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Displacement responses of a mysticete, an odontocete, and a phocid seal to construction-related vessel traffic

Pia Anderwald[1,2,*], Anja Brandecker[1], Mary Coleman[1], Clodagh Collins[1], Hannah Denniston[1], Michael Damien Haberlin[1], Mairéad O'Donovan[1], Róisín Pinfield[1], Fleur Visser[3,4], Laura Walshe[1]

[1]Coastal and Marine Research Centre, University College Cork, Haulbowline, Cobh, Co. Cork, Ireland
[2]Swiss National Park, Chastè Planta-Wildenberg, 7530 Zernez, Switzerland
[3]Kelp Marine Research, 1624 CJ, Hoorn, The Netherlands
[4]University of Amsterdam, IBED Institute, 1098 XH, Amsterdam, The Netherlands

ABSTRACT: Marine construction works often lead to temporary increases in vessel traffic, which, in addition to the construction activity itself, contribute to underwater ambient noise in the affected area and increase the risk of vessel collision for marine mammals. Using a 3 yr data set of cliff-based observations, we investigated whether the presence/absence of minke whales, bottlenose dolphins and grey seals varied with the overall number and type of vessels present during the construction of an underwater gas pipeline through a bay on the northwest coast of Ireland. Results from binary generalised estimation equations showed a positive relationship between the presence of bottlenose dolphins and the overall number of boats, as well as the number of construction vessels. However, the presence of the 2 taxa with higher hearing sensitivity at low frequencies — minke whales and grey seals — was negatively correlated with the total number of boats and the number of utility vessels (as well as the number of fishing boats in the case of minke whales). While bottlenose dolphins may have been attracted to either the vessels per se or high prey concentrations coinciding with construction activities, both minke whales and grey seals appear to have been displaced by high levels of vessel traffic, most likely due to noise disturbance. Careful consideration of mitigation measures, especially for taxa with low-frequency hearing, is therefore essential in the planning phase of offshore construction activities, which should also take local circumstances into account.

KEY WORDS: Offshore construction · Marine mammals · GEE · Noise disturbance

INTRODUCTION

Marine construction works related to the oil and gas or renewables industries invariably lead to a temporary increase in vessel traffic within a relatively small area. While activities such as dredging, drilling or rock-trenching per se already increase noise levels both below and above water, this associated increase in shipping activity further adds to ambient noise, especially below water. Indeed, the strongest sounds measured during a study on the characteristics of oil industry dredge and drilling noise in the Arctic were caused by a hopper dredge underway with a damaged propeller (Greene 1987). For marine mammals, there is an additional danger of collision with vessels (e.g. Kraus 1990, Wells & Scott 1997, Laist et al. 2001, Pesante et al. 2002), particularly if highly manoeuvrable fast boats, which are often used by security or for the transport of construction personnel, are involved.

*Email: panderwald@hotmail.com

One of the primary conservation concerns for marine mammals in the context of anthropogenic underwater noise from increases in vessel traffic is the effect of masking of biologically important sounds (Payne & Webb 1971, Southall 2004, Clark et al. 2009). Masking has the potential to affect intraspecific communication, predator/prey detection and navigation, and increased levels of stress have been reported in animals chronically exposed to high levels of anthropogenic noise (Rolland et al. 2012). The greatest potential for masking from shipping noise (mostly 10 Hz to 1 kHz) exists for taxa with high hearing sensitivity primarily at these lower frequencies, i.e. baleen whales, most pinnipeds and fish. However, potential for masking at higher frequencies (i.e. 1–25 kHz), relevant for odontocetes, exists when vessels are in close proximity to the animal (Götz et al. 2009).

The exact characteristics of vessel noise depend on ship type, size, speed, operational mode and other factors, and sound propagation underwater is dependent on parameters such as water depth and seabed type. The responses of animals to shipping and construction noise are therefore difficult to predict, and will also vary depending on species, individual, age, sex, prior experience and behavioural state (Myrberg 1990, Würsig & Evans 2001, Weilgart 2007).

The strongest behavioural response by marine mammals to industrial activity and/or increased vessel traffic is displacement from important feeding or breeding grounds that overlap with the area of impact. For example, gray whales *Eschrichtius robustus* were displaced from breeding lagoons by dredging and associated increases in shipping for 10 yr (Bryant et al. 1984) and by industrial noise for over 5 yr (Jones et al. 1994). Belugas *Delphinapterus leucas* in the Arctic fled from icebreakers at distances of 35 to 50 km and did not return to the area for 1 to 2 d afterwards (Finley et al. 1990, Cosens & Dueck 1993), and bottlenose dolphins *Tursiops truncatus* abandoned primary feeding grounds in Florida during periods of intense boat traffic (Allen & Read 2000).

