS-II block S in 2005, although this block covered a larger area (Figure 6). The mean density for the overall study areas is similar between SCANS-II and MiniSCANS-II but precision varies. In order to reliably infer trends in harbour porpoise abundance a dedicated trend analysis should be applied to the time series, which was beyond the scope of this project. This analysis is currently planned in the framework of the EU-funded HELCOM BLUES project that aims to conduct a trend analysis using a Bayesian analysis framework for the Belt Sea population.

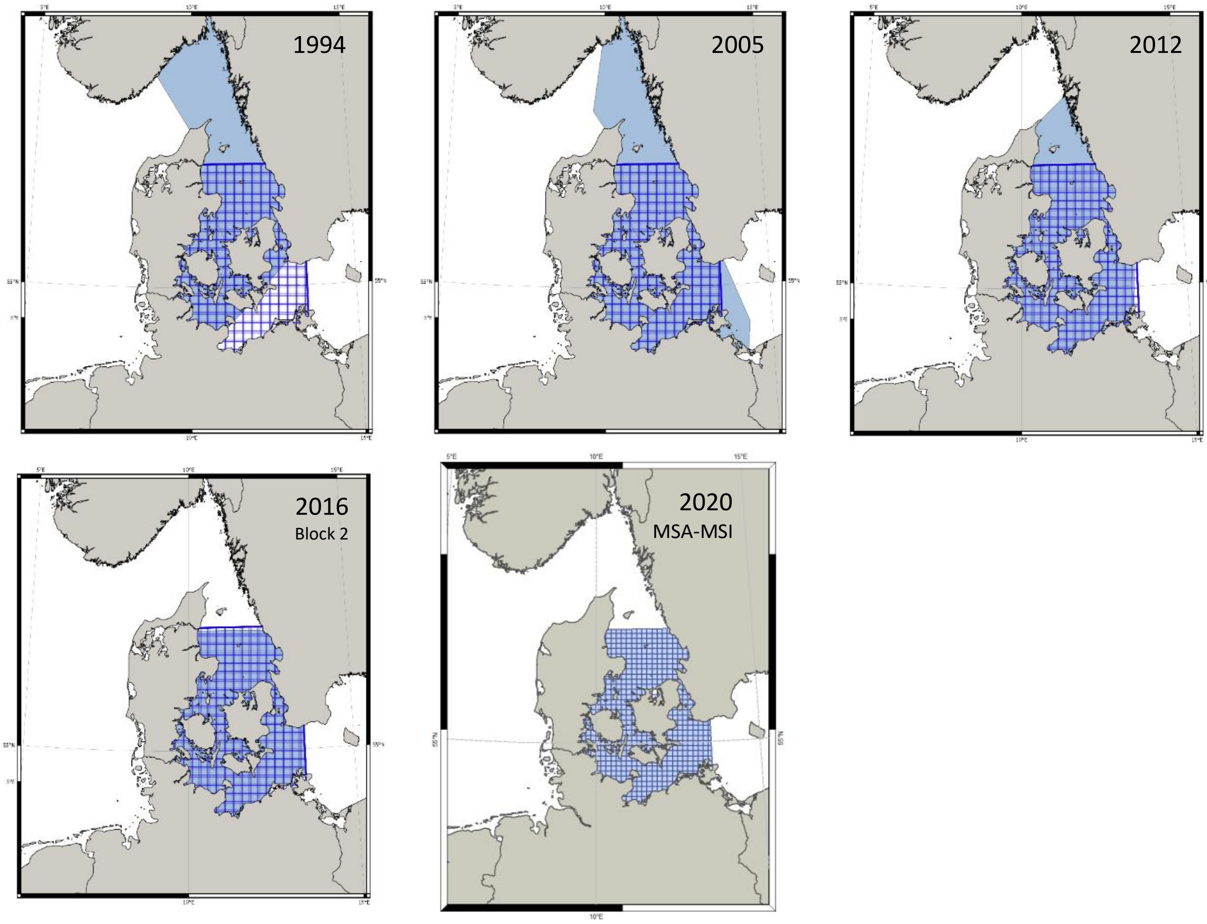


Figure 6. Areas covered during the three SCANS surveys (1994, 2005 and 2016) and the MiniSCANS surveys (2012 and 2020) in the Skagerrak/Kattegat/Belt Seas/western Baltic Sea (coloured light blue) compared with the area defined to represent the harbour porpoise Belt Sea population (Sveegaard et al., 2015) (cross-hatched dark blue). Figure modified from Hammond et al. (2021).

