Chapter 10. Spatio-temporal patterns of the harbour porpoise *Phocoena phocoena* in the Belgian part of the North Sea

J. Haelters¹, T.G. Jacques², F. Kerckhof¹ & S. Degraer²

¹Royal Belgian Institute of Natural Sciences, Management Unit of the North Sea Mathematical Models (MUMM), Marine Ecosystem Management Section, 3de en 23ste Linieregimentsplein, 8400 Oostende

²Royal Belgian Institute of Natural Sciences, Management Unit of the North Sea Mathematical Models (MUMM), Marine Ecosystem Management Section, Gulledelle 100, Brussels

*Corresponding author: J.Haelters@mumm.ac.be

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Abstract

The placement of offshore wind farms can have consequences for the ecosystem; one of the ecosystem components for which concerns exist is marine mammals. As the most common marine mammal in the Belgian part of the North Sea (BPNS) is the harbour porpoise, the focus of impact assessment lies on this species. Aerial surveys yielded actual population size estimates of low hundreds of animals up to 4000 individuals, which constitutes approximately 1.6% of the total North Sea population. Therefore the harbour porpoise should be considered a significant top of the food chain constituent of the BPNS. Passive acoustic monitoring using Porpoise Detectors (PoDs) demonstrated its potential to add to the information obtained through aerial surveys. Strandings data over four decades indicate a recent increase of the species in the southern North Sea, due to a southward shift in the population. The combined data from aerial surveys, passive acoustic monitoring and strandings monitoring revealed a clear seasonal pattern, with harbour porpoises being typically abundant in late winter and early spring (min. on average 0.68 ind./km²), while lower numbers (max. on average 0.31 ind./km²) tend to stay in more offshore and northerly waters from late spring to autumn. Erratic invasions of harbour porpoises in the BPNS might however blur the general seasonal spatio-temporal pattern, which complicates our understanding of its spatial distribution and migration behaviour. The combination of results obtained from different monitoring methods allows for a general assessment of the reference situation of this species, before the major development of offshore wind farms in Belgian waters.

Samenvatting

Het plaatsen van offshore windparken in de Noordzee kan gevolgen hebben voor het ecosysteem. Zeezoodieren vormen één van de ecosysteem componenten waarover bezorgdheid bestaat. Het inschatten van effecten concentreert zich op de bruinvvis, gezien dit het meest algemeen voorkomende zeezoodier is in Belgische wateren. Luchtsurveys toonden aan dat tussen enkele honderden en 4000 bruinvissen voorkomen in het Belgische deel van de Noordzee, of tot ongeveer 1.6% van de Noordzeepopulatie. Vandaar dat deze soort beschouwd wordt als een belangrijke toppredator in deze wateren. Naast luchtsurveys hebben ook andere technieken zoals passieve akoestische monitoring met Porpoise Detectors (PoDs) hun potentieel bewezen voor het aanleveren van extra informatie. Strandingsgegevens tonen aan dat in het laatste decennium een sterke stijging is opgetreden in het aantal bruinvissen in de zuidelijke Noordzee, als gevolg van een verschuiving van de populatie. De combinatie van luchtsurveys, passieve akoestische monitoring en de analyse van strandingsgegevens toont een duidelijk seizoenaal beeld, met een algemeen voorkomen van bruinvissen in de late winter en vroege lente (min. gemiddeld 0.68 ind./km²), en een lager aantal (max. gemiddeld 0.31 ind./km²), verder van de kust, van de late lente tot de herfst. Een onregelmatig voorkomende influx van dieren uit meer noordelijke wateren kan dit algemeen patroon vertroebelen. De combinatie van de resultaten van verschillende onderzoeksmethoden laat toe een algemene inschatting te voorzien voor de referentiesituatie m.b.t. bruinvissen in Belgische wateren, vóór de belangrijke ontwikkeling van offshore windparken.

10.1. General introduction

Recently, initiatives were taken to construct offshore wind farms in Belgian waters. Concern exists about the ecological impact of the construction and exploitation of offshore wind farms. For instance, in cetaceans the exposure to excessive noise can lead to damage, in the form of a temporary or permanent hearing threshold shift (Southall et al., 2007; Thompson, 2000; Verboom & Kastelein, 2005). Pile driving activities can disturb porpoises over tens of kilometres (Brandt et al., 2009; Diederichs et al., 2009; Lucke, 2010; Tougaard et al., 2006; 2009). As such, the monitoring of marine mammals is of vital importance for an adequate assessment of actual and possible effects of human activities at sea, such as offshore wind farms. On the basis of these assessments, measures can be proposed to avoid and/or mitigate impacts on the population of these protected species. Therefore,
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10.2. Material and methods

For investigating the baseline situation (population size, spatial and temporal occurrence) of the harbour porpoise in the Belgian part of the North Sea (BPNS), a combination of methods was used:

- aerial line transect sampling to assess population size and spatial distribution;
- passive acoustic monitoring (PAM) to investigate short- to medium-term variability (weeks to months) in (relative) abundance of harbour porpoises;
- strandings data analysis to extract information on medium- to long-term variability (months to years) in occurrence.

