Marine mammal surveys in Dutch North Sea waters in 2019

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Contents

Summary

Aerial surveys to estimate the abundance of Harbour Porpoise *Phocoena phocoena* were conducted on the Dutch Continental Shelf in summer 2019. These surveys followed predetermined track lines in four areas: A - Dogger Bank, B - Offshore, C - Frisian Front & D - Delta. Between 16 July and 4 August the entire Dutch Continental Shelf (DCS) was surveyed.

Marine mammals were assessed using line transect distance sampling methods. Density and abundance estimates were calculated. In total, 150 sightings of 189 individual Harbour Porpoises were collected. Porpoise densities varied between 0.54-1.76 animals/km² in the areas A-D. The overall density was 0.66 animals/km². The lowest density (0.46 animals/km²) was recorded in area A – Dogger Bank. The densities in the other areas were in the same order of magnitude, ranging between 0.68-071 animals/km².

In summer 2019 the total number of Harbour Porpoises on the Dutch Continental Shelf (areas A-D) was estimated at 38,911 individuals (CI = 20,791-76,822). This estimates falls in the range of abundance estimates since 2010, with a minimum of 25,998 (CI = 13,988 – 53,623 in 2010) and a maximum of 76,773 (CI = 43,414-154,265 in 2014) individuals. The confidence intervals of the abundance estimates overlap, indicating no statistically significant differences between the years. The time series, however, is relatively short to measure trends.

These abundance estimates show that up to a fifth of the North Sea population, estimated at 345,000-361,000 individuals, has been present on the Dutch Continental Shelf during the summer surveys in 2010-2019.

The results of these aerial surveys will feed into the OSPAR MSFD indicator on abundance and distribution of marine mammals.

In total 26 sightings of other marine mammal species than Harbour Porpoises were recorded. These comprised 22 sightings of seals (Grey Seal *Halichoerus grypus* and Harbour Seal *Phoca vitulina)*. The majority of the seals was observed in coastal waters off the Wadden Isles. Three single Minke Whales *Balaenoptera acutorostrata* were seen (feeding) in area A – Dogger Bank and B – Offshore, with another one sighted off effort in the same area. One sighting of a pod of two White-beaked Dolphins *Lagenorhynchus albirostris* was made in area B – Offshore.

This research is part of the BO-project 'monitoring bruinvis'.

1 Introduction

In the Dutch Harbour Porpoise conservation plan (Camphuysen & Siemensma, 2011) abundance estimates of the Dutch population of Harbour Porpoise *Phocoena phocoena* have been identified as one of the research needs with the highest priority. These assessments are needed to monitor the density and distribution of this protected species. They can be used to describe trends in national waters, efficacy of management actions as well as to evaluate potential impacts of anthropogenic activities.

Abundance estimates for the entire Dutch Continental Shelf were lacking until 2010 (Scheidat et al., 2012). In July 2010-March 2011, under the umbrella of the Shortlist Masterplan Wind programme, dedicated aerial surveys of the entire Dutch Continental Shelf were conducted for the first time, in three different seasons (Geelhoed et al., 2011 & 2013a). These surveys resulted in abundance estimates and distribution maps of Harbour Porpoises, thus providing a baseline for subsequent surveys in order to study annual and seasonal variations in the numbers and distribution of porpoises in Dutch waters.

As a follow-up, surveys of the Dutch Continental Shelf were conducted in spring 2012 and 2013 (Geelhoed et al., 2013b, 2014a), summer 2014, 2015, 2017 and 2018 (Geelhoed et al., 2014b; 2015;, 2018ab; Geelhoed & Scheidat, 2018). In this report we present the results of the aerial surveys conducted in July-August 2019. It was the sixth time ever a complete dedicated survey of Dutch waters took place in summer.

These surveys are conducted under the umbrella of the BO-project monitoring bruinvis, funded by the Ministry of Agriculture, Nature and Food Quality of The Netherlands. Apart from aerial surveys this BO-project contains diet studies, and studies on contaminant loads in stranded harbour porpoises. The results of these studies are published separately.

2 Assignment

This report presents the aerial survey results using line transect distance sampling as described in the original assignment of KRM monitoring bruinvis, a continuation of the Beleidsondersteunend Onderzoek program of the Ministry of Economic Affairs. This assignment consisted of aerial surveys of marine mammals on the entire Dutch Continental Shelf in 2019.

3 Materials and Methods

3.1 Study area, survey design and data acquisition

The study area included the entire Dutch section of the continental shelf (59,417 km²). The study area was divided into four sub-areas: A - Dogger Bank (9,615 km²), B - Offshore (16,892 km²), C - Frisian Front (12,023 km²) and D - Delta (20,797km²) (Figure 1). The design of the track line set-up was chosen to be parallel in areas C and D and zigzag in area A and B to ensure a representative coverage of the sub-areas and minimize off effort time between track lines. In addition, the direction of track lines followed depth gradients in order to get a better sample by minimising variance in encounter rates between transect lines (Buckland et al., 2001). The survey design has been the same since the first aerial surveys were conducted in 2008 (Scheidat et al., 2012).