Spatial distribution and observed hot spots

The density of harbour porpoises varied within the survey area of the MiniSCANS-II survey (Figure 4). High densities were observed around the island of Fehmarn as well as around the southern coast of Langeland and Lolland. High densities were also observed around the Danish island of Samsø, in the central Kattegat as well as along the Swedish coastline (from Laholm Bight to the area around Gothenburg; see locations' names in Figure 1). Sighting rates and densities were low in The Sound, Great Belt and Little Belt. This was a surprise since higher densities were expected based on estimates from previous surveys. These three areas were also identified as high density areas by means of satellite tracked porpoises and passive acoustic monitoring and are designated SACs under the EU Habitats Directive. Keeping in mind that the confidence limits are overlapping with previous surveys, the low densities found in these areas in 2020 could indicate a decline in population abundance, but other factors like the change in survey method and/or the transect design as well as dynamics of the harbour porpoise population in the Belt Sea, should be considered. This population has been studied extensively by satellite tracking, showing that while some juveniles and sub-adults occasionally move temporally out of the population management unit and into the Baltic Sea proper and the North Sea, the adult animals have not shown a tendency to do so (Sveegaard et al., 2011). Furthermore, it is known that porpoises from the Belt Sea population have morphological adaptations and genetic isolation that indicate that they are specialized to live in this habitat (Wiemann et al., 2010; Galatius et al., 2012). Thus, we consider it unlikely that the change in distribution was due to porpoises inhabiting the Belt Sea area had moved out of this area.

Very low sighting rates and densities were found towards the east in the Baltic Sea, and only two sightings (one individual each) were recorded east of longitude 12.45° E (Figure 3, Figure 4).

Methodological considerations

Line-transect distance sampling surveys using different platforms (either ship or aircraft) are a reliable method for assessing the abundance and density of cetaceans. In all SCANS and MiniSCANS surveys a state-of-the-art double platform approach was implemented, which allows for the impact of missed animals on the transect line to be corrected. As a result, absolute abundance could be estimated and should be comparable between methods. Nevertheless, both ship-based and aerial surveys do have their own advantages and limitations. Aerial surveys can be used to cover a larger area in a shorter time, taking advantage of preferable weather windows, and can also access areas with difficult habitat conditions (e.g., rocky shores). Similarly, ship-based surveys are also able to cover large areas (particularly offshore), however surveys typically have a longer duration as the vessel moves much slower. However, given the slower speed, there is a higher likelihood of observing porpoises on vessel surveys and each sighting is typically observed several times. Detection probability and ESW is smaller from an aircraft than from a ship. However, ship surveys are restricted to the time of charter and are less flexible in adjusting to weather conditions. Especially for surveys of the elusive harbour porpoise, good weather conditions and calm sea states are of great importance for a reliable population estimate. Furthermore, ship surveys require a much larger observer and ship crew, a longer rental period and are therefore significantly more expensive, which is one of the reasons that this method is often less preferable.

There are several differences between the two platforms, but still, absolute abundance should be comparable between methods. The low abundance reported in MiniSCANS-II is not expected to be the result of full aerial survey coverage.