The multi-method monitoring approach allows for a combination of the results of the different monitoring activities, which leads to a total scientific value higher than the mere sum of the individual approaches. Such combined approach is needed given the difficulties in elucidating the population dynamics of the most common marine mammal in one of the best studied marine areas in the world.

10.2.1. Aerial line transect sampling

The use of aerial surveys is considered a highly efficient way to assess the population size and distribution of marine mammals, especially in coastal waters with an airfield nearby. The advantage over ship based surveys is that predefined track lines can be covered easily, without having to take account of shipping lanes, anchorage areas and shallows. Also, a large area can be covered in a short period of time. The survey methodology used during 2008 and 2009 is line transect sampling (Buckland et al., 2001), in which a number of tracks are flown and observations are recorded together with their perpendicular distance to the observation platform.

The aircraft used was a high wing two-engine Norman Britten Islander, owned by the Royal Belgian Institute of Natural Sciences (RBINS). This aircraft was originally equipped with only one bubble window, allowing for only the observations of the observer at the bubble window to be used for analysis. From spring 2009 onwards, after the installation of a second bubble window, the observations of two observers could be used. The survey altitude was 600 ft (183 m), and the groundspeed was kept at 100 knots (185 km/h). Flights were only performed during good to moderate observation conditions (sea states of 1 to 2). The surveys covered parallel track lines, 5 km apart and perpendicular to the coastline to follow an onshore – offshore gradient. For practical and flight-technical reasons, survey tracks only started 5 km from the shore.

Observations of marine mammals were recorded, together with the angle perpendicular to the aircraft at which the animals were seen. A hand-held SUUNTO PM-5/360PC clinometer was used to measure the angle, from which the perpendicular distance to the aircraft was calculated. The track and
position of observations were recorded by GPS. The observations, together with the distances from the aircraft, allow for modelling a detection probability: the probability to observe an animal at a certain distance from the aircraft (Buckland et al., 2001). For analysing the collected data, the programme DISTANCE was used (Thomas et al., 2009). With this software, the most suitable detection model can be chosen for the data collected, and density, average group size and number of animals in the survey area are estimated. Also the Effective (half) Strip Width (ESW) is estimated: it indicates the theoretical width of the track for which the probability to miss animals within this width is equal to the probability to detect animals outside this width.

During 2008 and 2009, in total five successful surveys were performed: 8-9 April 2008, 5 May 2008, 18-19 February 2009, 14-20 May 2009 and 4-5 August 2009. The BPNS, with a surface of approximately 3.600 km², was only partly covered during the survey of 5 May 2008. The distances covered on track for the other four surveys ranged from 242 to 357 nautical miles (nm) (10 to 13 tracks), while the 5 May 2008 survey only covered 143 nm (6 tracks). The individual tracks varied in length between 20 and 34 nm.

The parameters applied, and the assumptions made for the data analysis, were:

- The detection probability of a group of animals is similar to the detection probability of a solitary animal.
- The detection probability remains constant over habitat type, season, time of the day, observer and density of animals. All data were pooled in order to establish a detection model: a half normal cosine adjusted distribution was selected as the detection function, on the basis of the Akaike Information Criterion (AIC) (Buckland et al., 2001).
- As not all animals are observed on the track (perception bias), and some are not visible because they are too deep to be observed (availability bias), a correction factor for g(0) needs to be applied. This factor indicates the probability to see an animal or group of animals at distance 0. For g(0) 0.45 was used, as estimated by Hiby (2008) for similar surveys; it was not possible to calculate this correction factor for the surveys undertaken. No confidence values were applied to g(0).

The detection model was based on 89 observations of a total of 105 porpoises. The resulting estimate of the ESW was 134 m (90% CI: 116 m – 154 m).