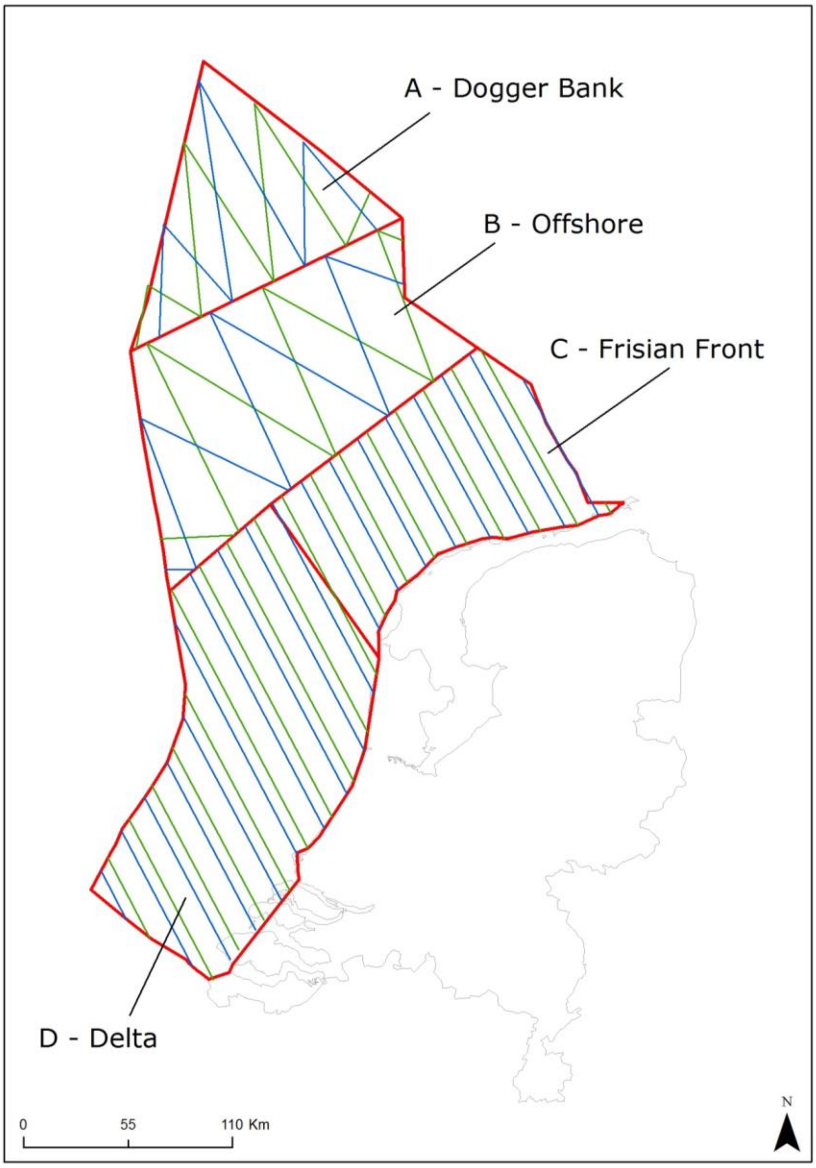

Figure 1. Map of the Dutch Continental Shelf with the planned track lines in study areas A - Dogger Bank, B - Offshore, C - Frisian Front and D - Delta. Colours indicate sets of track lines.

Surveys were conducted with a Partenavia 68, a high-winged twin-engine airplane equipped with bubble windows, flying at an altitude of ca. 183 m (600 ft) with a speed of ca. 186 km/hr (ca. 100 knots). Every four seconds the aircraft's position and time (to the nearest second) were recorded automatically onto a laptop computer connected to a GPS. Surveys were conducted by a team of three people. Sighting information and details on environmental conditions were entered by one person (the navigator) at the beginning of each transect and whenever conditions changed. Observations were made by two dedicated observers located at the bubble windows on the left and right sides of the aircraft. For each observation the observers acquired sighting data including species (all cetaceans and seals), declination angle measured with an inclinometer from the aircraft abeam to the group, group size, presence of calves, behaviour (Table 1), swimming direction, cue, and reaction to the survey plane. The perpendicular distances from the transect to the sighting were later calculated from aircraft altitude and declination angle. Environmental data included sea state (Beaufort scale), turbidity (4 classes, assessed by visibility of objects below the sea surface), cloud cover (in octaves), glare and subjective sighting conditions (Table 2). These sighting conditions represent each observer's subjective view of the likelihood that the observer would see a harbour porpoise within the search area should one be present, and could differ between left and right.

Table 1. Behavioural codes and description for marine mammals.

Code	Behaviour
Sw	directional swimming
Fasw	fast directional swimming or porpoising
Mill	milling, non-directional swimming
Log	resting/logging: not moving at the surface
Feed	Feeding
Headup	spyhop of seals vertically in the water column
Other	other behaviour, noted down in comments

Table 2. Description of subjective sighting conditions.

Sighting condition	Description
Good (G)	Observer's assessment that the likelihood of seeing a porpoise, should one occur within the search area, is good. Normally, good subjective conditions will require a sea state of two or less and a turbidity of less than two.
Moderate (M)	Observer's assessment that the likelihood of seeing a porpoise, should one occur within the searching area, is moderate. A subdivision between wicked (W) leaning towards good, and sucks (S) leaning towards poor is made.
Poor (P)	Observer's assessment that it is unlikely to see a porpoise, should one occur within the search strip.
Not possible to observe (X)	Observer off effort due to adverse circumstances

Surveys were conducted in weather conditions safe for flying operations (no fog or rain, visibility > 3km) and suitable for porpoise surveys (Beaufort sea state equal or less than 3). Surveys were conducted by Martin Baptist, Steve Geelhoed, Nicole Janinhoff and Hans Verdaat as observer and navigator. Peter Reijnhout from Zeelandair was the pilot.

3.2 Data quality check and data storage

All collected data was checked, e.g. for consistency of codes, corrected and subsequently stored in the Dutch database.

3.3 Data analysis

The survey data were collected using distance sampling techniques (Buckland et al., 2001; 2004). The collected sightings are used to calculate densities and abundance estimates, and to produce distribution maps. Only data from transect lines flown in good or moderate conditions were used in the analyses.
Densities and abundance estimates were calculated according to distance sampling methods, that yield absolute densities, i.e., the number of animals/km² with the associated 95% confidence interval (CI) and coefficient of variation (CV; Buckland et al., 2001). To do this the so called effective strip half-width

(ESW) is calculated. The ESW is calculated for each side of the track line separately. To obtain the first component to calculate the ESW the perpendicular distance of a sighting to the track line is measured. To calculate the distance of the sighting to the track line from air, the plane's altitude (600 feet = 183m) and the vertical or 'declination' angle to the animal are used. The latter is measured when it comes (or is estimated to come) abeam. By modelling a detection curve to all these distances the effective strip half-width is obtained; this is defined as the distance at which the expected number of detected objects would be the same as for the actual survey (Buckland et al., 2001).