Following plans for the construction of an underwater gas pipeline from the Corrib gas field 65 km offshore to its landfall site near Glengad in Broadhaven Bay, Co. Mayo, northwest Ireland, a marine mammal monitoring programme was initiated in the area in 2001. This programme has continued in each year of construction activity, i.e. during 2002, 2005, and continuously (including winter months) since 2008 (Ó Cadhla et al. 2003, Englund et al. 2006, Coleman et al. 2009, Visser et al. 2010, Anderwald et al. 2011, 2012a). Construction activities within the bay have consisted of acoustic (side-scan sonar) and ROV surveys, dredging, trenching, pipe-laying and rock-placement over the pipeline. Mitigation measures have included (1) the use of marine mammal observers onboard construction vessels with the authority to postpone or stop construction work if marine mammals are present in the immediate vicinity, and (2) a code of conduct for vessels and personnel operating within Broadhaven Bay (NPWS 2007).

The construction works inevitably resulted in an associated increase in boat traffic within the study area, and vessel activity has been monitored in parallel with cetacean occurrence in the area since 2009, the year of most intensive construction. Shipping activity within the study area reached a peak of 43 vessels during one scan of the bay in June 2009, while the pipeline was being laid. This included construction vessels, the 300 m pipe-lay vessel, utility boats and numerous safety rigid inflatable boats (RIBs) within Broadhaven Bay, an area of less than 9 × 9 km^2 (Fig. 1), which is normally only used by a maximum of 10 to 12 small to medium-sized (up to 15 m) local fishing boats. No marine construction-related activities have been conducted since November 2010.

Broadhaven Bay represents an important habitat for marine mammals, with 9 cetacean species and both seal species occurring in Ireland (grey *Halichoerus grypus* and harbour seals *Phoca vitulina*) recorded during the monitoring programme (Ó Cadhla et al. 2003, Englund et al. 2006, Coleman et al. 2009,

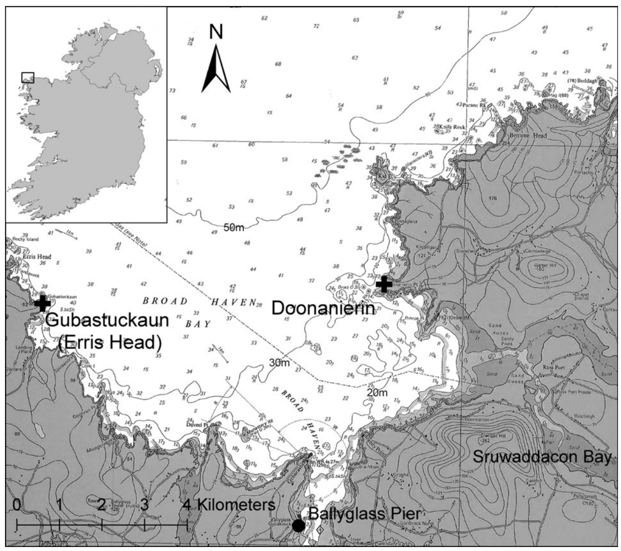

Fig. 1. Study area of Broadhaven Bay and surrounding area, indicating the 2 sites for land-based observations (crosses). Background map © Crown Copyright and/or database rights. Reproduced by permission of the Controller of Her Majesty's Stationery Office and the UK Hydrographic Office (www.ukho.gov.uk), licence no. 15985

Visser et al. 2010, Anderwald et al. 2011, 2012a). The regular presence of representatives of mysticetes (minke whale *Balaenoptera acutorostrata*), odontocetes and phocid seals makes the study area ideally suited to simultaneously investigating the impact of the construction-related increase in vessel traffic on the 3 marine mammal taxa.

We focused our analysis on minke whale, bottlenose dolphin and grey seal representing the 3 taxa because of the comparatively high sighting rates of these species during the monitoring programme and their year-round occurrence within Broadhaven Bay, combined with a lack of any significant pattern in seasonal presence (Anderwald et al. 2012b). The latter point was important to exclude the possibility of confounding effects by natural seasonal variation in the presence of animals (construction works and the associated increase in vessel traffic were mostly confined to the period between May and September).

Although the noise from some of the construction activities themselves (e.g. rock trenching) may at times have exceeded the noise from vessel movements, none of the 3 species had shown any difference in presence during days with and without construction activity or different categories thereof, such as dredging, trenching or pipe-laying, when only the summer months over all years of the monitoring programme were considered (Anderwald et al. 2012a). However, no baseline data on marine mammal presence for the pre-construction phase, nor direct measurements of underwater noise emitted from the construction activities, were available. The focus of the present analysis was therefore on the effects of construction-related increases in vessel activity, for which data had been collected in a consistent manner over a 3 yr period and which provided an alternative measure for disturbance from construction.

