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The effects of seismic activity on marine mammals in UK waters, 1998-2000

Carolyn J Stone

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Comments:	Observations of marine mammals seen during seismic surveys carried out in accordance with the *Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys (April 1998)* were forwarded to JNCC. This report presents an analysis of the data gathered from 1998-2000.

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Contents

1. Summary

1. 1,652 sightings of marine mammals (28,165 individuals) occurring during 201 seismic surveys in UK waters and some adjacent areas between 1998 and 2000 (plus two surveys in 1997) were analysed to examine the effects of seismic activity. A total of 44,551 hrs 50 mins were spent watching for marine mammals during these surveys.

2. The most frequently seen species were white-sided dolphins, white-beaked dolphins and pilot whales. Sperm whales, fin whales and minke whales were also seen with moderate frequency, with lower numbers of sightings of other species. Sighting rates of marine mammals peaked in July, with most occurring to the west of Shetland, in Rockall and in the northern North Sea.

3. Sighting rates of white-sided dolphins, white-beaked dolphins, *Lagenorhynchus* spp., all small odontocetes combined and all cetaceans combined were found to be significantly lower during periods of shooting on surveys with large airgun arrays. Sighting rates of the other species or species groups tested did not differ significantly with seismic activity.

4. Sighting rates were not found to differ significantly throughout the course of surveys with large airgun arrays. Sighting rates of several species were found to fluctuate significantly over the three-year period, but the only species showing a negative trend in this respect was the pilot whale, where sighting rates from seismic survey vessels declined after 1998, even allowing for geographical differences in survey effort. The reasons for this decline in sightings are not known.

5. Killer whales, all baleen whales combined, and all of the small odontocete species tested were found to be significantly further from large airgun arrays during periods of shooting than when the airguns were silent.

6. Some effects of seismic activity on the behaviour of marine mammals were evident during seismic surveys with large airgun arrays. Positive interactions (e.g. bow-riding) of cetaceans with the survey vessel or its equipment occurred significantly less often during periods of shooting than when the airguns were silent. There was a corresponding increased tendency for negative interactions during periods of shooting. For a number of species more pods were observed to be heading away from and/ or fewer towards the vessel during periods of shooting. During periods of shooting there was an increased tendency for small odontocetes to swim at speed, while all cetaceans combined and all baleen whales combined showed an increased tendency to alter course, mostly away from the vessel. Fin/ sei whales were less likely to remain submerged during periods of shooting. A significant reduction in the proportion of animals apparently feeding during periods of shooting was found when all cetaceans were combined.

7. There were indications that killer whales may be more tolerant of seismic activity in deeper waters. The same was found when all cetaceans were combined.

8. Effects of seismic activity were less on site surveys and other similar low power surveys than on surveys with large airgun arrays, but some effects were nevertheless noted. Sighting rates were significantly reduced during periods of shooting for all small odontocete species combined, but no significant differences were found in the distance of marine mammals from the airguns in relation to seismic activity. Positive interactions of cetaceans with the survey vessel or its equipment were reduced during periods of shooting. For all species tested fewer pods were observed to be heading towards and/ or more heading away from the vessel during periods of shooting. There was an increased tendency for cetaceans to breach or jump during periods of shooting, but there was no effect on swimming speed. When all cetaceans were combined they were found to be more likely to remain submerged during periods of shooting.

9. In general, small odontocetes showed the strongest avoidance response to seismic activity, with baleen whales and killer whales showing some localised avoidance, pilot whales showing few effects (although sightings of pilot whales declined after 1998 for unknown reasons) and sperm whales showing no observed effects from these data. It is suggested that the different groups of cetaceans adopt different strategies for responding to acoustic disturbance from seismic surveys.

10. Sample sizes for marine mammals encountered during the soft-start were too small to assess the effectiveness of this procedure as a mitigation tool.

11. Compliance with the *Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys* was greatest when dedicated marine mammal observers were used. Use of members of ships' crews to fulfil this role was the least effective alternative.

12. Dedicated marine mammal observers were more proficient at detecting marine mammals than other types of personnel. They were also able to detect animals out to greater distances. Their identification skills were better, and they recorded a broader range of behaviours. They were better at completing the standard recording forms.

13. The use of dedicated marine mammal observers is therefore recommended, both in terms of compliance with the requirements of the guidelines and the provision of high quality data.

2. Non-technical summary

Observers on board seismic survey vessels during 201 seismic surveys in UK waters and some adjacent areas between 1998 and 2000 (plus two surveys in 1997) recorded 1,652 sightings of marine mammals (28,165 individuals). Over 40,000 hrs were spent watching for marine mammals during these surveys. The most frequently seen species were white-sided dolphins, white-beaked dolphins and pilot whales. Sperm whales, fin whales and minke whales were also seen moderately often, with fewer sightings of other species. Sightings peaked in July, with most to the west of Shetland, in Rockall and in the northern North Sea.