One of the assumptions of line-transect distance sampling is that all animals on the track line are detected, which would mean that the chance to see all animals at a distance of 0 m from the track line is 1 (100%). For most animals, but in particular for cetaceans, this assumption is not true and a correction factor, called g(0), needs to be obtained to correct for the proportion of animals missed on the track line. In practice there are two reasons why animals are not recorded: 1. the animals are not "available" to be seen, (e.g. because they are sub-merged) or 2. they are missed by the observers ("observer bias"). To obtain a reliable estimate of absolute abundance (the number of animals in a given area e.g., the DCS) it is therefore needed to estimate the proportion of animals actually seen on the track line: the true value of g(0), and use the reciprocal of this value to correct the ESW. In the analysis g(0) values of 0.37 for good conditions and 0.14 for moderate conditions are used (taken from Scheidat et al., 2008).
Animal abundance in each stratum v (sub-areas A, B, C and D) was estimated using a Horvitz-Thompson-like estimator (Buckland et al., 2001; 2004) as follows:

$$\hat{N}_v = \frac{A_v}{L_v}\left(\frac{n_{\mathrm{gs}v}}{\hat{\mu}_{\mathrm{g}}} + \frac{n_{\mathrm{ms}v}}{\hat{\mu}_{\mathrm{m}}}\right)\bar{s}_v$$

where Av is the area of the stratum, L_v is the length of transect line covered on-effort in good or moderate conditions, n_{gsv} is the number of sightings that occurred in good conditions in the stratum, n_{msv} is the number of sightings that occurred in moderate conditions in the stratum, $\hat{\mu}_{\mathrm{g}}$ is the estimated total effective strip width in good conditions, $\hat{\mu}_{\mathrm{m}}$ is the estimated total effective strip width in moderate conditions and $\bar{s}_v$ is the mean observed school size in the stratum.

Group abundance by stratum was estimated by $\hat{N}_{v(\mathrm{group})} = \hat{N}_v / \bar{s}_v$

Total animal and group abundances of the entire Dutch Continental Shelf were estimated by:

$$\hat{N} = \sum_v \hat{N}_v \quad \text{and} \quad \hat{N}_{(\mathrm{group})} = \sum_v \hat{N}_{v(\mathrm{group})}$$

respectively. Densities were estimated by dividing the abundance estimates by the area of the associated stratum. Average group size across strata was estimated by $\hat{E}[s] = \hat{N} / \hat{N}_{(\mathrm{group})}$.
Coefficients of variation (CV) and 95% confidence intervals (CI) were estimated by a non-parametric bootstrap (999 replicates) within strata, using transect segments as the sampling units. The variance due to estimation of ESW was incorporated using a parametric bootstrap procedure which assumes the ESW estimates to be normally distributed random variables. More details on this method can be found in Scheidat *et al.* (2008; 2012).

Distribution maps were created by calculating densities per 1/9 ICES grid cell. This 1/9 ICES grid has latitudinal rows at intervals of 10', and longitudinal columns at intervals of 20'. ICES 1/9 rectangles intersecting with the DCS measure approximately 20x20km, resulting in areas ranging from 388 to 409 km^2, depending on latitude.
Densities per 1/9 ICES grid cell were calculated by dividing the total number of animals observed during good and moderate conditions by the total surveyed area. The surveyed area is the distance travelled multiplied by the total effective strip width (ESW). The effective strip half-width (ESW corrected for g(0) values) was defined as 76.5 m for good sighting conditions and 27 m for moderate sighting conditions on each side of the track line (Gilles et al., 2009; Scheidat et al., 2008). Densities in grid cells extending outside the borders of the surveyed area (e.g., the Wadden Sea) could be less reliable due to lower effort and habitat discontinuities within the grid cell. Grid cells with an effort less than 1 km^2 were omitted from the density calculations.

4 Results

4.1 Weather conditions and survey effort

The entire Dutch Continental Shelf was surveyed on three extensive days in the period 16 July-4 August (Figure 2, Table 3). Adverse and rapidly changing weather conditions after 17 July made it impossible to survey areas A – Dogger Bank and B – offshore shortly after the first flights. All in all, a total distance of 2142.2 km was surveyed on effort. Of this distance 76.5% was surveyed with good or moderate conditions on at least one side of the plane (Table 4).

