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Marine mammal sightings around oil and gas installations in the central North Sea

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*Relatively little is known about the distribution and diversity of marine mammals around offshore anthropogenic structures. We present results obtained from incidental sightings of marine mammals around oil and gas installations located 200 km off the Danish coast. A total of 131 sightings corresponding to about 288 animals were reported between May 2013 and May 2016. A total of seven marine mammal species were identified, five cetaceans: harbour porpoise (*Phocoena phocoena*), minke whale (*Balaenoptera acutorostrata*), white-beaked dolphin (*Lagenorhynchus albirostris*), killer whale (*Orcinus orca*), pilot whales (*Globicephala *spp.) and two species of pinnipeds: harbour (*Phoca vitulina*) and grey seals (*Halichoerus grypus*). The most sighted species were harbour porpoise (41%) and minke whale (31%). Relative counts and biodiversity of marine mammals observed around installations corresponded well with the expected distribution in the central North Sea. Several taxon-specific correlations were identified between number of sightings and environmental parameters (depth and latitude) or installation characteristics (installation aerial footprint). Furthermore, 85% of sightings were made during spring and summer and it is unclear whether the pattern observed reflected a natural seasonal occurrence of marine mammals in the area or an effect of reduced effort during autumn and winter. Despite the potential caveats, results obtained during this programme provide an insight into the relationship between marine mammals and oil and gas offshore installations in the North Sea.*

Keywords: Cetacean, pinniped, harbour porpoise, minke whale, diversity, offshore, platform, anthropogenic, volunteer programme

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INTRODUCTION

Marine ecological monitoring programmes have become an important tool for environmental management worldwide (Borja *et al.*, 2008; Borja & Elliott, 2013). The programmes provide managers and decision-makers with an essential source of relevant, reliable and timely science-based information that can be used to support the decision-making process (Elliott, 2011). The North Sea is a region with a wide range of industrial activities (OSPAR, 2010; Andersen *et al.*, 2013) and it is home for several protected marine mammal species (Kinze, 2001; Reid *et al.*, 2003; Hammond *et al.*, 2013). Acquisition of data on the distribution of highly migratory animals, such as marine mammals, over a wide geographic area, is challenging logistically and economically and often it requires large collaborative international efforts (Hammond *et al.*, 2013; Koblitz *et al.*, 2014). Alternative methods based on incidental sightings by sea-users (e.g. recreational sailors, fishermen, ferry goers) may be a cost-effective means to provide complementary valuable information to large regional surveys (Evans *et al.*, 2003; Kinze *et al.*, 2003; Loos *et al.*, 2009; Palacios *et al.*, 2012).

In recent years, participation of the public community in collection of ecological survey data has greatly intensified under the concept of 'citizen science' (Devictor *et al.*, 2010; Conrad & Hilchey, 2011). Adequately trained citizen scientists are a cost effective means to acquire valuable long-term data over a wide geographic area or access important scientific background information in new areas (Robinson *et al.*, 2013; Embling *et al.*, 2015). For example, marine mammal observations by shore-based citizen scientists have been collected for more than 40 years in the UK and the data have proven to be beneficial for coastal environmental management (Evans *et al.*, 2003, 2015; Reid *et al.*, 2003). Elsewhere, offshore incidental sightings have also contributed to the discovery of a major aggregation site for whale sharks in proximity to an offshore installation in the Al Shaheen area in the Arabian Gulf, 90 km off the coast of Qatar (Robinson *et al.*, 2013).

Incidental sightings of seals, dolphins and whales around oil and gas (O&G) installations in the North Sea have also been reported by offshore staff for several decades (Evans, 1976; Evans *et al.*, 2003), but rarely has there been sustained systematic effort (Todd *et al.*, 2016). To increase our knowledge on the relationship between marine mammals and the presence of O&G installations in the central Danish North Sea, an offshore marine mammal sighting reporting programme (MMSR) was initiated in May 2013. The programme was used as an incentive for staff working on and around offshore O&G installations in Denmark to report more systematically their incidental marine mammal sightings. Our objectives were (1) to collect local information on marine mammal occurrence and biodiversity around offshore O&G installations in the central Danish North Sea, and (2) to

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obtain a general picture of the regional distribution of marine mammals across an O&G activity region. Here, we present incidental sightings data collected during the first 3 years of the MMSR programme.

METHODS

Study site

Currently, there are about 25 fixed oil and gas installations in the Danish part of the central North Sea (Figure 1). Some of these installations are manned continuously by crew, while 'satellite' installations are visited occasionally by a small crew for a few hours. All installations are located around 200 km from the west coast of Denmark. In the north, installations are more recent with smaller submerged structures, and smaller permanent crew compared with the southern installations. Northern installations operate at depths ranging between 55 and 66 m, whereas southern installations operate at shallower depths ranging from 33 to 46 m (Table 1). Supply-, survey- and standby-boats, accommodation and drilling rigs are often placed or operate close to installations (within 750 m from the installations) increasing the size of crew associated with a specific installation for a period, which may range from hours to several weeks.