Due to the low-frequency hearing sensitivity of baleen whales and pinnipeds (e.g. Götz et al. 2009), it would be expected that particularly minke whales and seals might avoid the study area during days of intensive vessel traffic. However, this may also depend on the type of vessels involved. Since odontocete hearing is less sensitive at lower frequencies, bottlenose dolphins would be expected to be less affected. However, all species may avoid fast boats such as RIBs due to their less predictable movements and associated higher collision risk. We therefore investigated the presence/absence of the 3 species within Broadhaven Bay in relation to not only overall number of vessels present in the study area, but also numbers in different vessel categories, while simultaneously correcting for sighting efficiency.

MATERIALS AND METHODS

The study area is a relatively shallow open bay (8.6 km wide at the entrance) with a northward aspect and depths less than 50 m (Fig. 1). The nearby Inishkea Islands are part of one of the most important breeding areas for grey seals in Ireland (Kiely & Myers 1998, Ó Cadhla & Strong 2003, Cronin et al. 2007a, Ó Cadhla et al. 2008), while haul-out sites for harbour seals are also found within Broadhaven Bay and nearby Blacksod Bay (Cronin et al. 2007b).

Observational data considered for this analysis covered a 3 yr period between 10 May 2009 and 2 May 2012, for which year-round (except for the month of December) effort-related observations of both marine mammals and vessel activity within Broadhaven Bay were available.

Fieldwork

Land-based observers were positioned at 2 sites: Gubastuckaun at Erris Head (hereafter referred to as Erris Head; 62 m above mean sea level [MSL]) at the western entrance to the bay, and Doonanierin Point (54 m above MSL) on its eastern shoreline (Fig. 1), which between them provide a view over the entire study area of Broadhaven Bay and extending up to ca. 8 km offshore. Visual survey effort was conducted by 1 to 2 observers per site during all daylight hours in favourable weather conditions (sea state < Beaufort Force 4; swell height ≤2 m; visibility ≥7 km). The study area was scanned systematically with handheld binoculars (7 × 50 Steiner or 8 × 42 Nikon; covering the entire visible sea area) and a telescope (Kowa) equipped with a 32× wide-angle eye-piece (covering mainly areas ≥2 km from the observation points). Scans lasted 1 h ± 15 min (allowing for variation in time needed to record sightings of animals and vessels) and included 2 thorough scans through the search area, once with binoculars and once with a telescope, starting in the outer section of the bay and ending in the inner-most part. Each scan was followed by a 1 h break to allow observers to rest their eyes. Environmental conditions (sea state, swell height, visibility, precipitation and the extent of glare) and vessel activity were recorded at the start of each scan. The following vessel categories were used: construction vessels (25–300 m in length; including dredgers, the pipe-laying vessel, barges and tugs), utility vessels (15–30 m in length), RIBs (consisting mostly of security RIBs used to enforce a safety distance around construction vessels, and utility RIBs), motor boats (consisting of both commercial charter boats and recreational small to medium-sized boats, ≤20 m) and commercial fishing boats (mostly medium-sized local boats, ≤20 m, potting for crabs and lobster or fishing for mackerel).

Analysis

Due to their relatively small size and inconspicuous surface behaviour, seals are more difficult to detect in the water than bottlenose dolphins and minke whales (only seals in the water were considered for the present analysis). Moreover, grey and harbour seals co-occur in Broadhaven Bay, although the grey seal is the more common species (Ó Cadhla et al. 2003, Englund et al. 2006, Coleman et al. 2009, Visser et al. 2010, Anderwald et al. 2011, 2012a). The presence of both species within the study area and the difficulty of distinguishing between them at a distance from the cliff-based observation sites led to 35% of seal sightings being recorded as 'unidentified seals' over the study period (Visser et al. 2010, Anderwald et al. 2011, 2012a). This might have resulted in a negative bias in the analysis, if only positively identified grey seals had been included. The seal data were therefore analysed twice, once considering only positively identified grey seals, and once including all seal sightings (i.e. grey seals, harbour seals and unidentified seals). The data set for harbour seals alone (38 sightings in 26 scans between both observation sites) was too small to be analysed separately.

In order to account for temporal autocorrelation in the presence of bottlenose dolphins, minke whales and seals between consecutive scans within the same day, binary generalised estimation equations (GEEs) (Liang & Zeger 1986, Hardin & Hilbe 2002, Fitzmaurice et al. 2004) were constructed for the presence/absence of each species, using an auto-regressive (AR-1) correlation structure within the geepack library (Halekoh et al. 2006) implemented in the freeware R (R Development Core Team 2006). Day was used as a grouping variable (due to the high mobility of the 3 taxa relative to the small size of the study area, their presence within Broadhaven Bay between different days could be assumed as independent). However, since the field of view between Erris Head and Doonanierin Point partly overlapped and individuals were occasionally seen from both locations, sightings between the 2 sites were not independent and analyses were therefore conducted for each site separately.