The data gathered were analysed to examine the effects of seismic activity on marine mammals; the frequency of sightings of marine mammals, their distance from the airguns and their behaviour were compared for periods when the airguns were firing and when they were not firing. Surveys with large airgun arrays were analysed separately from site surveys with smaller arrays of airguns.

Some effects of seismic activity were observed, but the responses varied between species. During surveys with large airgun arrays, small odontocetes (dolphins and porpoises) showed the strongest avoidance response to seismic activity, with several species seen less often during periods of shooting, remaining further from the airguns and showing altered behaviour (e.g. less bow-riding, orienting away from the survey vessel, faster swimming). Larger odontocetes (killer whales, pilot whales and sperm whales) showed fewer responses to seismic activity. Killer whales occurred further from the airguns while they were firing, while pilot whales tended to orient away from the survey vessel during periods of shooting. Sightings of pilot whales have declined since 1998, although it is not known whether this is related to continued seismic activity. Sperm whales showed no observable effects from these data (although this does not mean that there was no disturbance, as there may have been effects that were not able to be examined using these data). Baleen whales (e.g. fin whale, minke whale) also showed fewer responses to seismic activity than small odontocetes - there were no effects observed for individual species, but when all baleen whale species were combined it was found that they occurred further from the airguns during periods of shooting, they altered course more often and tended to orient away from the survey vessel. Fin/ sei whales were less likely to remain submerged while the airguns were firing, possibly because levels of noise would have been greater at depth than near the water surface.

As the effects observed in response to seismic activity varied between the species, it is suggested that the different groups of cetaceans may adopt different strategies for responding to seismic disturbance. Such strategies might include the faster small odontocetes increasing their swimming speed and moving out of the immediate area, while the slower-moving baleen whales orient away and gradually increase their distance from the airguns, perhaps remaining near the surface as they do so, where noise levels are less.

The use of small airguns on site surveys and other similar low power surveys had less effect than large arrays of airguns, but some effects were nevertheless noted. There were fewer sightings of all small odontocete species combined when the airguns were firing during site surveys, but marine mammals were no further from the airguns. Actions like bow-riding occurred less often when the airguns were firing, and cetaceans were less likely to head towards the vessel at these times. Cetaceans breached or jumped more when the small airguns were firing, but there was no effect on swimming speed. Cetaceans were more likely to remain submerged when small airguns were firing.

Compliance with the *Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys* was greatest when dedicated marine mammal observers were used. Use of members of ships' crews to fulfil this role was the least effective alternative. Dedicated marine mammal observers were also more skilled at detecting marine mammals than other types of

personnel, and they detected animals out to greater distances. Their identification skills were better, and they recorded more behaviours. They were better at completing the standard recording forms. The use of dedicated marine mammal observers is therefore recommended, both in terms of compliance with the guidelines and the provision of high quality data.

3. Introduction

Marine mammals use sound to communicate and, in some cases, echolocate. The ability to detect calls from conspecifics, echolocation signals and other natural sounds is of paramount importance to them. Man-made sounds thus have the potential to interfere with their natural functions, such as feeding, social interactions (including breeding) and navigation, as well as having the potential to cause physical harm. Concern over the issue of acoustic disturbance to marine mammals has led to attention being focussed on seismic surveys as one of a number of potential sources of such disturbance. Seismic surveys use airguns to generate sound at low frequencies for geophysical purposes. These low frequencies overlap with those used by baleen whales. In addition, the airguns incidentally emit higher frequency sounds (Goold and Fish 1998) that overlap with those used by toothed whales and dolphins (odontocetes). Therefore, most species of cetacean may be affected by sounds produced during seismic surveys.

To address these concerns, the UK Department for Environment, Food and Rural Affairs (DEFRA) and the Joint Nature Conservation Committee (JNCC) issued the *Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys* (Appendix 2). Seismic surveys in the UK have been operated in accordance with these guidelines since their first publication in 1995. The guidelines have various requirements at both the planning stage and during the operation of a seismic survey. For example, for at least 30 minutes prior to commencing any use of the seismic sources observers should make a careful check for the presence of marine mammals within 500 m. If any marine mammals are detected then use of the airguns must be delayed until at least 20 minutes have elapsed since the last sighting. Whether marine mammals are detected or not, a soft-start procedure should be employed whenever possible, gradually building up the airgun power over at least 20 minutes from a low energy starting level. There is also a requirement that following the survey a report should be forwarded to JNCC, using standard JNCC recording forms (current versions of these are in Appendix 4). These forms are used to assess the implementation of the guidelines and the effects of seismic activity on marine mammals. Previous analyses of annual sets of data (Stone 1997, 1998a, 2000, 2001, 2003) have been limited by small sample sizes. The present report uses data sets combined over the years 1998 to 2000 to further our understanding of the effects of seismic activity on marine mammals.