Regional marine mammal surveys indicate that the most common cetaceans in the Danish central North Sea are harbour porpoise (*Phocoena phocoena*; 0.293 individuals km^{-2}), white-beaked dolphin (*Lagenorhynchus albirostris* 0.047 individuals km^{-2}), and minke whale (*Balaenoptera acutorostrata*; 0.028 individuals km^{-2}; Hammond *et al.*, 2013). Other marine mammal species are also known to occur in the area in lesser numbers: grey and harbour seals (*Halichoerus grypus; Phoca vitulina*), sperm whale (*Physeter macrocephalus*), fin whale (*Balaenoptera physalus*) and several species of dolphins including killer whale (*Orcinus orca*) and pilot whales (*Globicephala* spp.), as well as Atlantic white-sided (*Lagenorhynchus acutus*), bottlenose (*Tursiops truncatus*), common (*Delphinus delphis*) and striped dolphins (*Stenella coeruleoalba*) (Kinze, 2001; Evans *et al.*, 2003; Reid *et al.*, 2003; Hammond *et al.*, 2013).

Reporting system

Commencement of the Danish offshore marine mammal sighting reporting programme (MMSR) was communicated to offshore platform workers and contractors through different media: presentations, emails, information meetings, intranet, an internally distributed magazine, and posters displayed offshore. Status updates and reminders about the MMSR were sent monthly the first year and quarterly thereafter, via the same channels, to maintain as high a level of involvement of the volunteers as possible (Loos *et al.*, 2009). Charts and identification keys to assist recognition of the most common species expected in the central North Sea were prepared by marine mammal biologists (modified from Jefferson *et al.*, 2011 and http://www.hvaler.dk). The material was posted offshore on crew information boards and also made available in electronic format at the commencement of MMSR on 1 May 2013 and at each of the status updates and reminders.

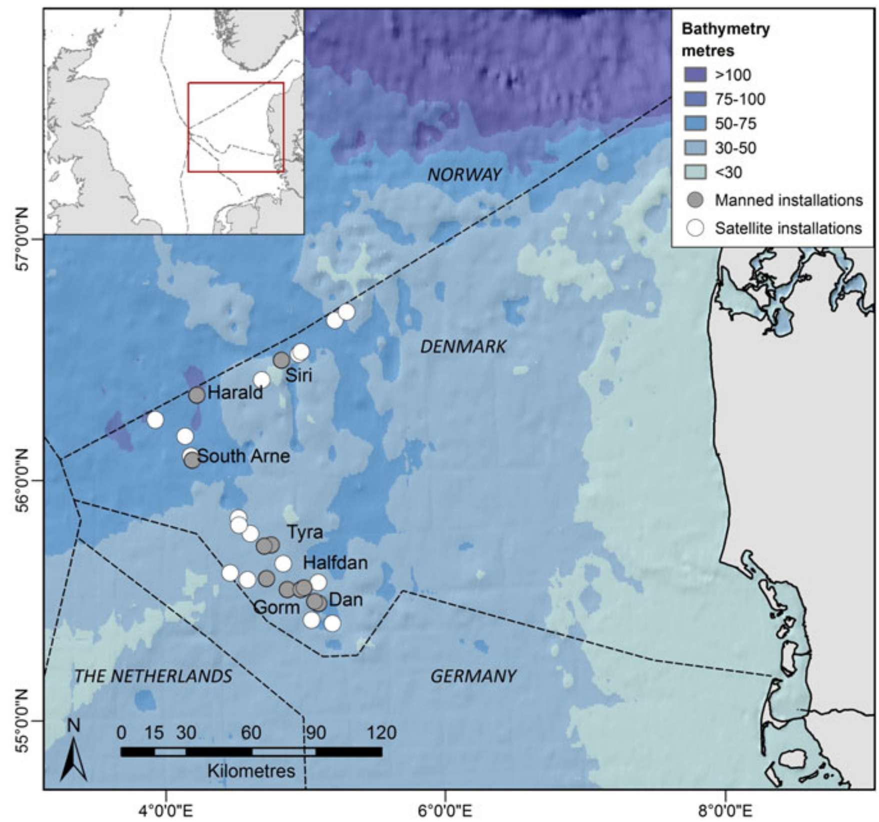

Fig. 1. Study area. Filled symbols show continuously manned installations and open symbols show satellite installations which are occasionally visited. Installation group names are indicated in Table 1.

Observations were made with the naked eye at an elevation of 25–70 m above sea level when stationed on installations or rigs and a maximum elevation of 15 m above sea level when stationed on boats. Volunteers reporting their incidental sightings were requested to report as a minimum: location, date and time of sighting, number of individuals (adult/calf) and behaviour. Individuals were identified to species level, though this was not always possible for dolphins (e.g. *Lagenorhynchus albirostris* or *L. acutus*) or seals, as differentiation can be difficult under typical offshore sighting conditions (Jefferson *et al.*, 2011). Some reports included a visual estimate of distance from installation to the marine mammal, an estimate of size of the animal and description of its colouration pattern. When several sightings of the same species were made by different reporters at the same time, day and from the same installation, only the sighting with the greatest number of individuals was used for further data analysis. Reports were usually provided by email within 24 h of sighting. Photographs and videos were provided when available, and marine mammal biologists made *a posteriori* identification of documented reports.

Weather conditions

Sightability of marine mammals generally depends on sea state and weather conditions (Clarke, 1982). For example harbour porpoises, the smallest and most common species expected in the area, can only be observed reliably at Beaufort sea states ≤2 (Teilmann, 2003). As reports were not provided with a sea state description, wind data collected on the platform were converted to the Beaufort scale. Empirical wind speed measurements were taken by wind gauges installed on the different installations. The measurements were not always available at some locations and the wind dataset collected at Tyra West was selected as a proxy for the wind conditions at all installations over the duration of the programme. This dataset was the most complete and correlated best with wind measurements collected at other installations ($r = 0.78–0.93$; $P < 0.001$). Average wind data were recorded as a 10-min window every hour. The measurements were taken in metres per second (m s^{-1}) at 30 m above sea level and back-calculated to a 10 m elevation using the formula: v (m s^{-1}; @10 m) = 0.876 v (m s^{-1} @ 30 m). Wind data were converted to the Beaufort scale by the formula $B = 1.20\ v^{2/3}$, where v is the wind speed in m s^{-1} at a 10 m elevation and B is rounded to obtain the Beaufort scale number (Beer, 1996). As sightings are not possible at night, only median wind speeds for daylight hours were used. Daylight start, end and duration were estimated using civilian day for the central North Sea (Todd *et al.*, 2009).