Two models were constructed for each species and site. The aim of the first model (Model A) was to investigate whether the presence of the 3 species was negatively affected by the overall number of vessels within the study area. This model therefore included the overall number of vessels recorded in a scan as an explanatory variable. In the second model (Model B), boat numbers were included separately by vessel category in order to test whether the presence and number of any particular type of vessel had a negative influence on the presence of the 3 species. Since the overall number of vessels is dependent on the numbers in each vessel category, these parameters could not be included in the same model. The sea state (in Beaufort scale) during each scan, as well as swell height (in metres), were also incorporated in the models as correction parameters for the detectability of animals (e.g. Buckland et al. 1993, Hammond et al. 2002). Model selection was performed in a stepwise backward procedure using the Wald test (Halekoh et al. 2006). Since no seasonal pattern was detected in the occurrence of bottlenose dolphins, minke whales or grey seals within the study area (Anderwald et al. 2012b), no correction for time of year was necessary.

RESULTS

The data set consisted of 174 days of cliff-based observations between 18 May 2009 and 2 May 2012, comprising a total of 815 scans (434 from Erris Head and 381 from Doonanierin Point). Sighting frequencies of minke whales and seals (i.e. presence of animals per scan) were twice as high from Erris Head as from Doonanierin Point; only bottlenose dolphins were sighted more frequently from Doonanierin Point (Table 1).

No explanatory variable significantly determined the presence/absence of bottlenose dolphins in either model for Erris Head (Table 2). However, for Doonanierin Point, the species' presence in a scan was positively correlated with the overall number of vessels (Model A), as well as the number of construction vessels (Model B; Table 2, Fig. 2), and there was a high correlation for the presence of bottlenose dolphins between consecutive scans within a day (Table 2).

By contrast, the detectability of minke whales from Erris Head showed a significant negative correlation with sea state and swell height (Models A and B, Table 2), and the presence of the species was negatively influenced by the overall number of vessels

Table 1. Sample sizes for sightings of each species from Erris Head and Doonanierin Point

	Erris Head	Doonanierin Point	Total
Effort			
No. of days	147	128	176
No. of scans	434	381	815
Sightings			
Bottlenose dolphins			
No. of days present	16	17	27
No. of scans present	22	31	53
No. of ind. per scan	1–100	3–100	1–100
Minke whales			
No. of days present	34	19	43
No. of scans present	49	25	74
No. of ind. per scan	1–3	1–4	1–4
Grey seals			
No. of days present	44	25	63
No. of scans present	65	31	96
No. of ind. per scan	1–6	1–11	1–11
All seals (grey, harbor and unidentified)			
No. of days present	62	49	92
No. of scans present	103	64	167
No. of ind. per scan	1–10	1–12	1–12

(Model A) and the number of both utility and fishing vessels (Model B; Table 2, Fig. 3), with only a weak correlation between consecutive scans (Table 2). For Doonanierin Point, no explanatory variable significantly determined the presence/absence of minke whales (Table 2).

Similarly to minke whales, the detectability of grey seals during scans from Erris Head was negatively correlated with sea state (Models A and B), and the species' presence was negatively influenced by the overall number of vessels (Model A) and the number of utility boats (Model B; Table 2, Fig. 4A–C), with a weak to moderate correlation between consecutive scans (Table 2a). However, for sightings from Doonanierin Point, only the variable sea state negatively influenced detections of grey seals, whereas the number of vessels showed no effect. The results for Models A and B were therefore identical (Table 2, Fig. 4D), and there was no correlation between consecutive sightings (Table 2).

When all seal sightings (grey, harbour and unidentified) were combined, the negative relationship between detections and sea state (Models A and B), as

Table 2. Summaries for final generalised estimation equation models (Model A; Model B) for presence/absence of bottlenose dolphins, minke whales, grey seals and all seals (including grey seal, harbour seal and unidentified seals) per scan from Erris Head and Doonanierin Point, with day as block variable. Model A refers to the model with overall number of vessels included; Model B refers to the model with number of vessels per category included. Where parameters were included in both models, results for both models are presented (Model A; Model B). The exceptions are for models for grey seal and all seals from Doonanierin Point, where Models A and B were identical. Results are given as parameter estimate ± SE. n/a: not applicable for Model A or B; –: not included in final model. Significance levels (Wald statistic): *p < 0.05; **p < 0.01, ***p < 0.001. Alpha refers to the correlation between consecutive scans