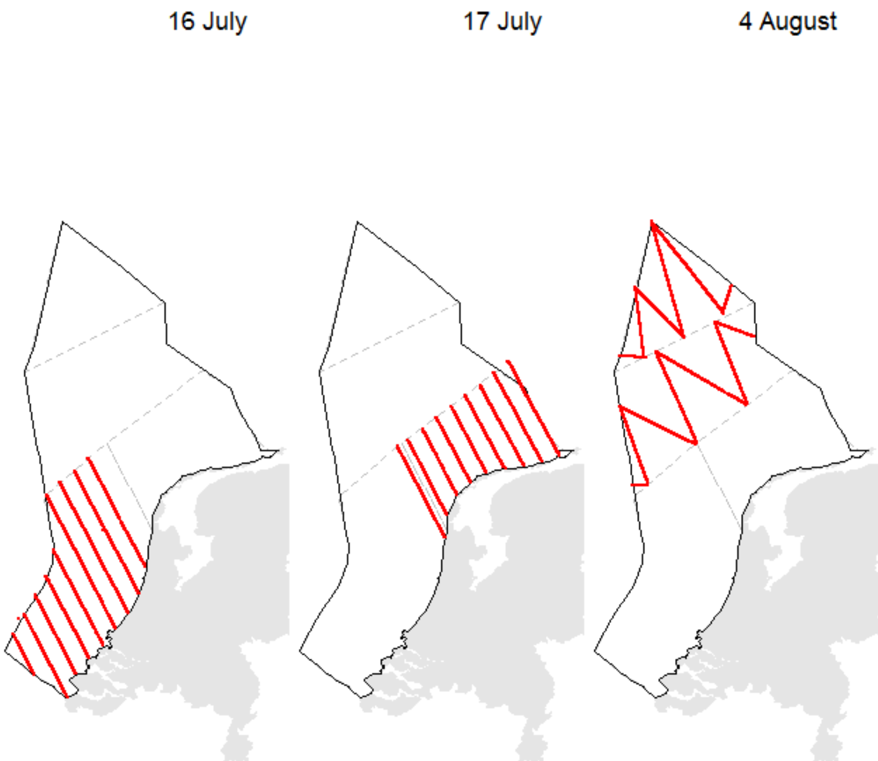

Figure 2. Survey effort per day July-August 2019.

Table 3. Survey dates and surveyed areas in July-August 2019.

Survey date	Surveyed area
16 July	Area D – Delta
17 July	Area C - Frisian Front & Area D – Delta
4 August	Area A - Dogger Bank & Area B – Offshore

Table 4. Total survey days, effort (surveyed distance), sighting conditions (g – good, m – moderate, p – poor, x – not possible to observe) and Harbour Porpoise sightings on both sides during the aerial surveys in July-August 2019. Navigator sightings are excluded.

Effort (km)	Sighting conditions (%)			Harbour Porpoise sightings (n)		
	G	m	p/x	Sightings	Individuals	Calves
2142.2	11.6	64.9	23.5	150	189	12

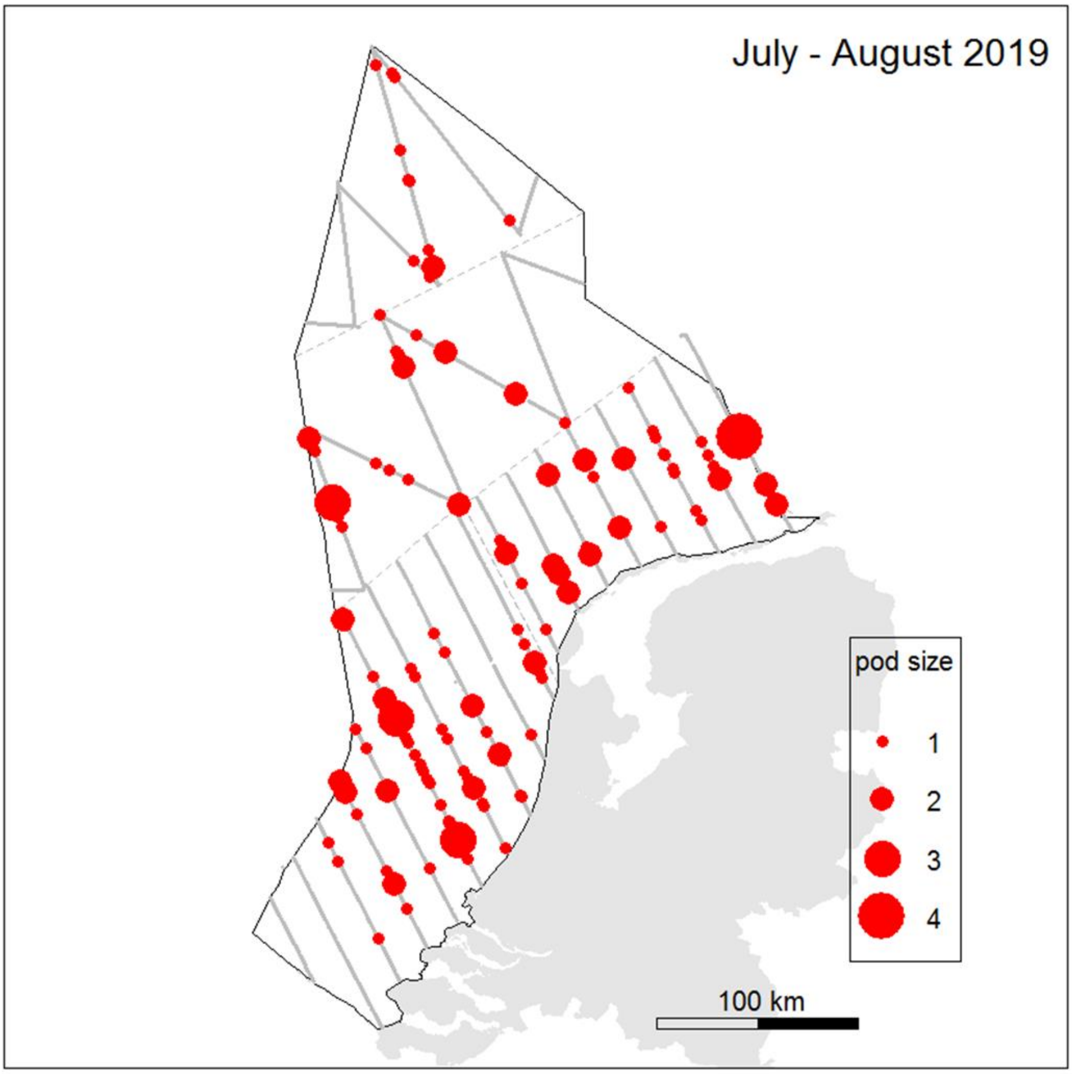

Figure 3. Harbour Porpoise sightings during the DCS survey in July-August 2019 (n =150).