Data analysis

The data included in the analyses are from sightings made during the three first years of MMSR, corresponding to the period from 1 May 2013 to 1 May 2016.

The total number of sightings for the different seasons was compared by a Kruskal–Wallis test (ANOVA by rank). Seasons were defined as winter (January–March), spring (April–June), summer (July–September) and autumn (October–December). Spearman's rank order correlations were estimated between total number of sightings and wind speed, as well as between total number of sightings and number of daylight hours at Beaufort ≤2.

Table 1. Danish installations overview in 2016. Construction date refers to construction of the first element of an installation which may have been expanded incrementally over the years. Areal footprint corresponds to cumulative area covered by the platform's legs at the seafloor and was estimated based on high resolution schematic drawing of the installations.

Region	Group name	Installation	Constructed year	Permanent crew (pers.)	Depth (m)	Cumulated footprint (m²)
North	HARALD	Harald	1996	16	66	3234
		Svend	1996	0	65	1218
	SIRI	Siri	1999	60	59	3128
		Nini	2003	0	60	1440
		Cecilie	2003	0	60	1474
	S. ARNE	South Arne	1999	75	61	3754
		WHP-E	2012	0	60	1054
		WHP-N	2012	0	60	1085
South	DAN	Dan F	1987	95	43	6996
		Dan B	1972	4	44	1639
		Kraka	1991	0	45	231
		Regnar	1993	0	45	93
	GORM	Gorm	1981	97	40	3581
		Skjold	1982	16	40	1451
		Rolf	1986	0	34	427
		Dagmar	1991	0	33	715
	HALFDAN	Halfdan A	1999	32	44	2164
		Halfdan B	2001	80	44	6075
		Halfdan C	2007	0	43	627
	TYRA	Tyra E	1982	96	42	4488
		Tyra W	1982	80	45	3944
		Roar	1996	0	46	372
		Tyra SE	2002	0	39	1006
		Valdemar A	1993	0	41	496
		Valdemar B	2007	0	42	262

Table 2. Summary of reported sightings from the Danish oil and gas activity area from 1 May 2013 to 1 May 2016. The summary is based on species/taxa and group size.

Species	Sightings (N)	Individuals (N)	Group size (N)				
			1	2	3–5	6–10	11–30
CETACEA (whales, dolphins and porpoises)							
Mysticeti (baleen whales)							
Balaenopteridae (rorquals)							
Common minke whale – *Balaenoptera acutorostrata*	41	62	32	5	3	1	–
Odontoceti (toothed whales)							
Delphinidae (marine dolphins)							
Killer whale – *Orcinus orca*	1	2	–	1	–	–	–
Pilot whale – *Globicephala* spp.	1	4	–	–	1	–	–
White-beaked dolphin – *Lagenorhynchus albirostris*	1	2	–	1	–	–	–
Unidentified dolphins	12	77	5	2	2	1	2
Phocoenidae (porpoise)							
Harbour porpoise – *Phocoena phocoena*	54	120	11	30	13	–	–
Unidentified cetacean	1	1	1	–	–	–	–
CARNIVORA (carnivores)							
Pinnipedia (sea lions, walrus and seals)							
Phocidae (true seals)							
Harbour seal – *Phoca vitulina*	1	1	1	–	–	–	–
Grey seal – *Halichoerus grypus*	5	5	5	–	–	–	–
Unidentified seals	14	14	14	–	–	–	–
Marine mammals	**131**	**288**	**69**	**39**	**19**	**2**	**2**

Furthermore, Spearman's rank order correlations were estimated between species-specific numbers of sightings and environmental parameters (depth, longitude and latitude ED50, UTM zone 31) or installation characteristics (construction year and aerial footprint; Table 1). Due to low numbers of sightings for some of the individual installations, sighting data were aggregated based on their proximity, in three installation groups (HARALD, SIRI, S. ARNE) in the northern area and four groups (DAN, GORM, HALFDAN and TYRA) in the southern area (Table 1 and Figure 1). Group of installations with larger crew have a higher number of potential volunteer reporters i.e. a proxy for observation effort; thus the Spearman correlations parameters (r- and ρ-values) were estimated on the sighting data that were corrected by calculating the ratio between raw sighting numbers and installation group crew size. Some species had a limited number of observations, preventing reliable specific data analysis. In such cases, sightings data analyses were done based on higher

Fig. 2. Minke whale photographed at Halfdan A in June 2014. Note the presence of a drilling rig and a supply boat. Credit: Henrik Ærenlund Olsen (Esvagt Promotor).

Table 3. Summary statistics of the Spearman correlation between number of sightings corrected for installations crew size, environmental parameters and installations characteristics (N = 7).