4. Methods

Data from 201 seismic surveys in UK and some adjacent waters were used, mostly from 1998 to 2000, but also including part of two surveys from 1997; all other data prior to 1998 did not include sufficient information on weather conditions, and therefore were not used in this analysis. These 201 surveys covered 152 quadrants (1° rectangles), including those passed in transit to or from the survey locations (Figure 1).

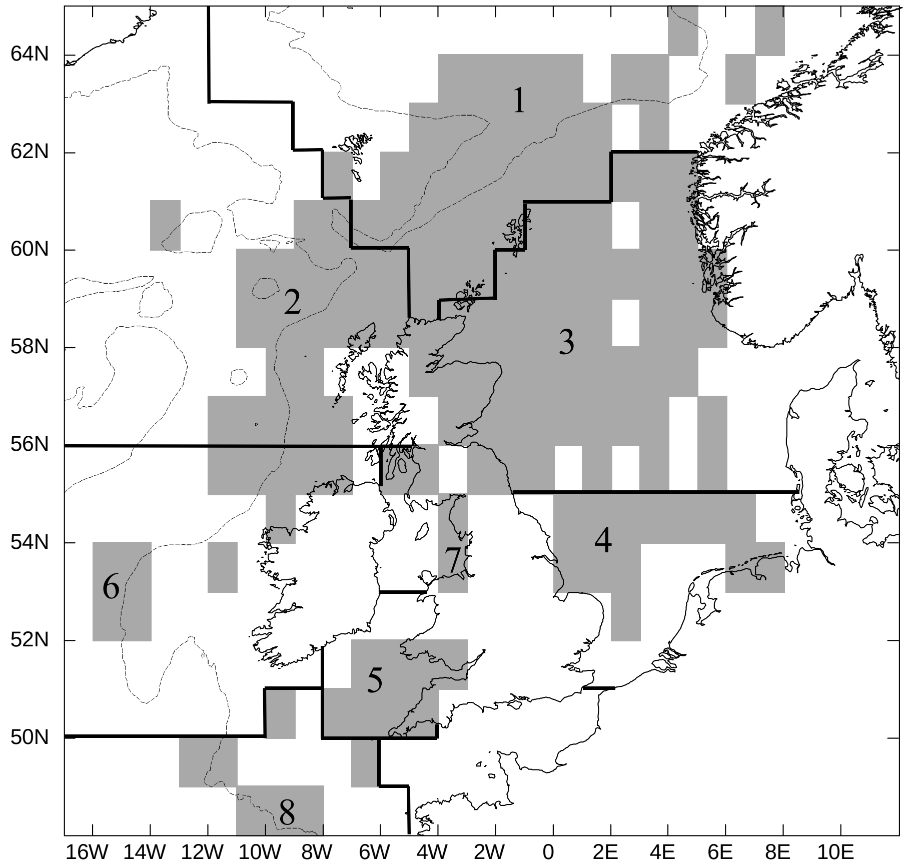

Figure 1 Quadrants surveyed for marine mammals from seismic surveys, with areas referred to in the text: 1) West of Shetland; 2) Rockall; 3) Northern North Sea; 4) Southern North Sea; 5) St. George's Channel and Bristol Channel; 6) West of Ireland; 7) Irish Sea; 8) South-West Approaches.

110 of the 201 surveys were 2D, 3D, 4D and 4C surveys, where the total airgun volume often exceeded 3000 cu. in. The remaining 91 surveys were rig site surveys or similar surveys (pipeline, cable route, debris or anchor search surveys) using low power equipment; these surveys are hereafter collectively termed site surveys. Where airguns were used on site surveys the total volume was typically 180 cu. in. or less. In order to test whether size of airgun array has an effect on the degree of disturbance of marine mammals, site surveys were analysed separately from surveys conducted with large airgun arrays.

Watches for marine mammals were carried out during daylight hours. Observers ranged from biologists experienced in marine mammal surveys to non-scientific personnel who had usually received basic training. Standard JNCC recording forms were completed (Appendix 3). The information contained on these included the duration of the watch for marine mammals, and the duration of seismic (= airgun) activity during the watch. Weather conditions were recorded daily (or occasionally more frequently) by observers. Sea state was classed as 'glassy', 'slight', 'choppy' or 'rough', or defined according to the Sea Criteria of the World Meteorological Organisation (HMSO 1983). Swell was classed as 'low' (< 2 m), 'medium' (2-4 m) or 'large' (> 4 m), and visibility categorised as 'poor' (< 1 km), 'moderate' (1-5 km) or 'good' (> 5 km). When marine mammals were encountered, the information recorded included date, time, seismic activity, location, depth, species, number, direction of travel both relative to the vessel and in compass points, behaviour and the closest distance of approach to the airguns. Observers were asked to provide descriptions of marine mammals to support their identification. Where descriptions were missing or inadequate, or did not correspond with the identification given, identifications were amended on the basis of the information available. This usually involved downgrading of identifications from one species to a group of similar species which the animal could have been, based on the description given. Videos or photographs, where available, were used to confirm identification.