4.2 Harbour Porpoise sightings – pod size and behaviour

In total, 150 sightings with 189 individual Harbour Porpoises, including 12 calves (6%), were collected (Table 4). These sightings are shown in Figure 3. Most sightings concerned single individuals, with an average pod size of 1.3 individuals.

The majority of the sightings concerned directionally swimming animals (69%, n = 103); 16% was milling or resting at the surface (n = 25). One animal was qualified as feeding, associated with a fish ball, and attracted seabirds.

4.3 Harbour Porpoise - distribution

The distribution of porpoises (animals/km²) per 1/9 ICES grid cell is shown in Figure 4. Harbour Porpoises were widely distributed and showed a homogenous distribution in a band from area D – Delta north to the southern part of area B - offshore. The distribution was more patchy in the areas north of this band, but Harbour Porpoises were virtually absent in large areas in northern part of area B - offshore and the adjacent southern part of area A – Dogger Bank.

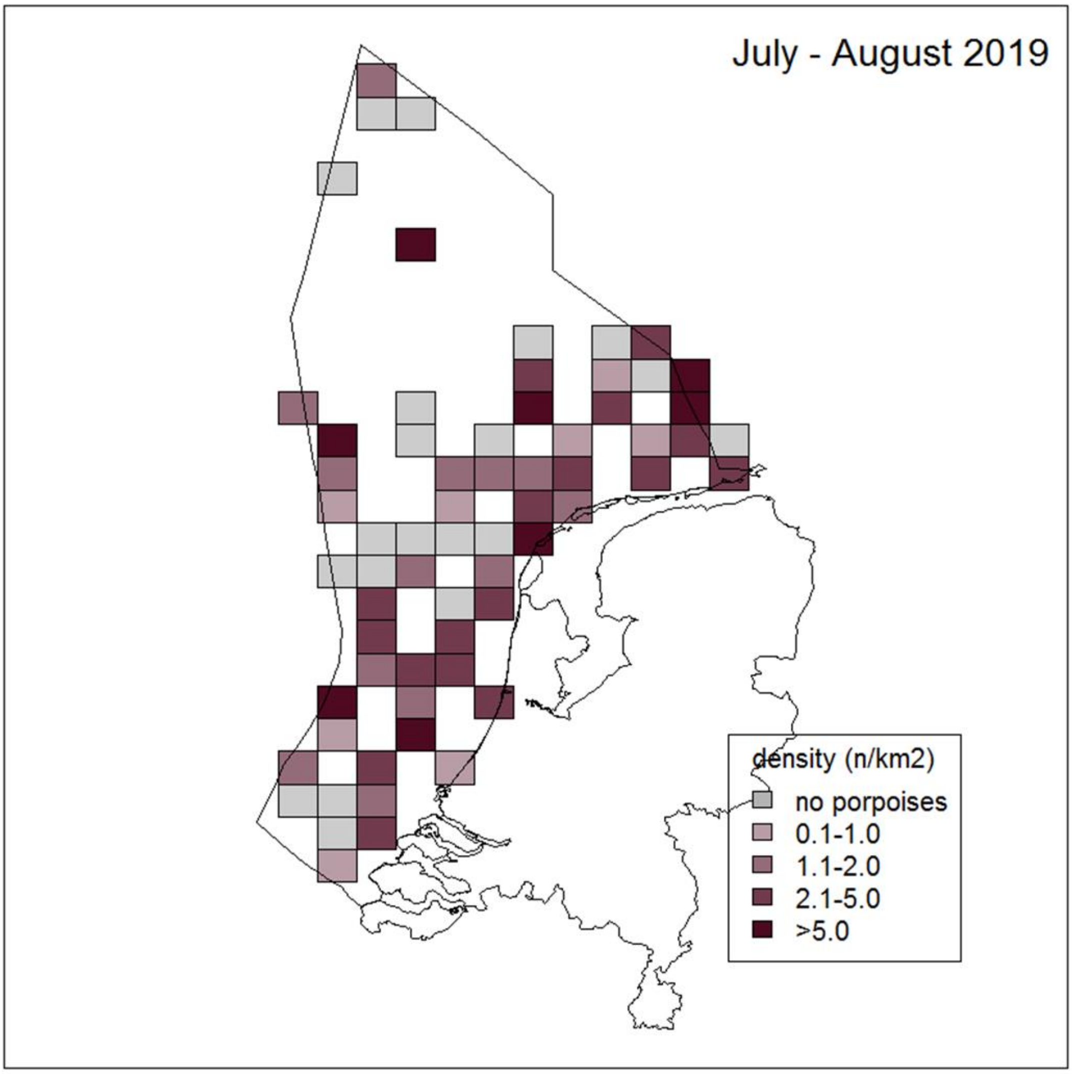

Figure 4. Density distribution of Harbour Porpoises (animals/km²) per 1/9 ICES grid cell, July-August 2019. Only sightings under good and moderate conditions were used. Grid cells with low effort (< 1 km²) are omitted.

4.4 Harbour Porpoise - densities and abundance estimates

Densities of Harbour Porpoises were estimated for each survey stratum (areas A-D) as well as for the whole DCS. Table 5 gives an overview of density (animals/km²) as well as abundance estimate (number of animals) per survey area. The overall density was 0.66 animals/km². The lowest density (0.46 animals/km²) was recorded in area A – Dogger Bank. The densities in the other areas were in the same order of magnitude, ranging between 0.68-071 animals/km² (Table 5).

Table 5. Abundance estimates of Harbour Porpoises for July-August 2019 per area.