Sightings	*r*	*ρ*
Marine mammals (131 sightings)		
Latitude (N)	−0.43	0.337
Longitude (E)	0.14	0.760
Depth (m)	−0.11	0.819
Installation year	0.04	0.933
Installation footprint (m^2)	0.25	0.589
Harbour porpoise (54 sightings)		
Latitude (N)	**−0.92**	**0.003*****
Longitude (E)	0.59	0.159
Depth (m)	−0.61	0.144
Installation year	−0.46	0.302
Installation footprint (m^2)	**0.79**	**0.033****
Minke whale (41 sightings)		
Latitude (N)	−0.21	0.645
Longitude (E)	−0.11	0.819
Depth (m)	−0.07	0.879
Installation year	0.08	0.867
Installation footprint (m^2)	0.04	0.939
Seals (20 sightings)		
Latitude (N)	0.71	0.071
Longitude (E)	−0.29	0.535
Depth (m)	**0.82**	**0.023***
Installation year	0.51	0.240
Installation footprint (m^2)	−0.54	0.215
Dolphins (15 sightings)		
Latitude (N)	**0.75**	**0.052***
Longitude (E)	−0.64	0.119
Depth (m)	**0.89**	**0.007****
Installation year	0.59	0.162
Installation footprint (m^2)	−0.64	0.119

Significant correlations are highlighted in bold and marked with $^{*}P \leq 0.05$, $^{**}P \leq 0.01$ and $^{***}P \leq 0.005$.

taxonomic level sighting data e.g. Delphinidae (dolphins) or Phocidae (seals).

Kruskal–Wallis's and Spearman's statistical parameter for each of the tests were estimated using STATISTICA v.12.

RESULTS

General results

A total of 131 marine mammal incidental sightings corresponding to about 288 individuals were reported during the three years of the marine mammal sighting reporting programme (MMSR; 1 May 2013 to 1 May 2016; Table 2). The most sighted species around the Danish oil and gas installations were harbour porpoise (41%) and minke whale (31%). Other marine mammals sighted included at least three species of dolphins (11%) – killer whale, pilot whale and white-beaked dolphin, and two species of seals (15%) – harbour and grey seals. Harbour porpoise calves were observed in 50% of the porpoise sightings from May to September, and dolphin calves were observed twice in July. About 20% of reports were documented either by photographs or videos (Figure 2; online Supplementary file), and marine mammal biologists confirmed that species identification in 26 out of the 28 documented reports was reported correctly by offshore staff.

Marine mammals were most frequently observed solitarily or in groups of two individuals (Table 2). Sightings of pods of more than five individuals were relatively rare (3%) and only reported for minke whales and dolphin species. Marine mammal sightings were most often reported from offshore fixed installations (65%) and nearby standby boats (31%). Animals were observed swimming under installation legs out to a distance of several hundred metres. On several occasions, seals were observed resting intermittently on the lower structures of the installations for several days, and in one instance, pictures showed a young grey seal on the deck of the smallest standby-boat.

Interestingly, sightings of some fish species were also reported as part of the MMSR. A 0.5 m wide sunfish (*Mola mola*) was seen at Valdemar in June 2014, and another was photographed at Halfdan B in July 2015. An ~10 m long basking shark (*Cetorhinus maximus*) was reported and video recorded feeding around the Tyra East installation in October 2015 (https://youtu.be/H93WTZp4xv8).

Temporal and spatial variability

There were significant seasonal differences between the numbers of marine mammal sightings (Kruskal–Wallis; N = 12; $P = 0.053$). The majority of reported sightings were made during spring (40%) and summer (48%), whereas only three sightings (2%) were made during autumn. The highest number of sightings was made in July with a total of 37 (Figure 3). Daylight hours available ranged from a monthly average of 286 h for autumn and winter to 467 h for spring and summer. Additionally, Beaufort wind force ≤2 corresponded to an estimated 11% of the daytime in spring, 17% in summer, 5% in autumn and 8% in winter. July had the highest number of daytime hours with about 545 h and an estimated 39% of the daytime with Beaufort wind force ≤2. The overall number of monthly sightings decreased with increasing wind speed (Spearman $\rho < 0.001$; $r^2 = 0.79$) and with decreasing daytime hours with Beaufort wind force ≤2 (Spearman $\rho < 0.001$; $r^2 = 0.73$). The total number of daytime hours with Beaufort wind force ≤2 was 667 in the first year (1 May 2013 to 1 May 2014), 461 h in the second year and 460 h in the third year. The number of reported marine mammal sightings was 33 during the first monitoring year, 58 during the second year, and 40 during the third year.

Ninety-three per cent of sightings were made around southern installations, particularly at HALFDAN (40%; Figure 4). Sightings from southern installations were mostly of harbour porpoise (50%) and minke whale (33%), but dolphins (13%) and seals (5%) were also observed. At northern installations, sightings were mostly of minke whale (75%) and one single report of four harbour porpoises. There were significant taxon specific correlations between sighting numbers and some of the environmental characteristics (latitude and depth) and installations characteristics (aerial installation footprint; Table 3). This relationship was particularly strong for harbour porpoise, with an increase in the number of sightings from north to south (Spearman $\rho = 0.003$; $r^2 = 0.85$). There was also an increase in number of harbour porpoise sightings with aerial installation footprint (Spearman $\rho = 0.033$; $r^2 = 0.62$). The number of sightings increased with increasing depth for seals (Spearman $\rho = 0.023$; $r^2 = 0.67$) and dolphins (Spearman $\rho = 0.007$; $r^2 = 0.79$).