Weather conditions influenced the ability of observers to detect marine mammals, with sighting rates increasing as sea state and swell decreased and as visibility increased. Periods of poor weather were therefore discarded when comparing sighting rates or distance of animals from the source in relation to seismic activity. In these cases only periods with sea states of 'glassy' or 'slight' (equivalent to sea state 3 or less), 'low' swell and 'good' visibility were used.

Sample sizes were small for many species. Non-parametric statistical tests appropriate for small sample sizes were used (Siegel and Castellan 1988). Species maps were drawn after summing the number of individuals of a species in each ¼ ICES square (15' latitude x 30' longitude). All maps were plotted using DMAP for Windows, and show the 1,000 m isobath (dashed line).

5. An overview of marine mammal sightings and survey effort

There were 1,652 sightings of marine mammals (28,165 individuals) (Table 1). 64% of sightings were identified to species level, and a further 17% were identified as being one of a pair or group of similar species.

Table 1 Summary of marine mammal sightings from seismic survey vessels

Species	*Number of sightings*	*Number of individuals*
Unidentified seal sp.	6	6
Grey seal	15	16
Common seal	6	6
Unidentified cetacean sp.	41	358
Unidentified whale sp.	59 *[1]	163
Unidentified large whale sp.	54 *[1]	129
Northern right whale (probable)	1	1
Humpback whale	8	10
Blue whale	4 *[1]	4
Fin whale	116 *[1]	244
Sei whale	13	16
Unidentified fin/ blue whale	10	18
Unidentified fin/ sei whale	56 *[1]	97
Unidentified fin/ sei/ blue whale	6	9
Unidentified fin/ sei/ humpback whale	27	40
Unidentified fin/ sei/ blue/ humpback whale	17	36
Minke whale	79 *[1]	103
Sperm whale	123 *[1]	191
Unidentified humpback/ sperm whale	12	17
Unidentified medium whale sp.	8	13
Unidentified beaked whale sp.	3	3
Northern bottlenose whale	2	11
Sowerby's beaked whale	1	1
Pilot whale	172 *[1]	3,384
Killer whale	61	357
Unidentified dolphin sp.	226 *[1]	6,203
Unidentified dolphin sp. not porpoise	34	432
Risso's dolphin	10	28
Bottlenose dolphin	34 *[1]	321
Unidentified unpatterned dolphin sp.*[2]	2	12
White-beaked dolphin	172 *[1]	1,365
White-sided dolphin	198 *[1]	12,879
Unidentified *Lagenorhynchus* sp.*[3]	44 *[1]	815
Common dolphin	24 *[1]	246
Striped dolphin	5 *[1]	255
Unidentified common/ white-sided dolphin	4	143
Unidentified common/ striped dolphin	5	39
Unidentified common/ white-sided/ striped dolphin	1	65
Unidentified patterned dolphin sp.*[4]	5	18
Harbour porpoise	37	111
Total	**1,652**	**28,165**

*[1] includes mixed species sightings
*[2] unpatterned dolphin = Risso's/ bottlenose dolphin
*[3] *Lagenorhynchus* sp. = white-beaked/ white-sided dolphin
*[4] patterned dolphin = white-beaked/ white-sided/ common/ striped dolphin

The most frequently seen positively identified species were white-sided dolphins, white-beaked dolphins and pilot whales. Sperm whales, fin whales and minke whales were seen with moderate frequency, with lower numbers of sightings of other species. Fewer harbour porpoises were seen than might have been expected. There were 48 mixed species sightings, of which the most common combination was of pilot whales and white-sided dolphins (14 sightings). There were ten sightings of pilot whales with unidentified dolphins and seven sightings of fin whales with white-sided dolphins. Other combinations of species occurred only on one or two occasions.

Dolphins, pilot whales and killer whales usually occurred in groups (mean pod size = 19.67 for pilot whales, 5.85 for killer whales, 7.94 for white-beaked dolphins, 65.05 for white-sided dolphins). Baleen whales and sperm whales tended to occur either singly or in small groups (mean pod size = 2.10 for fin whales, 1.30 for minke whales, 1.55 for sperm whales). Sighting rates of marine mammals peaked during the month of July (Figure 2), although more time was spent watching in August (Figure 3). Maps of marine mammal distribution are included in Appendix 1 (although the majority of sightings occurred during the years 1998 to 2000, some sightings recorded on these maps occurred during the two surveys in 1997 that are also included in this report). Most sightings occurred to the West of Shetland, in Rockall and in the Northern North Sea.