	Bottlenose dolphin	Minke whale	Grey seal	All seals
Erris Head				
Intercept	−3.29 ± 0.37***; −3.12 ± 0.29***	0.87 ± 0.76; 1.13 ± 0.75	0.47 ± 0.66; 0.44 ± 0.67	0.41 ± 0.53; 0.63 ± 0.56
Sea state	– ; –	−0.86 ± 0.33**; −0.87 ± 0.33**	−0.86 ± 0.28**; −0.9 ± 0.29**	−0.73 ± 0.23**; −0.75 ± 0.24**
Swell height	– ; –	−0.70 ± 0.29*; −0.68 ± 0.29*	– ; –	– ; –
No. of all vessels	0.06 ± 0.05; n/a	−0.11 ± 0.04*; n/a	−0.08 ± 0.04*; n/a	– ; n/a
No. of construction vessels	n/a ; –	n/a ; –	n/a ; –	n/a ; –
No. of utility vessels	n/a ; –	n/a ; −0.48 ± 0.16**	n/a ; −0.39 ± 0.14**	n/a ; −0.23 ± 0.1*
No. of RIBs	n/a ; –	n/a ; –	n/a ; –	n/a ; –
No. of motor boats	n/a ; 0.3 ± 0.15	n/a ; –	n/a ; –	n/a ; –
No. of fishing boats	n/a ; –	n/a ; −0.23 ± 0.09*	n/a ; –	n/a ; –
Alpha	0.14 ± 0.15; 0.2 ± 0.21	0.15 ± 0.08; 0.15 ± 0.09	0.26 ± 0.09; 0.25 ± 0.08	0.36 ± 0.09; 0.35 ± 0.09
Doonanierin Point				
Intercept	−2.82 ± 0.35***; −2.66 ± 0.31***	−1.05 ± 0.85; −2.46 ± 0.25***	−0.26 ± 0.7	0.18 ± 0.54
Sea state	– ; –	−0.76 ± 0.41; –	−1.06 ±0.35**	−0.85 ± 0.26**
Swell height	– ; –	– ; –	–	–
No. of all vessels	0.07 ± 0.03*; n/a	– ; n/a	– ; n/a	– ; n/a
No. of construction vessels	n/a ; 0.27 ± 0.08**	n/a ; −0.42 ± 0.23	n/a ; –	n/a ; –
No. of utility vessels	n/a ; –	n/a ; –	n/a ; –	n/a ; –
No. of RIBs	n/a ; –	n/a ; –	n/a ; –	n/a ; –
No. of motor boats	n/a ; –	n/a ; –	n/a ; –	n/a ; –
No. of fishing boats	n/a ; –	n/a ; –	n/a ; –	n/a ; –
Alpha	0.65 ± 0.28; 0.65 ± 0.32	0.24 ± 0.18; 0.25 ± 0.15	0.01 ± 0.04	0.01 ± 0.05

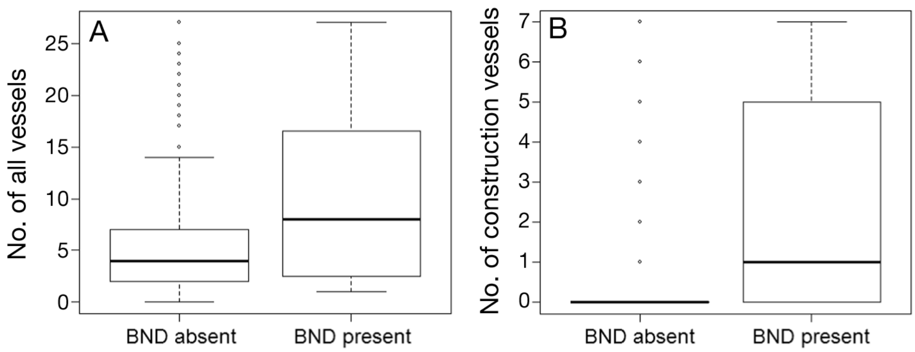

Fig. 2. Boxplots for significant variables left in final generalised estimation equations for presence/absence of bottlenose dolphins (BND) from Doonanierin Point. (A) Number of all vessels from Model A. (B) Number of construction vessels from Model B. Boxplots show median, interquartile range (box height) and median ± 1.5 × interquartile range (borders of vertical line). Outliers are indicated as dots