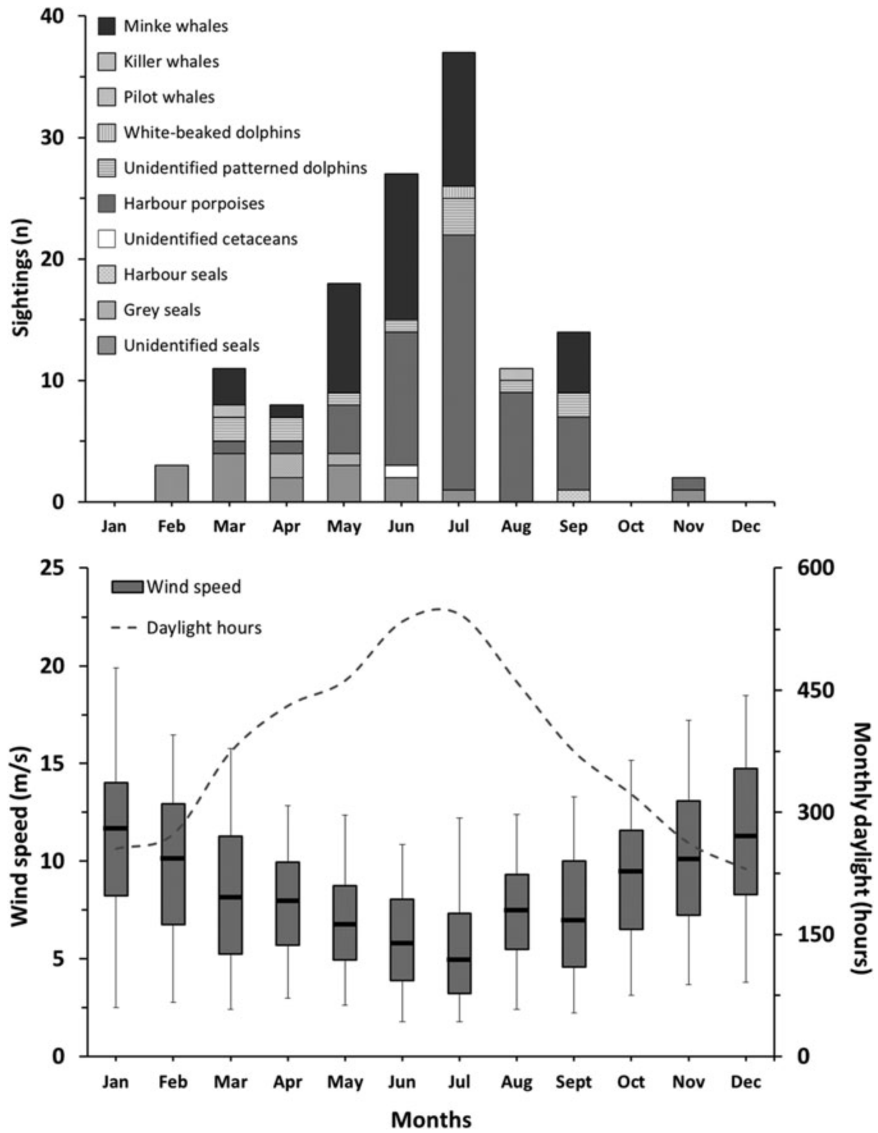

Fig. 3. Monthly marine mammal sighting counts (top) and corresponding wind speed and daylight hours (bottom). Box plots indicate civilian daylight hours median wind speed (line), 25 and 75% (lower and upper box sides) and 5 and 95% over the duration of the reporting programme (lower and upper whiskers) limits (N = 693–1698).

DISCUSSION

This study adds to the existing knowledge that marine mammals are relatively frequently present around offshore oil and gas (O&G) structures (Todd *et al.*, 2009, 2016; Triossi *et al.*, 2013; Balle *et al.*, 2014; Arnould *et al.*, 2015). A total of at least seven marine mammal species have been identified during the first three years of the Danish offshore marine mammal sighting reporting programme (MMSR), namely five cetacean species – harbour porpoise, minke whale, killer whale, white-beaked dolphin and pilot whale, and two pinniped species – harbour and grey seals. Sighted cetaceans and their relative number of observations generally reflected expected marine mammal abundance and diversity in the central North Sea (Reid *et al.*, 2003; Hammond *et al.*, 2013). Sightings of other cetacean species such as Atlantic white-sided dolphin (*Lagenorhynchus acutus*) and common dolphin (*Delphinus delphis*) close to stationary O&G installations have been reported previously in the UK (Todd *et al.*, 2016) and in Denmark (Steffen Sanvig Bach, personal communication).

Anthropogenic marine structures can act as artificial reefs that locally increase fish biodiversity and biomass (Pickering & Whitmarsh, 1997; Langhamer, 2012). This has proven to be the case also for O&G installations operating at <100 m depth in the North Sea, where installations attract and concentrate a wide range of fish species (Soldal *et al.*, 2002; Fujii, 2015, 2016). These include, for example, cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), saithe (*Pollachius virens*), sand eel (*Ammodytes* spp.), mackerel (*Scomber scombrus*), sprat (*Sprattus sprattus*), herring (*Clupea harengus*) and several species of flat fish (Pleuronectid spp.), which are all known prey species for the marine mammal species observed during this reporting programme (Thompson *et al.*, 1996; Abend & Smith, 1997; Pauly *et al.*, 1998; Olsen & Holst, 2001; Sveegaard *et al.*, 2012). Similarly, increased availability of prey items are associated with presence of top predators around a wide range of