10.2.2. Passive acoustic monitoring

PAM devices are increasingly popular for short- to medium-term (i.e. weeks to months) monitoring of cetaceans, both for basic ecological research and for impact assessment of human activities. The PAM devices used during 2009 were C-PoDs (Porpoise Detectors, manufactured by Chelonia Ltd). PoDs consist of a hydrophone, a processor, batteries and a digital timing and logging system (www.chelonia.co.uk). They are anchored under water at selected locations, and have autonomy of up to four months. A PoD does not record sound itself: it generates a raw file with for each sound event characteristics, such as its time of occurrence, duration, dominant frequency and sound pressure level. The raw file can be analysed with dedicated software that applies a filter to only retain those clicks identified as being in trains. The program identifies trains that originate from cetaceans (within a certain probability), and trains that originate from other sources (such as boat SONARs). It can distinguish, using typical frequencies, between harbour porpoises and dolphins. The data thus obtained give an indication of the (relative) abundance around the device, up to a distance of approximately 300 m.

The advantage of using PoDs for monitoring cetaceans, is that they provide continuous information on a short- to medium-term period, independent of weather conditions, and in between aerial surveys. A difficulty in using PoDs is the mooring system, which should be cost-efficient. PoDs, even with robust mooring systems, are regularly lost (eg. Diederichs et al., 2009; Brasseur et al., 2004). Also, PoDs do not provide for an estimate of the absolute abundance of cetaceans.

During 2009, two C-PoDs were moored in autumn, a period when no aerial surveys were undertaken. For the mooring of both PoDs, a tripod (Van den Eynde et al., 2010) was used: the PoD was attached to the central column of the tripod, at 1.5 m above the seafloor. A first PoD was moored from 19 October 2009 to 9 December 2009 at the Gootebank (51°26.9’N, 002°52.6’E; 21.4 km
offshore; depth of 22 m below mean low water spring (MLLWS)). The second PoD was moored from 6 November 2009 to 19 May 2010, with short interruptions for servicing (51°21.4’N, 003°07.0’E; 4.5 km offshore; depth of 6.5 m below MLLWS).

The data were analysed using CPOD.exe software version 1.054. The measure for harbour porpoise presence is detection positive minutes per day (dpm), which is the number of minutes per day in which the presence of harbour porpoises was detected. Only high and moderate train quality data (high and moderate detection probability) were used, and the species filter was set to harbour porpoises.

10.2.3. The collection of additional data

Many other sources of information on marine mammals can be used to shed some light on their occurrence, ecology and health status in the BPNS. They include strandings data and the results of the necropsy on stranded animals. Yearly trends in strandings can reflect trends in the number of harbour porpoises at sea, and seasonal migrations can be revealed. Investigations of stranded animals can point at problems that the population is facing, such as bycatch, disease, or previous exposure to excessive noise (Jauniaux et al., 2002).

Being legally protected, stranded and accidentally caught marine mammals must be reported to the authorities, represented by the RBINS; to all possible extent, carcasses are collected and made available for scientific research purposes. As a consequence of the legal requirements, in combination with the easy public access to the shoreline, the dense human presence of the shore and the fact that coastal authorities and members of the public are well informed, the marine mammals strandings database managed by the RBINS can be considered as fairly complete from 1990 onwards.

For this paper, general trends in monthly and yearly (i.e. medium- to long-term variability) strandings data are presented. The data include a very small number of animals found dead at sea, and animals accidentally caught and brought into port by fishermen. They also include accidentally caught animals that were discarded and subsequently washed ashore. A more detailed analysis of the strandings data of harbour porpoises in Belgium and the Netherlands up to 2007 was reported in Haelters & Camphuysen (2009).

10.3. Results

10.3.1. Aerial surveys

Three to 43 harbour porpoises were detected by observers on task during each of the aerial surveys, which renders a population size estimate for the BPNS ranging from 201 to 3,994 individuals (Table 1). The average group size varied between 1.00 and 1.35 individuals. The May 2008, May 2009 and August 2009 surveys (i.e. late spring and summer) indicated the lowest density of harbour porpoises (max. 0.31 ind./km²), while the aerial surveys of April 2008 and February 2009 (i.e. late winter and early spring) indicated a much higher density (min. 0.68 ind./km²).
Table 1. Overview of the number of observed animals by on-task observers and the estimate of the average group size, density and abundance within a surface area equivalent to the Belgian part of the North Sea, i.e. 3600 km² (CI, confidence interval). No estimate of the number of animals was made for the survey of 5 May 2008, given the incomplete coverage of the study area.