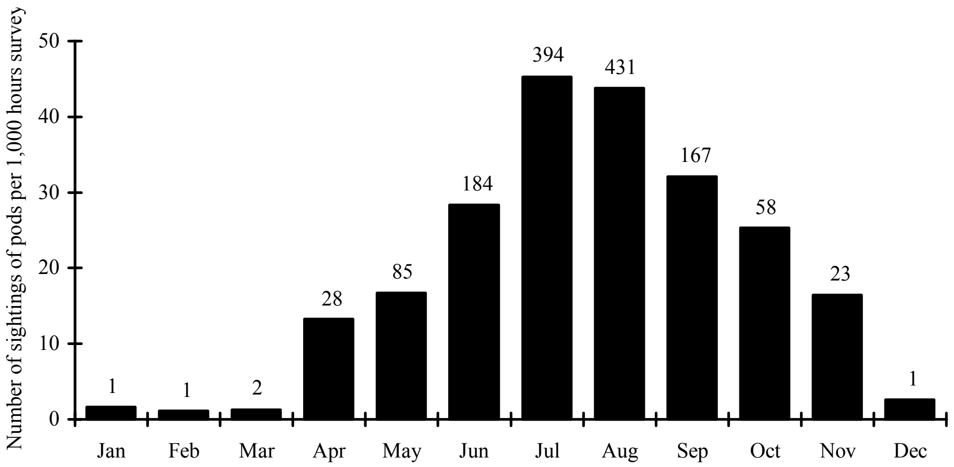

Figure 2 Sighting rates of marine mammals (including seals) per month, with number of sightings (only includes surveys where effort was correctly recorded). Data were not corrected for sea conditions or other factors affecting the ability to detect marine mammals.

The length of time spent watching for marine mammals was summed for surveys where 'Location and Effort' recording forms were completed correctly (133.5 of the 201 surveys). Most of the time spent watching for marine mammals was on surveys with large airgun arrays, and the proportion of time spent shooting was also higher on these surveys (Table 2). The time spent watching for marine mammals during site surveys equated to only 12% of the total time spent watching during all surveys, reflecting the short duration of most site surveys. When the airguns were not firing the survey vessels were engaged in a variety of activities e.g. turning between survey lines, deploying, retrieving or carrying out maintenance on the airguns and streamers, waiting for weather conditions to improve, time-sharing with other seismic survey vessels, and steaming between survey areas and ports. In the case of site surveys, some of the periods when the airguns were not firing were occupied by analogue surveys for which airguns were not used, although various other items of equipment (e.g. side scan sonar, boomers and pingers) were used.

Table 2 Effort during seismic surveys

Type of survey	*Time spent watching for marine mammals*	*Time spent shooting during the watch for marine mammals*	*Proportion of time spent shooting*
Surveys with large airgun arrays	39,168 hrs 06 mins	14,809 hrs 46 mins	37.81%
Site surveys	5,383 hrs 44 mins	930 hrs 16 mins	17.28%
Total effort	44,551 hrs 50 mins	15,740 hrs 02 mins	35.33%

The time spent watching for marine mammals and the total time spent shooting during these watches peaked in August, although the proportion of time spent shooting peaked in May (Figure 3). Most survey effort was concentrated in areas Northern North Sea and West of Shetland (Figure 4), although the proportion of time spent shooting was greatest in areas West of Ireland, Rockall and the South-West Approaches. Survey effort was highly seasonal in all areas except the Southern North Sea (Figure 5). In most areas the proportion of time spent shooting increased during the summer months.

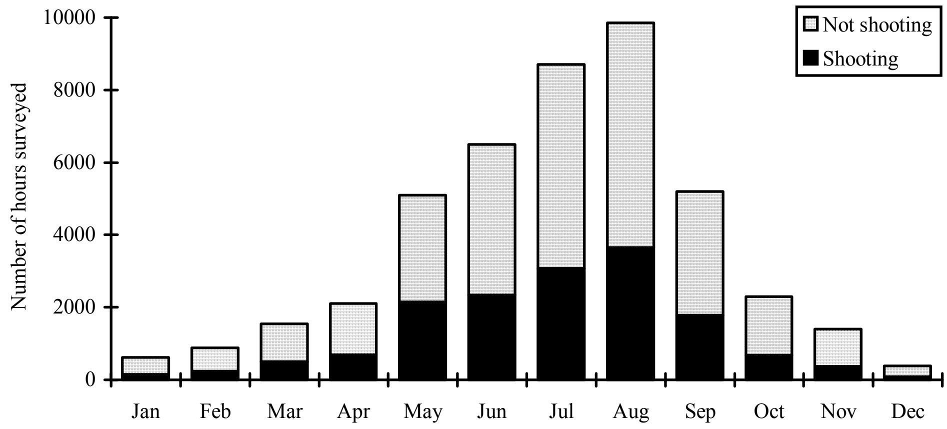

Figure 3 Length of time spent watching for marine mammals, and seismic activity during watches (only includes surveys where effort was correctly recorded).