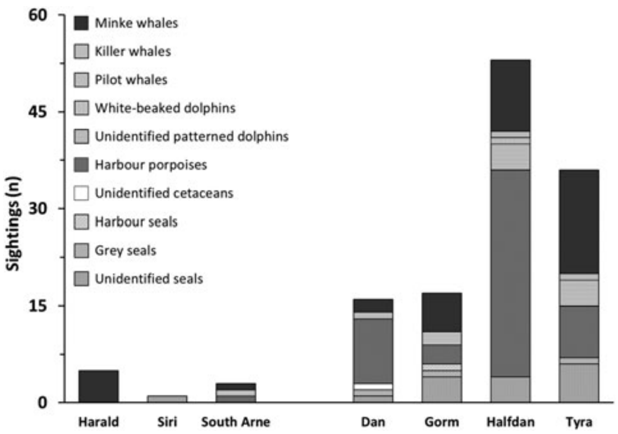

Fig. 4. Marine mammal sightings counts at northern and southern installations from 1 May 2013 to 1 May 2016.

marine structures such as a reconstructed stony reef (Mikkelsen *et al.*, 2013), a large bridge (Brandt *et al.*, 2014), O&G facilities (Todd *et al.*, 2009, 2016; Arnould *et al.*, 2015), and wind farms (Russell *et al.*, 2014).

Occurrence of harbour seals around southern installations at about 200 km from the closest shore is notable, as they are known typically to forage in coastal waters (Thompson *et al.*, 1996; Tollit *et al.*, 1998; Tougaard *et al.*, 2008). Observed utilization of structures or boats as a temporary haul-out location, combined with potential increased foraging success, are likely to motivate some individual seals to these longer distance offshore visits (McConnell *et al.*, 1999; Russell *et al.*, 2014; Arnould *et al.*, 2015). Some seals were shown to forage actively and selectively around submerged pipelines and wind turbine structures within less than a year of their installation (Russell *et al.*, 2014; Arnould *et al.*, 2015). This suggests the ability of marine mammals to rapidly identify and utilize these artificial habitats for foraging. Since the offshore O&G industry has been present in the North Sea for more than four decades, utilization of offshore installations as a foraging opportunity by marine mammals is therefore likely to be well-established (e.g. through social learning; Whitehead, 2010).

As data presented here are based on incidental sightings, the absence of standardized design does not allow an evaluation of the absolute abundance of species (Loos *et al.*, 2009; Robinson *et al.*, 2013). Nevertheless, the data could be correlated with several environmental parameters and installation related characteristics. The increasing number of harbour porpoise sightings towards the south may be related to proximity of the southern installation with areas where this species is known to occur in numbers (Gilles *et al.*, 2009, 2016; Hammond *et al.*, 2013). Other taxonomic relationships with depth and installation aerial footprint could be explained by differences in prey availability (Pickering & Whitmarsh, 1997; Fujii, 2015). More data would be required to make these correlations species specific, and confirm their validity while accounting for possible confounding effects of other environmental factors or installation characteristics.

Most sightings reported under the MMSR were made during spring and summer. Distribution data collected from vessel and aerial surveys in the central part of the North Sea show similar temporal variations (Evans *et al.*, 2003; Gilles *et al.*, 2009; De Boer, 2010). In particular, it is suggested that a relatively higher abundance of harbour porpoise in spring and summer can be expected in the central North sea, due to seasonal porpoise population movement from coastal areas to offshore areas (Gilles *et al.*, 2009, 2016). Such seasonality in occurrence of marine mammals close to O&G platforms could be natural, and reflect a change in prey availability (De Boer, 2010; Sveegaard *et al.*, 2012; Fujii, 2015; Gilles *et al.*, 2016). On the other hand, the combined effect of shorter days and harsher weather conditions significantly reduces the likelihood of detecting marine mammals based on visual surveys (Clarke, 1982; Teilmann, 2003). Such an effect was also observed in other surveys based on incidental sightings data (Kinze *et al.*, 2003; Loos *et al.*, 2009). The estimation of weather corrected data would require a standardized reporting format including significantly more information (Teilmann, 2003). Alternatively, long-term continuous acoustic monitoring studies (unaffected by weather and daylight hours) could help fill some of the gaps in our knowledge of seasonal distribution of marine mammals in the vicinity of anthropogenic structures.

The MMSR has proven to be a useful incentive for reporting offshore sightings. It provides us with relatively long-term marine mammal occurrence and biodiversity data in offshore O&G activity areas. The caveats associated with incidental sighting data are acceptable, as long as data analyses and inferences based on these analyses are made accordingly. Implementation of a more standardized reporting programme to gain additional knowledge on seasonality or species abundance estimates is possible (Evans & Hammond, 2004; Todd, 2016). However, we predict that the additional reporting requirements would inevitably lead to a significant reduction in the number of reports from offshore working volunteers staff and a loss of valuable scientific information (Borja & Elliott, 2013).

SUPPLEMENTARY MATERIAL

The supplementary material for this article can be found at https://doi.org/10.1017/S0025315417000406.

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REFERENCES

Abend A.G. and Smith T.D. (1997) Differences in stable isotope ratios of carbon and nitrogen between long-finned pilot whales (*Globicephala melas*) and their primary prey in the western north Atlantic. *ICES Journal of Marine Science: Journal du Conseil* 54, 500–503.

Andersen J.H., Stock A., Heinänen S., Mannerla M. and Vinther M. (2013) Human uses, pressures and impacts in the Eastern North Sea. *Technical Report from DCE – Danish Centre for Environment and Energy*, no. 18, 136 pp.