	Density (animals/km²)	**95% CI**	**Abundance (n animals)**	**95% CI**	**CV**
Area A – Dogger Bank	0.46	0.11 - 1.05	4380	1017 - 10,056	0.51
Area B – Offshore	0.68	0.29 - 1.39	11,557	4825 - 23,437	0.38
Area C – Frisian Front	0.69	0.40 - 1.34	8262	4780 - 16,093	0.32
Area D – Delta	0.71	0.24 - 1.64	14,713	4987 - 34,130	0.48
Total DCS	0.66	0.35 -1.39	38,911	20,791 - 76,822	0.35

These densities correspond to a total number of Harbour Porpoises on the Dutch Continental Shelf (areas A-D) of 38,911 animals (CI = 20,791 - 76,822, Table 5) in July -August 2019. The numbers of animals were more or less proportionately distributed over the areas, with areas B, C and D holding 88.7% of all animals, whilst they comprise 83.4% of the total area of the DCS.

4.5 Other marine mammals - sightings

During the surveys 27 sightings of other marine mammal species were made on effort (Table 6). Two other cetacean species than Harbour Porpoise were observed: Minke Whale Balaenoptera acutorostrata., and White-beaked Dolphin Lagenorhynchus albirostris. Three Minke Whales were seen in the northern part of the DCS, in area A Dogger Bank and in the northwest corner of area B - Offshore on the 4th of August (Figure 5). Several fish balls and feeding seabirds were also seen in these areas. One of the Minke Whales was feeding, accompanied by tens of Northern Gannets Morus bassanus and Black-legged Kittiwakes Rissa tridactyla. Off effort one more sighting of a single animal was made in this area. One small pod of two White-beaked Dolphins was seen in area B – Offshore (Figure 6).

Seals (Grey Seal *Halichoerus grypus* and Harbour Seal *Phoca vitulina)* were seen in all areas, but the majority was seen in the vicinity of the coast, with a concentration north of the Wadden Isles near their haul out sites (Figure 7). Most seals were not identified to species level, but Grey Seals (n = 4) were seen in Areas B – Offshore and in the northwest of area D – Delta. The coastal sightings were not identified to species level, but the majority was tentatively identified as Harbour Seal. Numbers of seals, Minke Whale and White-beaked Dolphin were too low to calculate densities and abundance estimates.

Table 6. Total survey days, effort (surveyed distance), and on effort sightings of marine mammals other than Harbour Porpoise during the aerial surveys in July-August 2019.

Effort	**Minke Whale**		**White-beaked Dolphin**		**Seals**	
(km)	**Sightings**	**N**	**Sightings**	**N**	**Sightings**	**N**
2142.2	3	3	1	2	22	23

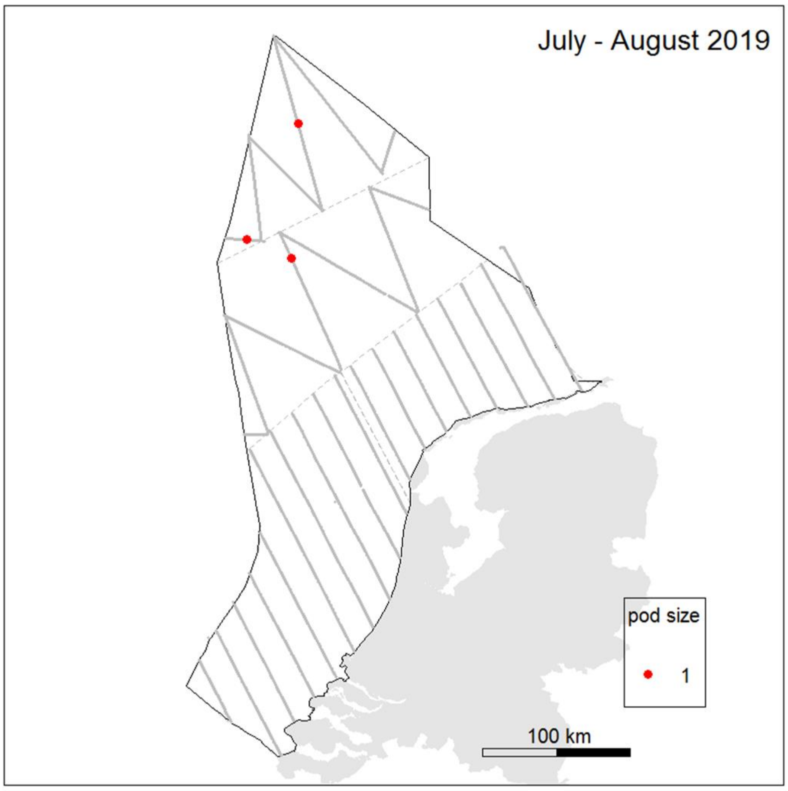

Figure 5. Minke whale sightings during the DCS survey in July-August 2019.