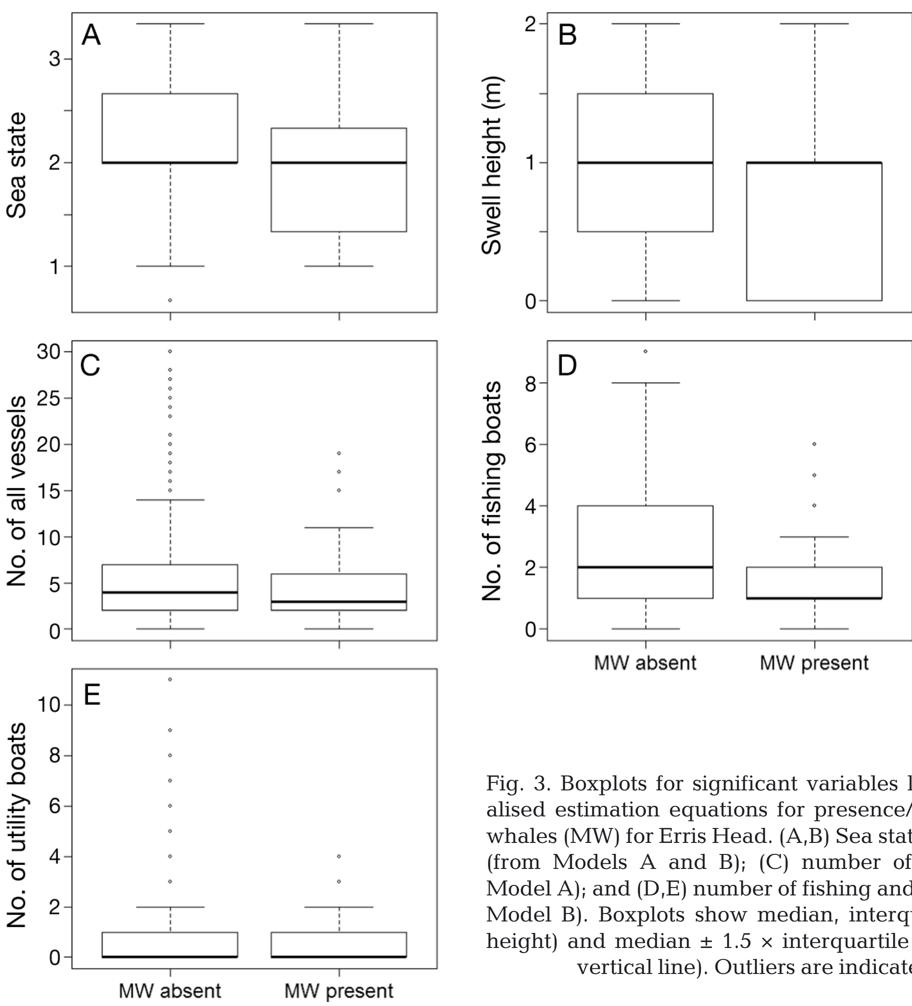

Fig. 3. Boxplots for significant variables left in final generalised estimation equations for presence/absence of minke whales (MW) for Erris Head. (A,B) Sea state and swell height (from Models A and B); (C) number of all vessels (from Model A); and (D,E) number of fishing and utility boats (from Model B). Boxplots show median, interquartile range (box height) and median ± 1.5 × interquartile range (borders of vertical line). Outliers are indicated as dots

well as the number of utility boats (Model B), remained for Erris Head, although the overall number of vessels was not included in the final Model A (Table 2, Fig. 5A,B). Correlations between consecutive scans were moderate (Table 2). As was found for grey seals alone, the results of both models for Doonanierin Point were identical, with only sea state negatively influencing detectability (Table 2, Fig. 5C).