Arnould J.P.Y., Monk J., Ierodiaconou D., Hindell M.A., Semmens J., Hoskins A.J., Costa D.P., Abernathy K. and Marshall G.J. (2015) Use of anthropogenic sea floor structures by Australian fur seals: potential positive ecological impacts of marine industrial development? *PLoS ONE* 10, e0130581.

Balle J.D., Clausen K.T., Mikkelsen L., Wisniewska D.M. and Teilmann J. (2014) *Harbour Porpoises and Noise Around an Operating Oil and Gas Production Platform in the North Sea – Status Report*. DCE.

Beer T. (1996) *Environmental oceanography*. Boca Raton, FL: CRC Press, 402 pp.

Borja A., Bricker S.B., Dauer D.M., Demetriades N.T., Ferreira J.G., Forbes A.T., Hutchings P., Jia X., Kenchington R., Marques J.C. and Zhu C. (2008) Overview of integrative tools and methods in assessing ecological integrity in estuarine and coastal systems worldwide. *Marine Pollution Bulletin* 56, 1519–1537.

Borja Á. and Elliott M. (2013) Marine monitoring during an economic crisis: the cure is worse than the disease. *Marine Pollution Bulletin* 68, 1–3.

Brandt M.J., Hansen S., Diederichs A. and Nehls G. (2014) Do man-made structures and water depth affect the diel rhythms in click recordings of harbor porpoises (*Phocoena phocoena*)? *Marine Mammal Science* 30, 1109–1121.

Clarke R. (1982) An index of sighting conditions for surveys of whales and dolphins. *Report of the International Whaling Commission* 32, 559–561.

Conrad C.C. and Hilchey K.G. (2011) A review of citizen science and community-based environmental monitoring: issues and opportunities. *Environmental Monitoring and Assessment* 176, 273–291.

De Boer M.N. (2010) Spring distribution and density of minke whale *Balaenoptera acutorostrata* along an offshore bank in the central North Sea. *Marine Ecology Progress Series* 408, 265–274.

Devictor V., Whittaker R.J. and Beltrame C. (2010) Beyond scarcity: citizen science programmes as useful tools for conservation biogeography. *Diversity and Distributions* 16, 354–362.

Elliott M. (2011) Marine science and management means tackling exogenic unmanaged pressures and endogenic managed pressures – a numbered guide. *Marine Pollution Bulletin* 62, 651–655.

Embling C.B., Walters A.E.M. and Dolman S.J. (2015) How much effort is enough? The power of citizen science to monitor trends in coastal cetacean species. *Global Ecology and Conservation* 3, 867–877.

Evans P.G.H. (1976) An analysis of sightings of Cetacea in British waters. *Mammal Review* 6, 5–14.

Evans P.G.H., Anderwald P. and Baines M.E. (2003) *UK cetacean status review*. Bangor: English Nature, Peterborough and the Countryside Council for Wales, 160 pp.

Evans P.G.H. and Hammond P.S. (2004) Monitoring cetaceans in European waters. *Mammal Review* 34, 131–156.

Evans P.G.H., Pierce G.J., Veneruso G., Weir C.R., Gibas D., Anderwald P. and Santos M.B. (2015) Analysis of long-term effort-related land-based observations to identify whether coastal areas of harbour porpoise and bottlenose dolphin have persistent high occurrence and abundance. *JNCC Report*, no. 543. Peterborough: Joint Nature Conservation Committee, 147 pp.

Fujii T. (2015) Temporal variation in environmental conditions and the structure of fish assemblages around an offshore oil platform in the North Sea. *Marine Environmental Research* 108, 69–82.

Fujii T. (2016) Potential influence of offshore oil and gas platforms on the feeding ecology of fish assemblages in the North Sea. *Marine Ecology Progress Series* 542, 167–186.

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.

Gilles A., Viquerat S., Becker E.A., Forney K.A., Geelhoed S.C.V., Haelters J., Nabe-Nielsen J., Scheidat M., Sveegaard S., van Beest F.M., van Bemmelen R. and Aarts G. (2016) Seasonal habitat-based density models for a marine top predator, the harbour porpoise, in a dynamic environment. *Ecosphere* 7, e01367. doi: 10.1002/ecs2.1367.

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.

Jefferson T.A., Webber M.A. and Pitman R.L. (2011) *Marine mammals of the world: a comprehensive guide to their identification: a comprehensive guide to their identification*. London: Academic Press.

Kinze C.C. (2001) *Havepattedyr I Nordatlanten (Marine mammal in the North Atlantic)*. Copenhagen: Gads Forlag, 191 pp.

Kinze C.C., Jensen T. and Skov T. (2003) *Fokus på hvaler i Danmark 2000–2002*. Copenhagen: Fiskeri- og Søfartsmuseet.

Koblitz J.C., Amundin M., Carlström J., Thomas L., Carlén I., Teilmann J., Tregenza N., Wennerberg D., Kyhn L., Svegaard S., Koza R., Kosecka M., Pawliczka I., Tiberi Ljungqvist C., Brundiers K., Wright A., Mikkelsen L., Tougaard J., Loisa O., Galatius A., Jüssi I. and Benke H. (2014) Large-scale static acoustic survey of a low-density population – estimating the abundance of the Baltic Sea harbor porpoise. *Journal of the Acoustical Society of America* 136, 2248.

Langhamer O. (2012) Artificial reef effect in relation to offshore renewable energy conversion: state of the art. *Scientific World Journal* 2012, 8.