Observed anthropogenic activities

In stratum MSI (Rügen), during the survey on 03 July 2020, a pile-driving vessel was observed in the Danish offshore wind farm "Kriegers Flak" (Figure 7). Detailed information from the owner of "Kriegers Flak" offshore wind farm, Vattenfall, showed that pile-driving began in May 2020 and ended in the fall 2020. Requested activity protocols indicated that shortly before our aerial surveys, pile-driving was conducted between 00:47 and 04:00 on 02 July 2020 and between 05:42 and 09:03 on 03 July 2020. Foundations were driven into the seabed by piling, which was mitigated by a noise abatement system of double big bubble curtains (DBBC). In stratum MSI no harbour porpoise was observed and in the adjacent stratum MSE (The Sound) only two sightings were recorded despite good survey conditions. Whether the pile-driving and associated disturbance due to vessels on the construction site was a reason for porpoises to abandon the entire stratum is very speculative and unlikely, due to the reduced disturbance effect using DBBC noise abatement (Tougaard et al., 2009; Dähne et al., 2017). The area is expected to hold rather low densities of porpoises (e.g. Scheidat et al., 2008), but zero porpoise observations were not expected and additional explanations should therefore be considered.

In the northern part of the Little Belt, construction of the Baltic Pipeline was taking place at the time of the MiniSCANS-II survey (https://www.baltic-pipe.eu/). The Little Belt area was surveyed on 27 June, but during June 2020, as identified in the Baltic Pipe EIA, no pile-driving or other intense noise-generating activities were conducted (Jeppe Hjelmsted Floor, Energinet, 28 May 2020, pers. comm.). However, from 20-29 June a backhoe dredging vessel "Wadden 3", was dredging each day just north of the Little Belt Natura 2000 site, which may have disturbed the distribution of porpoises in the northern Little Belt.

Further anthropogenic activities observed during MiniSCANS-II included a variety of different vessel types including container ships, ferries and fishing vessels (Appendix A) and fishing activities, including set nets, throughout the survey area (Appendix B). The scope of this report is limited to depict the different anthropogenic activities observed while surveying.

Figure 7. The pile-driving ship "Svanen" photographed during the aerial survey conducted in area MSI (03 July 2020) ©ITAW, Nadya Ramírez-Martínez.

Conclusion

MiniSCANS-II was successfully conducted and estimated an abundance of 17,301 harbour porpoises (95% CI = 11,695-25,688; CV = 0.2), with a corresponding density of 0.41 individuals/km² (95% CI = 0.28-0.61), for the Belt Sea population. This is the lowest estimate since the first survey was conducted in 1994. However, the variance especially of the earlier estimates are high and, therefore, a dedicated trend analysis needs to be conducted. Still, the results should raise some concern about the status of the population, and it is important to repeat the survey soon with the same methodology to enlarge the time series of robust abundance estimates. This could be achieved in the framework of the planned SCANS-IV survey in 2022. The results presented here are integral to the assessment of the Belt Sea population as undertaken by HELCOM in its Holistic Assessment of the Ecosystem Health of the Baltic Sea (HOLAS) and for the Marine Strategy Framework Directive assessments of Good Environmental Status.

Acknowledgements

We thank the funding agencies for making this survey possible: the Danish Environmental Protection Agency, the German Federal Agency for Nature Conservation (BfN) and the Swedish Agency for Marine and Water Management (SwAM).

Special thanks to BioFlight A/S (Roskilde) for safe flights, flexibility in implementing ideas and organizing surveys short notice and for sharing their experience in different weather conditions. We would also like to thank them for their hospitality during the stay of the German crew in Denmark. Furthermore, we thank Philip Hammond and Claire Lacey to provide estimates, figures and tables from the SCANS surveys. We especially would like to thank our teams, the navigators, observers and "ground crew" for being flexible and available for conducting surveys even during these challenging times and always being supportive with words and deeds.

References

Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., Borchers, D.L. and Thomas, L. (2001). Introduction to distance sampling estimating abundance of biological populations.