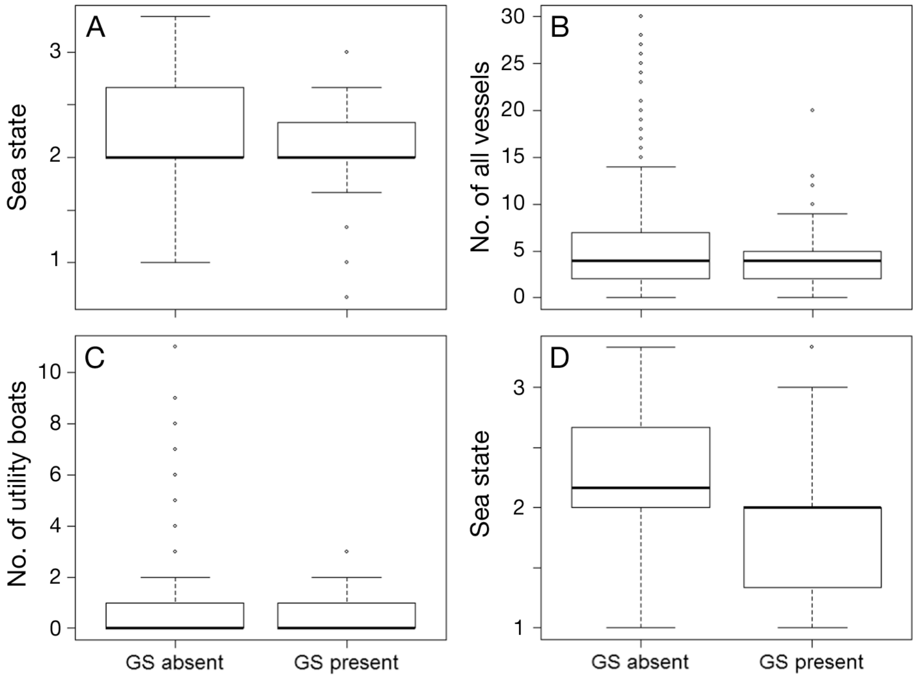

Fig. 4. Boxplots for significant variables left in final generalised estimation equations for presence/absence of grey seals (GS). (A) Sea state (from Models A and B for Erris Head); (B) number of all vessels (from Model A for Erris Head); (C) number of utility boats (from Model B for Erris Head); and (D) sea state (from Models A and B for Doonanierin Point). Boxplots show median, interquartile range (box height) and median ± 1.5 × interquartile range (borders of vertical line). Outliers are indicated as dots

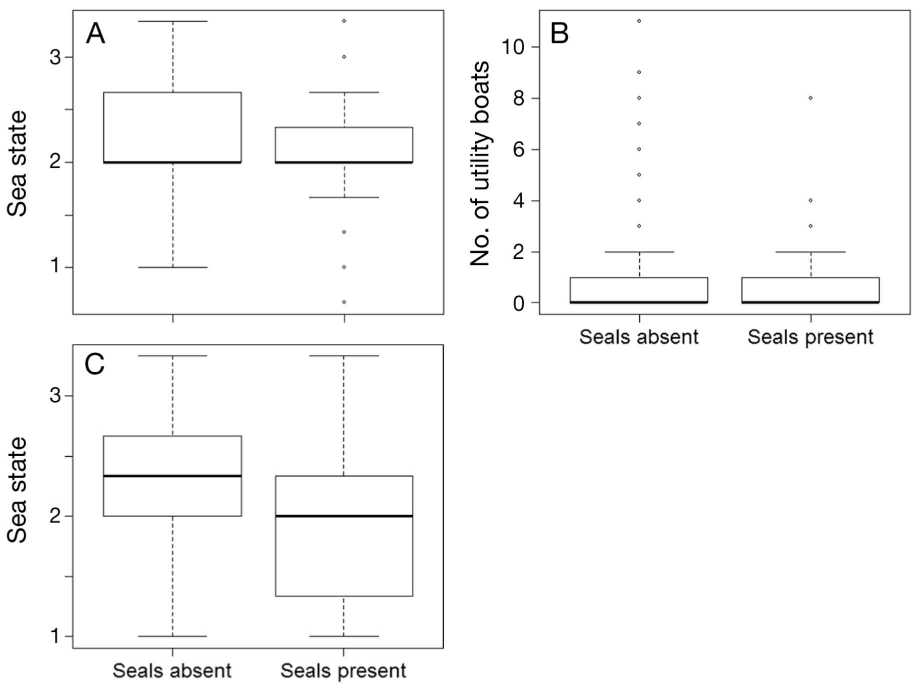

Fig. 5. Boxplots for significant variables left in final generalised estimation equations for presence/absence of grey, harbour and unidentified seals. (A) Sea state (from Models A and B for Erris Head); (B) number of utility boats (from Model B for Erris Head); and (C) sea state (from Models A and B for Doonanierin Point). Boxplots show median, interquartile range (box height) and median ± 1.5 × interquartile range (borders of vertical line). Outliers are indicated as dots

DISCUSSION

Bottlenose dolphins, minke whales and seals differ in their spatial usage of Broadhaven Bay (Anderwald et al. 2012b), which resulted in minke whales and seals being detected more frequently from Erris Head, but bottlenose dolphins being present during a higher proportion of scans from Doonanierin Point (Table 1). These different patterns of fine-scale habitat use between taxa influenced statistical power, so that the final models for presence/absence of bottlenose dolphins from Erris Head and minke whales from Doonanierin Point did not include any significant variable, while presence/absence of the most frequently recorded taxon — grey seals and all seal sightings combined — from Doonanierin Point was influenced by sea state only. We therefore concentrate on the results from Doonanierin Point for bottlenose dolphins and on the results from Erris Head for minke whales, grey seals and all seal sightings combined.