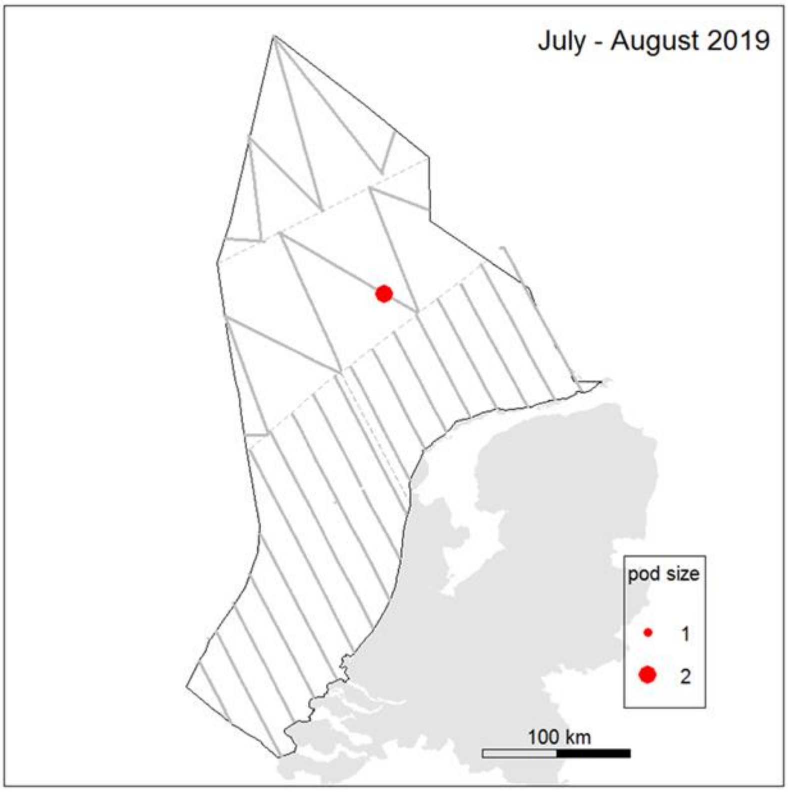

Figure 6. White-beaked Dolphin sightings during the DCS survey in July-August 2019.

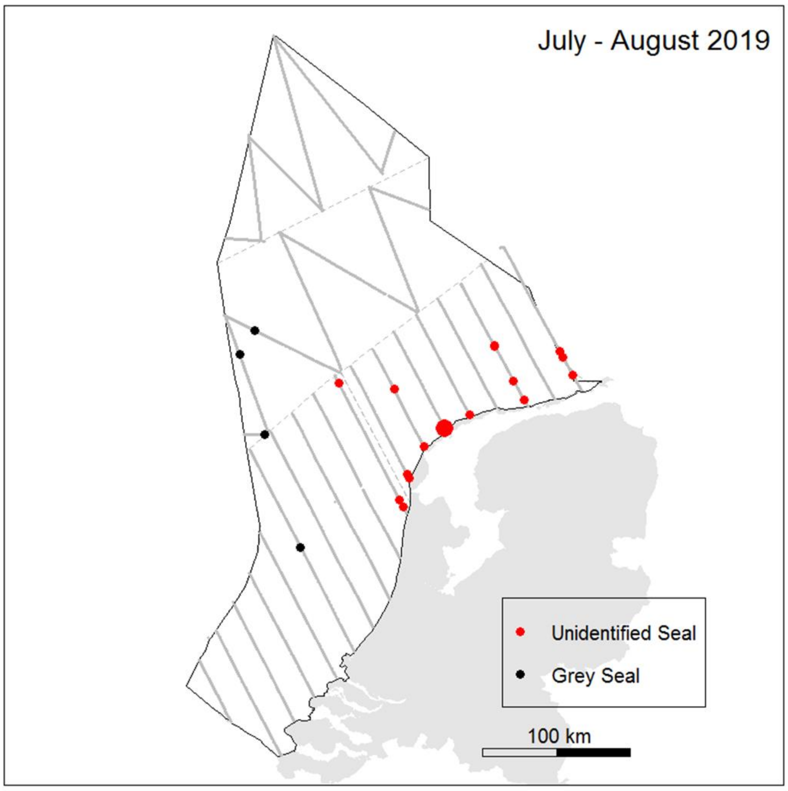

Figure 7. Seal sightings during the DCS survey in July-August 2019.

5 Discussion

Wageningen Marine Research and its predecessor IMARES have been conducting aerial surveys in Dutch North Sea waters since May 2008. Five DCS wide surveys have been conducted previously in the month of July, in 2010, 2014, 2015, 2017 and 2018. Densities and abundance estimates of Harbour Porpoises are presented in Table 7 and the appendix, showing that summer densities vary between 0.14 and 3.08 animals/km^2 in the different years, highlighting that the density between the sub-areas is highly variable.

The abundance estimate for the DCS in 2019 of 38,911 individuals (CI = 20,791-76,822) lies between the minimum estimate in 2010 (n = 25,998; CI = 13,988 – 53,623) and the maximum estimate in 2014 (n = 76,773; CI = 43,414-154,265). Neither the DCS abundance estimate, nor the abundance estimates per sub-area show a trend. The confidence intervals of the abundance estimates overlap, indicating no statistically significant differences between the years. The time series, however, is relatively short to measure trends.

Table 7. Density and abundance estimates of Harbour Porpoises obtained in July 2010-2019 (Geelhoed et al. 2011, 2013a, 2014b. 2018, 2019, Geelhoed & Scheidat 2018).

	Density (animals/km^2)	**C95% CI**	**Abundance (n animals)**	**95% CI**	**CV**
2010	0.44	0.24-0.90	25,998	13,988–53,623	0.34
2014	1.29	0.73–2.60	76,773	43,414–154,265	0.34
2015	0.70	0.36-1.34	41,299	21,194-79,256	0.33
2017	0.79	0.41–1.86	46,902	24,389–93,532	0.35
2018	1.07	0.58-2.02	63,514	34,276-119,734	0.32
2019	0.66	0.35-1.39	38,911	20,791- 76,822	0.35

The Harbour Porpoises in Dutch waters belong to the population that uses the wider North Sea (Evans et al., 2009). This whole area was surveyed during the summers of 2005 and 2016 (SCANS-II and SCANS-III), resulting in an abundance estimate of 355.000 and 345.000 individuals respectively (Hammond et al., 2013, 2017). Using a model-based approach, with the SCANS data and national surveys, Gilles et al. (2016) estimated the population size to number 361,000 individuals in 2005-2013. The results from the DCS surveys indicate that up to a fifth of the North Sea population has been present on the Dutch Continental Shelf in summer 2010-2019.

6 Conclusions

The dedicated aerial survey of the Dutch Continental Shelf in summer 2019 resulted in an abundance estimate of 38,911 individuals (CI = 20,791-76,822). This estimate falls within the range of abundance estimates since 2010, with a minimum of 25,998 (CI = 13,988 – 53,623 in 2010) and a maximum of 76,773 (CI = 43,414-154,265 in 2014) individuals. The confidence intervals of the abundance estimates overlap, indicating no statistically significant differences between the years. The time series, however, is relatively short to measure trends.