Carlén, I., Thomas, L., Carlström, J., Amundin, M., Teilmann, J., Tregenza, N., Tougaard, J., Koblitz, J.C., Sveegaard, S., Wennerberg, D., Loisa, O., Dähne, M., Brundiers, K., Kosecka, M., Kyhn, L.A., Ljungqvist, C.T., Pawliczka, I., Koza, R., Arciszewski, B., Galatius, A., Jabbusch, M., Laaksonlaita, J., Niemi, J., Lyytinen, S., Gallus, A., Benke, H., Blankett, P., Skóra, K.E. and Acevedo-Gutiérrez, A. (2018). Basin-scale distribution of harbour porpoises in the Baltic Sea provides basis for effective conservation actions. Biological Conservation 226: 42-53. https://doi.org/10.1016/j.biocon.2018.06.031

Dähne, M., Tougaard, J., Carstensen, J., Rose, A. and Nabe-Nielsen, J. (2017). Bubble curtains attenuate noise from offshore wind farm construction and reduce temporary habitat loss for harbour porpoises. Marine Ecology Progress Series 580: 221-237

European Commission (2012). Commission note on the designation of special areas of conservation. European commission.

Galatius, A., Kinze, C.C. and Teilmann, J. (2012). Population structure of harbour porpoises in the Baltic region: evidence of separation based on geometric morphometric comparisons. Journal of the Marine Biological Association of the United Kingdom 92 (08): 1669-1676

Gilles, A., Scheidat, M. and Siebert, U. (2009). Seasonal distribution of harbour porpoises and possible interference of offshore wind farms in the German North Sea. Marine Ecology Progress Series 383: 295-307.10.3354/meps08020

Gilles, A., Viquerat, S., Becker, E., Forney, K., Geelhoed, S., Haelters, J., Nabe-Nielsen, J., Scheidat, M., Siebert, U. and Sveegaard, S. (2016). Seasonal habitat-based density models for a marine top predator, the harbor porpoise, in a dynamic environment. Ecosphere 7 (6): e01367

Habitats Directive (1992). Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. Official Journal of the European Union 206: 7-50

Hammond, P., Berggren, P., Benke, H., Borchers, D., Collet, A., Heide-Jørgensen, M., Heimlich, S., Hiby, A., Leopold, M.F. and Øien, N. (2002). Abundance of harbour porpoise and other cetaceans in the North Sea and adjacent waters. Journal of Applied Ecology 39 (2): 361-376

Hammond, P., Lacey, C., Gilles, A., Viquerat, S., Börjesson, P., Herr, H., Macleod, K., Ridoux, V., Santos, M. and Scheidat, M. (2021). Estimates of cetacean abundance in European Atlantic waters in summer 2016 from the SCANS-III aerial and shipboard surveys - Revised version.

Hammond, P.S., Benke, H., Breggren, P., Collet, A., Heide-Jørgensen, M.P., Heimlich-Boran, S., Leopold, M. and Øien, N. 1995. The distribution and abundance of harbour porpoises and other small cetaceans in the North Sea and adjacent waters. Final Report under European Commission, Project LIFE 92-2/UK/027. Sea Mammal Research Unit, Gatty Marine Laboratory, University of St Andrews, Fife, UK.

Hammond, P.S., Macleod, K., Berggren, P., Borchers, D.L., Burt, L., Cañadas, A., Desportes, G., Donovan, G.P., Gilles, A., Gillespie, D., Gordon, J., Hiby, L., Kuklik,

I., Leaper, R., Lehnert, K., Leopold, M., Lovell, P., Øien, N., Paxton, C.G.M., Ridoux, V., Rogan, E., Samarra, F., Scheidat, M., Sequeira, M., Siebert, U., Skov, H., Swift, R., Tasker, M.L., Teilmann, J., Van Canneyt, O. and Vázquez, J.A. (2013). Cetacean abundance and distribution in European Atlantic shelf waters to inform conservation and management. Biological Conservation 164: 107-122.10.1016/j.biocon.2013.04.010

Heide-Jørgensen, M.-P., Mosbech, A., Teilmann, J., Benke, H. and Schultz, W. (1992). Harbour porpoise (*Phocoena phocoena*) densities obtained from aerial surveys north of Fyn and in the Bay of Kiel. Ophelia 35 (2): 133-146

Heide-Jørgensen, M., Teilmann, J., Benke, H. and Wulf, J. (1993). Abundance and distribution of harbour porpoisesPhocoena phocoena in selected areas of the western Baltic and the North sea. Helgolander Meeresuntersuchungen 47 (3): 335-346