<table>
<thead>
<tr>
<th>Survey</th>
<th>Number of observations (number of animals)</th>
<th>Group size (ind.) (90% CI)</th>
<th>Density (ind./km²) (90% CI)</th>
<th>No of animals per 3600 km² (90% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8-9 April 2008</td>
<td>40 (43)</td>
<td>1.11 (1.02-1.22)</td>
<td>1.11 (0.75-1.64)</td>
<td>3994 (2707-5892)</td>
</tr>
<tr>
<td>5 May 2008</td>
<td>5 (5)</td>
<td>1 (-)</td>
<td>0.31 (0.08-1.31)</td>
<td>-</td>
</tr>
<tr>
<td>18-19 February 2009</td>
<td>20 (27)</td>
<td>1.35 (1.09-1.67)</td>
<td>0.68 (0.46-1.01)</td>
<td>2448 (1652-3627)</td>
</tr>
<tr>
<td>14-20 May 2009</td>
<td>12 (13)</td>
<td>1.08 (1.00-1.24)</td>
<td>0.17 (0.09-0.31)</td>
<td>600 (321-1122)</td>
</tr>
<tr>
<td>4-5 August 2009</td>
<td>3 (3)</td>
<td>1 (-)</td>
<td>0.06 (0.02-0.14)</td>
<td>201 (83-488)</td>
</tr>
</tbody>
</table>

In April 2008 and February 2009 harbour porpoises were present both in inshore and more offshore waters, whereas May 2008, May 2009 and August 2009 only yielded observations further offshore, in the northern half of the BPNS (Figure 1).

Figure 1. Left panel: Detections of harbour porpoises during the 2008 surveys: 8-9 April (grey circles) and 5 May (dark grey stars). Right panel: Detections of harbour porpoises during the 2009 surveys: 18-19 February (grey circles), 14-20 May (dark grey stars) and 4-5 August (black squares). Observations made off track, as well as those made by the observer at the side of the aircraft without bubble window, are included.

10.3.2. Passive acoustic monitoring

PoD moorings in November and early December 2009 showed a more frequent detection of harbour porpoises further offshore compared to nearshore waters (Wilcoxon signed rank test: p < 0.001), suggesting that in autumn harbour porpoises were more common further offshore than inshore (Figure 2). Furthermore, an increase in the number of detection positive minutes per day (dpm/d) was observed from October to December in offshore waters (mid October to mid November 2009: average 17 dpm/d; mid November to early December 2009: average 32 dpm/d). Nearshore, the number of
detection positive minutes per day was generally low, with on average 9 dpm/d between early December 2009 and the end of May 2010. Short periods of a higher number of detections were found between mid December and early January (on average 13 dpm/day), between the end of January and early February (20 dpm/d), and from the end of March into the first fortnight of April (21 dpm/d).

Figure 2. Detection positive harbour porpoise minutes per day (Y-axis) – or the number of minutes per day in which porpoises were present around the PoD (floating average over 3 days) - at the offshore Gootebank site (20 October to 8 December 2009: black line) and at the nearshore MOW1 site (7 November to 30 May 2010, with short interruptions for servicing the PoD: grey line). The data obtained during the day of the mooring and the day of retrieval of the PoD are excluded.

10.3.3. Strandings data

Based on the strandings data, an increase in the number of stranded animals from the late 1990s onwards was found: while only a few animals (max. 6 ind./y) washed ashore between 1970 and 1997; this number increased to more than 85 ind./y in the period 2005-2007 (Figure 3). In 2008 and 2009, the increase was interrupted, with respectively 62 and 66 ind./y.

Figure 3. Total number of stranded harbour porpoises in Belgium from 1970 to 2009.

The monthly numbers of stranded animals peaked from March to May (in total 43% of all stranded animals) and in August (13%) (Figure 4). Only few animals washed ashore in July (6%) and between October and January (in total 16%). Grouping of strandings data in different periods (figure 3) indicates that the seasonality has not changed since the 1970ies.
10.4. Discussion

10.4.1. Importance of Belgian waters for harbour porpoises

Since aerial surveys yielded actual population size estimates of up to about 4,000 individuals (spring 2008), harbour porpoises should be considered a significant top of the food chain constituent of the marine ecosystem in the BPNS, as was expected by the environmental impact report prepared for licensing the environmental permits (MUMM, 2004; 2008). This number, which is the first absolute estimate of the number of porpoises in the BPNS, means that up to 1.6% of the total North Sea population of harbour porpoises, estimated at a quarter of a million individuals (SCANS II, 2008), can at least occasionally be found in the BPNS. Given its significant presence and its protection status, at the Belgian as well as at the European level (Habitats Directive 92/43/EEC, Annex 2), it is clear that the harbour porpoise legitimately takes an important position when it comes to the evaluation of the ecological effects of the construction and exploitation of offshore wind farms, as well as other human activities in the marine environment, such as trammel net fisheries.