These abundance estimates show that up to a fifth of the North Sea population, estimated at 345,000-361,000 individuals, has been present on the Dutch Continental Shelf during the summer surveys in 2010-2019.

The results of these aerial surveys will feed into the OSPAR MSFD indicator on abundance and distribution of marine mammals.

The Dutch aerial survey results has been used to assess the impact of anthropogenic activities in Dutch waters, as well as on an international scale. One impact is the bycatch of harbour porpoise in Dutch gillnet fisheries. Using the estimated bycatch rates in combination with the abundance estimates allowed an assessment of the scale of the impact on the (national) population (Scheidat et al., 2018). The Dutch aerial survey data has also been fed into an international database of all North Sea range states that apply the same 'SCANS-like' methodology. This includes survey efforts in Denmark, Germany, the UK and Belgium as well as the actual SCANS surveys. This database provided the data needed to model the impact of anthropogenic noise, such as produced through piling of wind mills, in the North Sea. It has also been used in other assessment schemes, such as presented by Merchant et al. (2018). The need for long-term comparable and high quality datasets remains high in the future as large-scale changes in the North Sea ecosystem are predicted. The highly mobile harbour porpoise reacts quickly to changes in the food availability, and as such is an indicator in the ecosystem. It is also a species considered especially vulnerable to a number of human activities and as such is a good indicator species for the impacts these can have on its population as well as the system.

7 Quality Assurance

Wageningen Marine Research utilises an ISO 9001:2015 certified quality management system. This certificate is valid until 15 December 2021. The organisation has been certified since 27 February 2001. The certification was issued by DNV GL.

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9 Appendix: abundance estimates and densities, 2010-2019

2019	**Density (animals/km²)**	**C95% CI**	**Abundance (n animals)**	**95% CI**	**CV**
Area A – Dogger Bank	0.46	0.11 - 1.05	4380	1017 - 10,056	0.51
Area B – Offshore	0.68	0.29 - 1.39	11,557	4825 - 23,437	0.38
Area C – Frisian Front	0.69	0.40 - 1.34	8262	4780 - 16,093	0.32
Area D – Delta	0.71	0.24 - 1.64	14,713	4987 - 34,130	0.48
Total DCS	0.66	0.35 -1.39	38,911	20,791 - 76,822	0.35
2018	**Density (animals/km²)**	**C95% CI**	**Abundance (n animals)**	**95% CI**	**CV**
Area A – Dogger Bank	0.63	0.30 - 1.43	6020	2859 - 13,704	0.41
Area B – Offshore	1.76	0.87 - 3.44	29,722	14,663 - 58,170	0.36
Area C – Frisian Front	1.38	0.63 - 2.84	16,595	7618 - 34,120	0.37
Area D - Delta	0.54	0.26 - 1.06	11,176	5400 - 22,078	0.35
Total DCS	1.07	0.58 - 2.02	63,514	34,276 - 119,734	0.32
2017					
Area A – Dogger Bank	0.14	0.01 - 0.29	1325	167 – 2833	0.46
Area B – Offshore	1.28	0.55 - 2.92	21,584	9229 – 49,331	0.44
Area C – Frisian Front	0.53	0.08 - 1.53	6360	991– 18,402	0.64
Area D - Delta	0.85	0.41 - 1.66	17,631	8595 – 34,552	0.37
Total DCS	0.79	0.41 – 1.86	46,902	24,389 – 93,532	0.35
2015					
Area A – Dogger Bank	1.12	0.43-2.25	10,748	4113 – 21,676	0.39
Area B – Offshore	0.80	0.17-1.20	13,573	7 002 – 26,606	0.35
Area C – Frisian Front	0.44	0.20-0.98	5304	2354 -11,798	0.43
Area D - Delta	0.56	0.41-1.58	11,674	3542 -24,958	0.45
Total DCS	0.70	0.36-1.34	41,299	21,194- 79,256	0.33
2014					
Area A – Dogger Bank	3.08	1.50 -6.45	29,689	14,375 – 61,995	0.37
Area B – Offshore	0.37	0 – 1.21	6297	0 – 20,509	0.96
Area C – Frisian Front	1.83	0.97 – 4.11	22,010	11,623 – 49,439	0.39
Area D - Delta	0.90	9.46 – 1.84	18,778	9548 – 38,167	0.36
Total DCS	1.29	0.73 – 2.60	76,773	43,414 – 154,265	0.34
2010					
Area A – Dogger Bank	0.40	0.18 - 0.85	3806	1738 – 8165	0.40
Area B – Offshore	0.48	0.21 - 1.06	8055	3589 – 17,872	0.42
Area C – Frisian Front	0.34	0.05 - 0.89	4039	553 – 10,701	0.62
Area D - Delta	0.48	0.21 - 1.06	10,098	4341 – 22,024	0.40
Total DCS	0.44	0.24 - 0.90	25,998	13,988 – 53,623	0.34

Justification

Report C016/20
Project Number: 4312100087

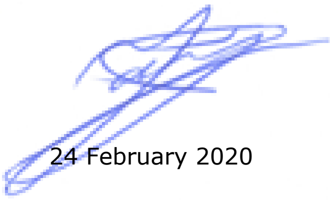
The scientific quality of this report has been peer reviewed by a colleague scientist and a member of the Management Team of Wageningen Marine Research

Approved: Meike Scheidat
Senior researcher
Wageningen Marine Research

Signature: 

Date: 24 February 2020

Approved: Jakob Asjes
Manager Integration
Wageningen Marine Research

Signature: 

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With knowledge, independent scientific research and advice, **Wageningen Marine Research** substantially contributes to more sustainable and more careful management, use and protection of natural riches in marine, coastal and freshwater areas

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