Loos P., Cooke J., Deimer P., Fietz K., Henning V. and Schütte H.-J. (2009) Opportunistic sightings of harbour porpoises (*Phocoena phocoena*) in the Baltic Sea at Large: Kattegat, Belt Sea, Sound, Western Baltic and Baltic Proper. In *Proceedings of the 17th Meeting of the ASCOBANS Advisory Committee*, Cornwall, UK.

McConnell B.J., Fedak M.A., Lovell P. and Hammond P.S. (1999) Movements and foraging areas of grey seals in the North Sea. *Journal of Applied Ecology* 36, 573–590.

Mikkelsen L., Mouritsen K., Dahl K., Teilmann J. and Tougaard J. (2013) Re-established stony reef attracts harbour porpoises *Phocoena phocoena*. *Marine Ecology Progress Series* 481, 239–248.

Olsen E. and Holst J.C. (2001) A note on common minke whale (*Balaenoptera acutorostrata*) diets in the Norwegian Sea and the North Sea. *Journal of Cetacean Research and Management* 3, 179–184.

OSPAR Commission (2010) *Quality Status Report 2010*. London: OSPAR Commission, 176 pp.

Palacios D.M., Herrera J.C., Gerrodette T., Garcia C., Soler G.A., Avila I.C., Bessudo S., Hernandez E., Trujillo F. and Flórez-González L. (2012) Cetacean distribution and relative abundance in Colombia's Pacific EEZ from survey cruises and platforms of opportunity. *Journal of Cetacean Research and Management* 12, 45–60.

Pauly D., Trites A.W., Capuli E. and Christensen V. (1998) Diet composition and trophic levels of marine mammals. *ICES Journal of Marine Science: Journal du Conseil* 55, 467–481.

Pickering H. and Whitmarsh D. (1997) Artificial reefs and fisheries exploitation: a review of the 'attraction versus production' debate, the influence of design and its significance for policy. *Fisheries Research* 31, 39–59.

Reid J.B., Evans P.G.H. and Northridge S.P. (2003) *Atlas of cetacean distribution in North-West European waters*. Peterborough: Joint Nature Conservation Committee, pp. 76.

Robinson D.P., Jaidah M.Y., Jabado R.W., Lee-Brooks K., Nour El-Din N.M., Malki A.A.A., Elmeer K., McCormick P.A., Henderson A.C., Pierce S.J. and Ormond R.F.G. (2013) Whale sharks, *Rhincodon typus*, aggregate around offshore platforms in Qatari waters of the Arabian Gulf to feed on fish spawn. *PLoS ONE* 8, e58255.

Russell D.J.F., Brasseur S.M.J.M., Thompson D., Hastie G.D., Janik V.M., Aarts G., McClintock B.T., Matthiopoulos J., Moss S.E.W. and McConnell B. (2014) Marine mammals trace anthropogenic structures at sea. *Current Biology* 24, R638–R639.

Soldal A.V., Svellingen I., Jørgensen T. and Løkkeborg S. (2002) Rigs-to-reefs in the North Sea: hydroacoustic quantification of fish in the vicinity of a "semi-cold" platform. *ICES Journal of Marine Science: Journal du Conseil* 59(Suppl.), S281–S287.

Sveegaard S., Andreasen H., Mouritsen K., Jeppesen J., Teilmann J. and Kinze C. (2012) Correlation between the seasonal distribution of harbour porpoises and their prey in the Sound, Baltic Sea. *Marine Biology* 159, 1029–1037.

Teilmann J. (2003) Influence of sea state on density estimates of harbour porpoises (*Phocoena phocoena*). *Journal of Cetacean Research and Management* 5, 85–92.

Thompson P.M., McConnell B.J., Tollit D.J., Mackay A., Hunter C. and Racey P.A. (1996) Comparative distribution, movements and diet of harbour and grey seals from Moray Firth, NE Scotland. *Journal of Applied Ecology* 33, 1572–1584.

Todd V.L., Pearse W.D., Tregenza N.C., Lepper P.A. and Todd I.B. (2009) Diel echolocation activity of harbour porpoises (*Phocoena phocoena*) around North Sea offshore gas installations. *ICES Journal of Marine Science: Journal du Conseil* 66, 734–745.

Todd V.L.G. (2016) Mitigation of underwater anthropogenic noise and marine mammals: the 'death of a thousand' cuts and/or mundane adjustment? *Marine Pollution Bulletin* 102, 1–3.

Todd V.L.G., Warley J.C. and Todd I.B. (2016) Meals on wheels? A decade of megafaunal visual and acoustic observations from offshore oil & gas rigs and platforms in the North and Irish seas. *PLoS ONE* 11, e0153320.

Tollit D.J., Black A.D., Thompson P.M., Mackay A., Corpe H.M., Wilson B., Parijs S.M., Grellier K. and Parlane S. (1998) Variations in harbour seal *Phoca vitulina* diet and dive-depths in relation to foraging habitat. *Journal of Zoology* 244, 209–222.

Tougaard J., Teilmann J. and Tougaard S. (2008) Harbour seal spatial distribution estimated from Argos satellite telemetry: overcoming positioning errors. *Endangered Species Research* 4, 113–122.

Triossi F., Willis T.J. and Pace D.S. (2013) Occurrence of bottlenose dolphins *Tursiops truncatus* in natural gas fields of the northwestern Adriatic Sea. *Marine Ecology* 34, 373–379.

and

Whitehead H. (2010) Conserving and managing animals that learn socially and share cultures. *Learning and Behavior* 38, 329–336.

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