Hiby, L. (1999). The objective identification of duplicate sightings in aerial survey for porpoise. Marine mammal survey and assessment methods. Balkema, Rotterdam: 179-189

Hiby, L. and Lovell, P. (1998). Using aircraft in tandem formation to estimate abundance of harbour porpoise. Biometrics: 1280-1289

Lah, L., Trense, D., Benke, H., Berggren, P., Gunnlaugsson, Þ., Lockyer, C., Öztürk, A., Öztürk, B., Pawliczka, I. and Roos, A. (2016). Spatially explicit analysis of genome-wide SNPs detects subtle population structure in a mobile marine mammal, the harbor porpoise. PLoS One 11 (10): e0162792

Marine Strategy Framework Directive (2008). Directive 2008/56/EC of the European Parliament and of the Council. Journal. Council Decision of 2008

Marshall, L. (2020). dssd: Distance Sampling Survey Design. R package version 0.2.0. R. p. v. 0.2.0

Nachtsheim, D., Unger, B., Ramírez Martínez, N., Schmidt, B., Gilles, and Siebert, U. (2020). Monitoring of marine mammals in the German North and Baltic Sea in 2019. Report for Federal Agency for Nature Conservation, 7 pp.

Nachtsheim, D.A., Viquerat, S., Unger, B., Ramírez-Martínez, N.C., Siebert, U. and Gilles, A. (2021). Small cetacean in a human high-use area: Trends in harbour porpoise abundance in the North Sea over two decades. Frontiers in Marine Science 7: 1135

R Core Team (2018). R: A Language and Environment for Statistical Computing

Scheidat, M., Gilles, A., Kock, K.-H. and Siebert, U. (2008). Harbour porpoise *Phocoena phocoena* abundance in the southwestern Baltic Sea. Endangered Species Research 5 (2-3): 215-223.10.3354/esr00161

Sveegaard, S., Galatius, A., Dietz, R., Kyhn, L., Koblitz, J.C., Amundin, M., Nabe-Nielsen, J., Sinding, M.-H.S., Andersen, L.W. and Teilmann, J. (2015). Defining management units for cetaceans by combining genetics, morphology, acoustics and satellite tracking. Global Ecology and Conservation 3: 839-850.10.1016/j.gecco.2015.04.002