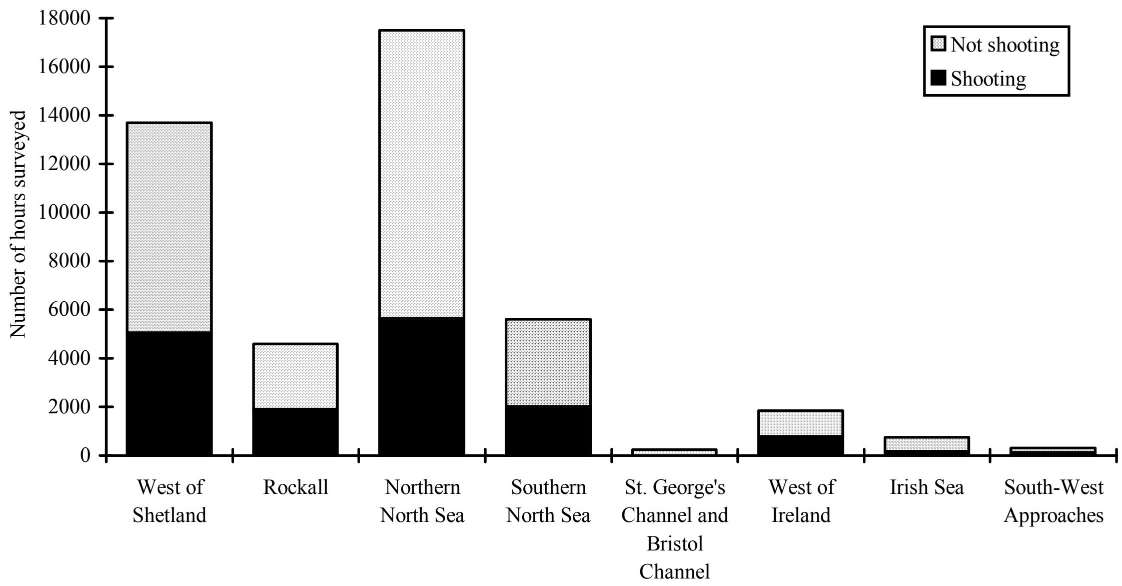

Figure 4 Length of time spent watching for marine mammals in each area, and seismic activity during watches (all months combined; only includes surveys where effort was correctly recorded).