The harbour porpoise has however not always been abundantly present in Belgian waters, as illustrated by the tenfold increase in yearly numbers of stranded animals from 1970 to 2009. One should however take into account that strandings data may be slightly biased by meteorological conditions and incidental catches. Between 2003 and 2007, for example, 19% to 63% of stranded animals for which a cause of death could be identified, had drowned in fishing gear (Haelters & Camphuysen, 2009). The increase has also been observed in Dutch waters (Camphuysen & Peet, 2006), and it can be interpreted as a return of the harbour porpoise to the southern North Sea due to a shift in the population, rather than a population increase. The redistribution of harbour porpoises in the North Sea may have been caused by local reductions in prey availability, especially in the northern part of the North Sea (Camphuysen 2004, SCANS II, 2008). These reductions are probably caused by changes in environmental conditions.

10.4.2. Short- to medium-term spatio-temporal patterns

The spatio-temporal distribution of the harbour porpoises in Belgian waters indicates that harbour porpoises are abundant in the BPNS in late winter and early spring, while lower numbers tend to stay in the more offshore and more northerly waters in late spring and summer. Although aerial surveys are lacking in autumn, PoD measurements indicated (1) a more offshore distribution in that period and (2) increasing harbour porpoise densities from autumn to late winter.
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Next to the aerial surveys, the same spatio-temporal pattern was also picked up by the strandings data analysis, showing a peak of stranded animals in March to May, which should be linked to the high nearshore densities of harbour porpoises. The relatively late peak of strandings in May can partly be explained by the washing ashore of decomposed animals, many of which probably already died in April (Haelters et al., 2006). The second peak of strandings in August also mainly concerned decomposed carcasses of juvenile organisms that drifted in from more offshore waters (MUMM, unpublished data).

The yearly seasonal population size and geographic distribution cycle, as described above, however also seems to be blurred by more erratic events, complicating our understanding of the harbour porpoise’s spatial distribution and migration behaviour. Two examples of such erratic events were detected during the present study. First, a dip in number of strandings (decrease: ± 30 %) was observed in 2008 and 2009. This dip coincided with a more offshore distribution of harbour porpoises in late winter and spring 2008 and 2009, as shown by incidental sightings reported to MUMM (MUMM, unpublished data; Haelters & Camphuysen, 2009; Haelters, 2009). It should hence not be interpreted as a decrease in population size. Secondly, the high number of strandings in September-October 2009 suggests a short intrusion into Belgian waters.

10.4.3. Recommendations

In the framework of the monitoring of effects of the construction and exploitation of offshore wind farms, it is advised to perform aerial surveys on a more regular basis and to extend its seasonal coverage to periods of the year, in which estimates of density are currently lacking. Aerial surveys covering the BPNS should be performed immediately prior to, during and after pile driving activities (cfr. Lucke, 2010).

The results of the PoD moorings demonstrate the potential of this PAM device. Even a low number of PoDs provides continuous information on the spatio-temporal patterns of harbour porpoises in the BPNS, in addition to discrete data obtained through aerial surveys. It is hence advised to further the exploitation of PoDs in Belgian waters. Such information is important, for instance in the planning stages of construction activities for offshore wind farms. PAM can also provide information about effects on harbour porpoises of construction and exploitation of offshore wind farms.

A continuation of the long-term data series on marine mammal strandings is advised, given its added scientific value, complementary to both aerial and PAM surveys.

10.5. Conclusions

Given the actual high density of harbour porpoises in the BPNS, the BPNS should be considered seasonally of international importance to this protected marine mammal. Harbour porpoises however do not show a random spatio-temporal distribution in the BPNS: they are found abundantly throughout the whole BPNS in late winter and spring, whereas lower numbers tend to occur in more offshore waters in late spring to early winter. In some years, this general seasonal spatio-temporal cycle might be blurred by erratic shifts in density or spatial distribution. Whereas we now start having a proper view on the harbour porpoise’s spatio-temporal distribution, it still remains, for instance, impossible to disentangle the cause-effect relationships behind these patterns. The data however allow for a first good visualization of the spatio-temporal patterns of harbour porpoises in Belgian waters prior to the major development of offshore wind farms (i.e. reference condition).

10.6. Acknowledgements

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10.7. Literature