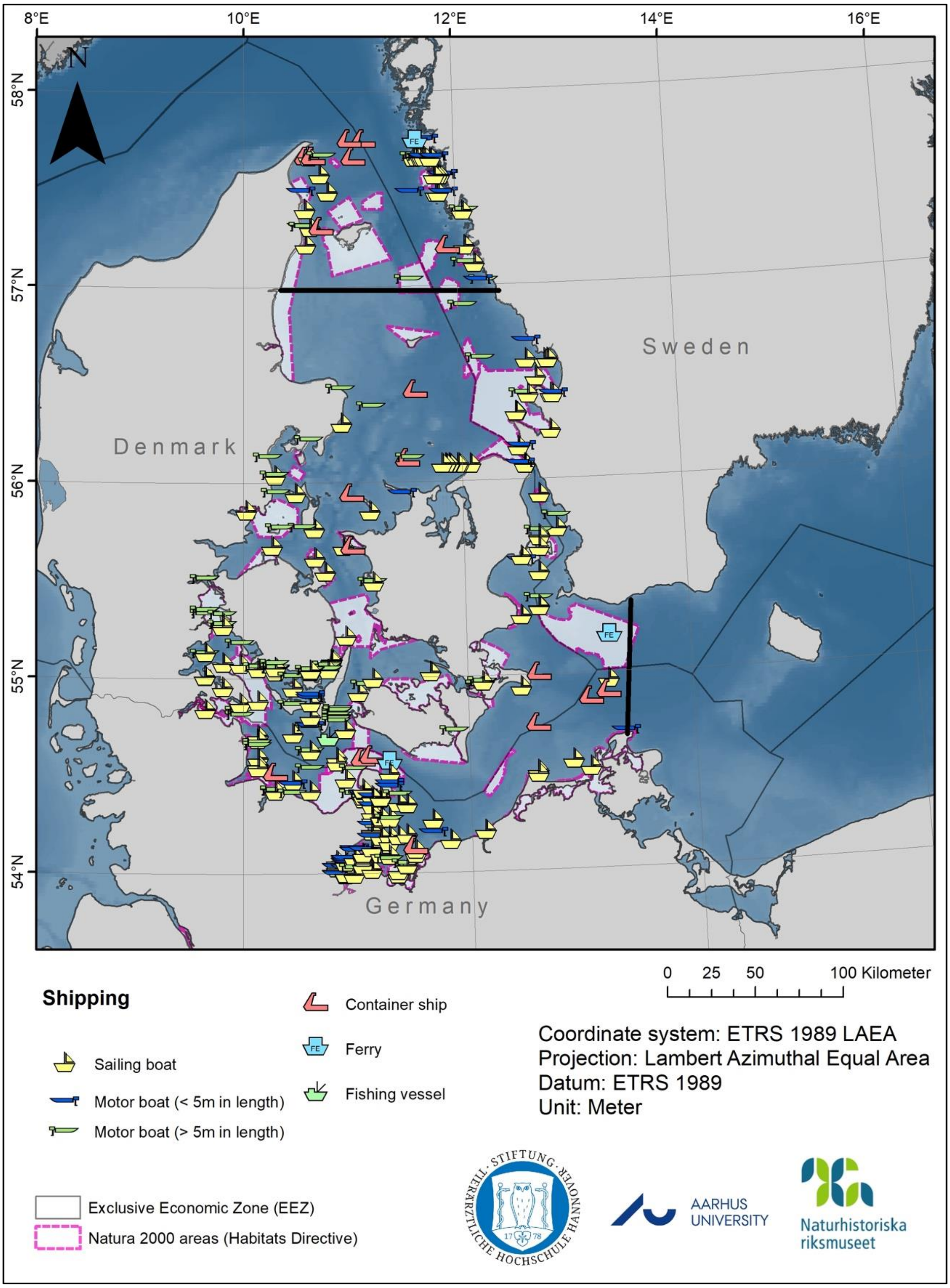
Sveegaard, S., Teilmann, J., Tougaard, J., Dietz, R., Mouritsen, K.N., Desportes, G. and Siebert, U. (2011). High-density areas for harbor porpoises (*Phocoena phocoena*) identified by satellite tracking. Marine Mammal Science 27 (1): 230-246

Tougaard, J., Carstensen, J., Teilmann, J., Skov, H. and Rasmussen, P. (2009). Pile driving zone of responsiveness extends beyond 20 km for harbor porpoises (*Phocoena phocoena* (L.)). The Journal of the Acoustical Society of America 126 (1): 11-14