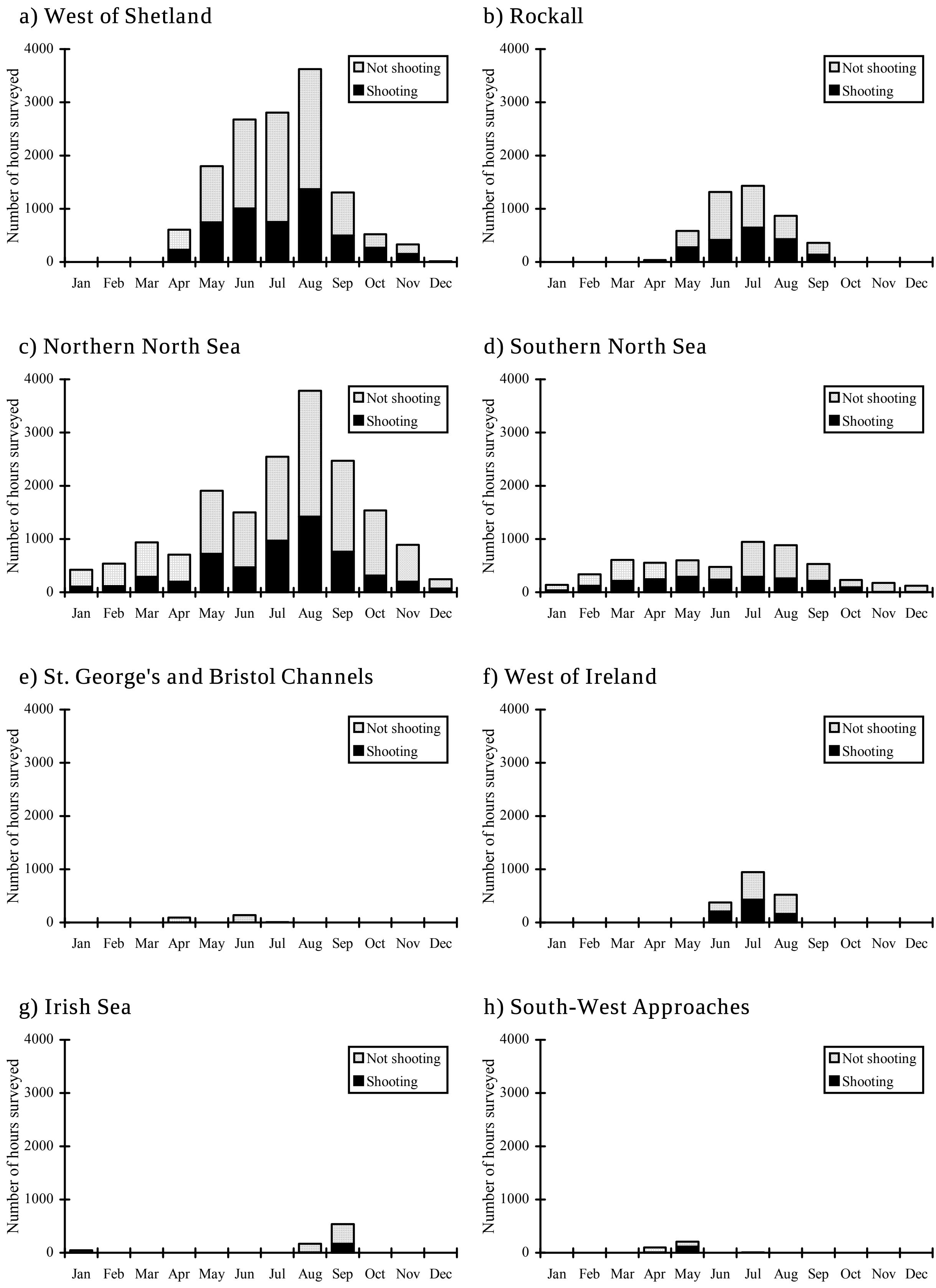

Figure 5 Comparison of survey effort throughout the year for the different surveyed areas (only includes surveys where effort was correctly recorded).

Weather conditions varied considerably. Most of the time spent watching for marine mammals was when sea states were categorised as 'slight', but the proportion of time spent shooting was greatest in 'glassy' sea states (Figure 6). The amount of time spent watching for marine mammals and the proportion of time spent shooting both peaked in conditions of 'low' swell. Most time was spent watching in conditions of 'good' visibility, but visibility had little effect on the proportion of time spent shooting.

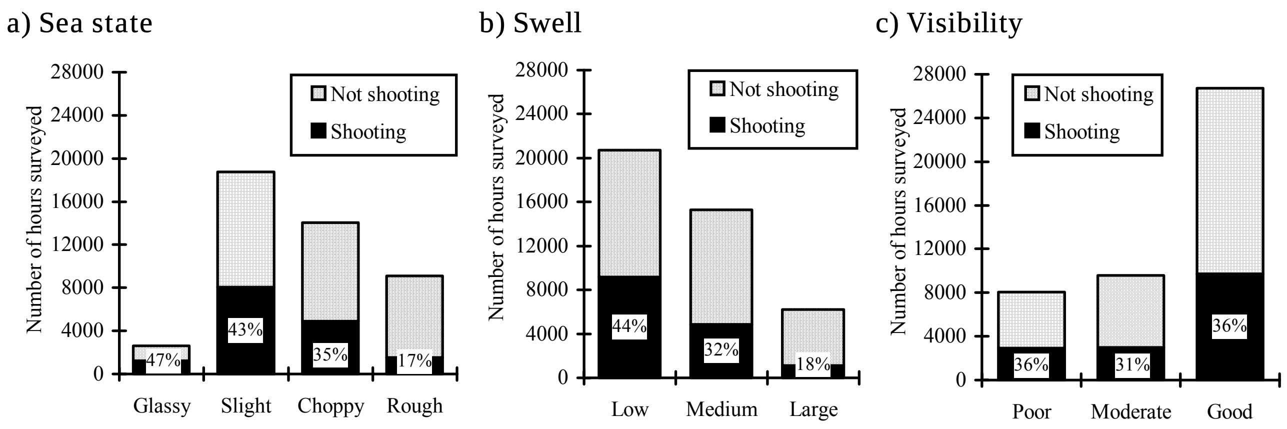

Figure 6 Length of time spent watching for marine mammals in different weather conditions in relation to seismic activity, with percentage of time spent shooting (only includes surveys where effort was correctly recorded).

6. Effects of seismic activity on marine mammals

6.1 Sighting rate of marine mammals

Sighting rates were calculated per unit effort (i.e. per 1,000 hours of observations), using only data from surveys where effort was recorded correctly (66% of surveys). Sighting rates were compared between periods of shooting and periods when the airguns were not firing. Variations in sighting rate due to location, season or ability of the observer were controlled by using matched pairs within each day of each survey. As weather could vary considerably even within one day, only periods of good weather conditions were used.

In general, on surveys with large airgun arrays more cetaceans were seen when the airguns were not firing (Figure 7). Sighting rates of all cetaceans combined, all small odontocetes combined, and the *Lagenorhynchus* species (both individual species and a group comprising all *Lagenorhynchus* species combined) were significantly reduced during periods of shooting (Table 3). None of the other species tested showed any significant difference in sighting rate with seismic activity. For site surveys, a significant reduction in sighting rate during periods of shooting was only observed when all small odontocetes were combined (Figure 8; Table 3).