Bottlenose dolphin presence from Doonanierin Point showed a positive relationship with overall vessel numbers (Model A), as well as with the number of construction vessels (Model B). This is particularly surprising since the area near Doonanierin Point, which was most frequently used by the dolphins, coincided with the centre of construction activity. Both the overall number of boats and the number of construction vessels reached a peak during June and July 2009, around the time that the pipeline was being laid, and this coincided with a high frequency of bottlenose dolphin sightings, although the species normally only visits the study area about once or twice a month on average (Anderwald et al. 2012b). It is unclear whether the dolphins were attracted to the vessels themselves or to particularly high prey concentrations within the study area at the time, and whether prey availability may have been directly or indirectly linked to the construction activities (e.g. through disturbance of the seabed). If the animals in Broadhaven Bay were not directly attracted to the high concentrations of vessels during construction works but to high prey concentrations instead, there may still have been subtle responses to the high vessel traffic, such as changes in diving and breathing, surface or foraging behaviour or changes in vocalisations (e.g. Janik & Thompson 1996, Lesage et al. 1999, Au & Green 2000, Nowacek et al. 2001, van Parijs & Corkeron 2001, Hastie et al. 2003, Buckstaff 2004, Foote et al. 2004, Sini et al. 2005, Lemon et al. 2006). However, in our case, it was not possible to observe from the cliff any subtle behavioural differences between times of high and low vessel traffic.

In contrast to bottlenose dolphins from Doonanierin Point, the presence of both minke whales and grey seals from Erris Head was significantly negatively correlated with both the overall number of vessels and the number of utility vessels within Broadhaven Bay. Although the overall number of vessels no longer showed a significant effect when all seal sightings were considered in the analysis, the negative relationship with the number of utility vessels remained consistent. The presence of minke whales additionally showed a negative relationship with numbers of fishing boats, which was the most frequently recorded vessel type present in the area outside times of construction activity. This suggests that the overall number of vessels may have been more important than a particular vessel type in influencing the presence of this species in the study area. However, for both minke whales and seals, the environmental variables determining sightability of animals (sea state and swell height for minke whales; sea state only for seals) showed the most important contribution to the models, while relationships with vessel numbers were weaker by comparison (Table 2, Figs. 3–5). Despite the significance of parameters, none of the results suggested an extreme displacement response to high vessel numbers, but slight degrees of avoidance instead (Figs. 3–5).

The peak in the number of utility boats coincided with the peak in overall number of vessels and number of construction vessels in June and July 2009 at the height of construction activities. Although smaller than construction vessels, utility boats often have strong engines emitting low-frequency underwater noise and move around more than the more stationary construction vessels. However, by comparison to the smaller utility RIBs, they are slower and move in straighter lines, thus being more predictable to marine mammals. If the consistent negative correlation between numbers of utility boats and the presence of minke whales, grey seals and all seals combined indeed represents a cause and effect relationship, it is therefore most likely that the animals used the study area less during times of high vessel traffic due to noise rather than an increased collision risk. The fact that this negative effect on both taxa was observed from Erris Head, on the opposite side of the bay to where the centre of construction activity and thus vessel traffic was located, supports this hypothesis, since animals would still be affected by vessel noise at this distance, but not by danger of vessel collision. The results are also in agreement with the greater hearing sensitivity of both baleen whales and seals at low frequencies (e.g. Götz et al. 2009), while the opposite result for bottlenose dolphins could be explained by odontocetes' low-sensitivity hearing at these frequencies.

By comparison to other studies on the effects of underwater noise on baleen whales and seals, the negative relationship between the presence of these taxa and vessel traffic, though the effect size was small, represents a relatively strong result. For example, there was no clear evidence that feeding humpback whales *Megaptera novaeangliae* off southeastern Alaska avoided the noise of an airgun even at received levels of up to 172 dB, or continuous industrial noise (20 Hz–1 kHz) at 116 dB (Malme et al. 1985). Similarly, foraging blue *Balaenoptera musculus* and fin whales *Balaenoptera physalus* off California did not show any obvious responses to a low-frequency sound source at received levels of ca. 140 dB re 1 µPa (Croll et al. 2001). Finally, ringed seals *Phoca hispida* in the water in Alaska showed no obvious reactions to received levels of pile-driving sounds of ca. 150 dB re 1 µPa (Blackwell et al. 2004). It is possible that local conditions in Broadhaven Bay (e.g. reflection of noise from the rocky shore surrounding the bay) may lead to increased effects of vessel noise for minke whales and seals.

Our results suggest that amongst the representatives of mysticetes, odontocetes and phocid seals investigated here, mysticetes and seals are more sensitive to (construction-related) vessel traffic than odontocetes, at least with respect to the particular species investigated here, and given the local conditions. Careful consideration of mitigation measures not only for cetaceans or haul-out sites for seals, but also for seals in the water, are therefore essential in the planning phase of projects involving activities such as dredging, rock trenching or laying of undersea pipelines. Since local circumstances may account for variation in responses to anthropogenic disturbance, both within and between species (e.g. residency of individuals, importance of an area for feeding and breeding), such mitigation measures should also be site-specific.

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