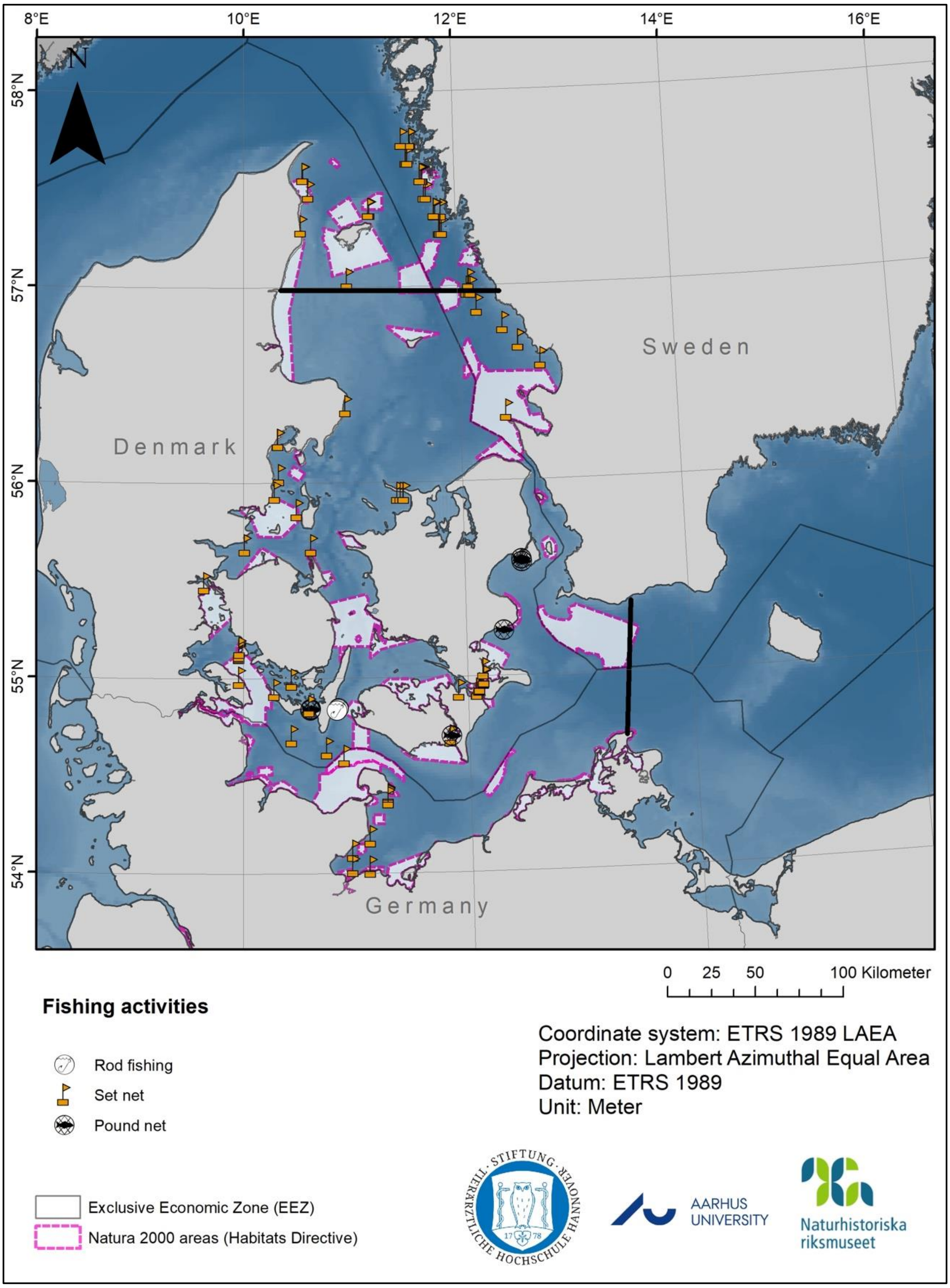
Viquerat, S., Herr, H., Gilles, A., Peschko, V., Siebert, U., Sveegaard, S. and Teilmann, J. (2014). Abundance of harbour porpoises (*Phocoena phocoena*) in the western Baltic, Belt Seas and Kattegat. Mar biol 161 (4): 745-754

Wiemann, A., Andersen, L.W., Berggren, P., Siebert, U., Benke, H., Teilmann, J., Lockyer, C., Pawliczka, I., Skóra, K. and Roos, A. (2010). Mitochondrial Control Region and microsatellite analyses on harbour porpoise (*Phocoena phocoena*) unravel population differentiation in the Baltic Sea and adjacent waters. Conservation Genetics 11 (1): 195-211

Appendix



Appendix A. Shipping activities and pile-driving activities in the offshore windfarm (Kriegers Flak) observed during MiniSCANS-II. The map shows all Natura 2000 areas in the study area, where the harbour porpoise is listed as protected species. The thick black lines indicate the borders of the management area of the Belt Sea population (defined in Sveegaard et al., 2015).



Appendix B. Fishing activities observed during MiniSCANS-II. The map shows all Natura 2000 areas in the study area, where the harbour porpoise is listed as protected species. The thick black lines indicate the borders of the management area of the Belt Sea population (defined in Sveegaard et al., 2015).