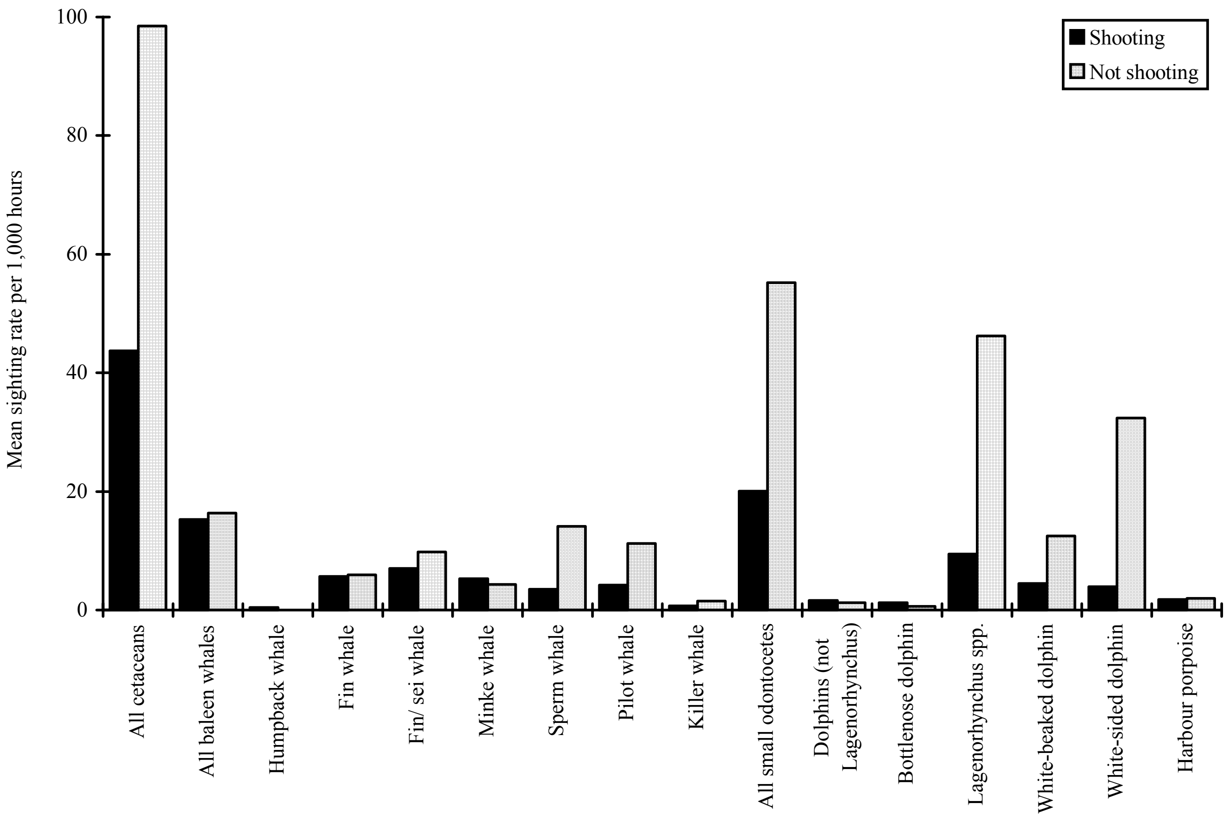

Figure 7 Sighting rates of marine mammals in relation to seismic activity (excluding site surveys).

Table 3 Statistical significance of difference in sighting rate of marine mammals in relation to seismic activity, using Wilcoxon signed ranks test (z = Wilcoxon statistic; n = sample size; P = probability; n.s. = not significant; - = insufficient data). Matched pairs (shooting versus not shooting) were compared for each day of each survey, using only periods when weather conditions favoured the detection of marine mammals.

	Surveys with large airgun arrays			*Site surveys*		
Species	***z***	***n***	***P***	***z***	***n***	***P***
All cetaceans combined	2.005	193	0.0222	1.006	19	n.s.
All baleen whales combined	0.585	65	n.s.	-1.069	3	n.s.
Humpback whale	-1.604	3	n.s.	-	-	-
Fin whale	0.082	30	n.s.	-	-	-
Fin/ sei whale*[1]	0.228	36	n.s.	-	-	-
Minke whale	0.547	23	n.s.	-	-	-
Sperm whale	0.578	23	n.s.	0.000	3	n.s.
Pilot whale	0.735	31	n.s.	-	-	-
Killer whale	1.244	9	n.s.	-	-	-
All small odontocetes combined	2.290	128	0.0110	2.116	14	0.0170
Dolphins (not *Lagenorhynchus*)*[2]	-0.933	14	n.s.	-	-	-
Bottlenose dolphin	-0.908	9	n.s.	-	-	-
Lagenorhynchus spp.*[3]	3.685	85	0.0001	-	-	-
White-beaked dolphin	1.916	35	0.0274	-	-	-
White-sided dolphin	2.806	49	0.0025	1.362	9	n.s.
Harbour porpoise	0.345	14	n.s.	-	-	-

*[1] includes fin whales, sei whales and unidentified fin/ sei whales

*[2] includes Risso's dolphins, bottlenose dolphins, common dolphins, striped dolphins and any unidentified combination thereof

*[3] includes white-beaked dolphins, white-sided dolphins and unidentified *Lagenorhynchus* sp.

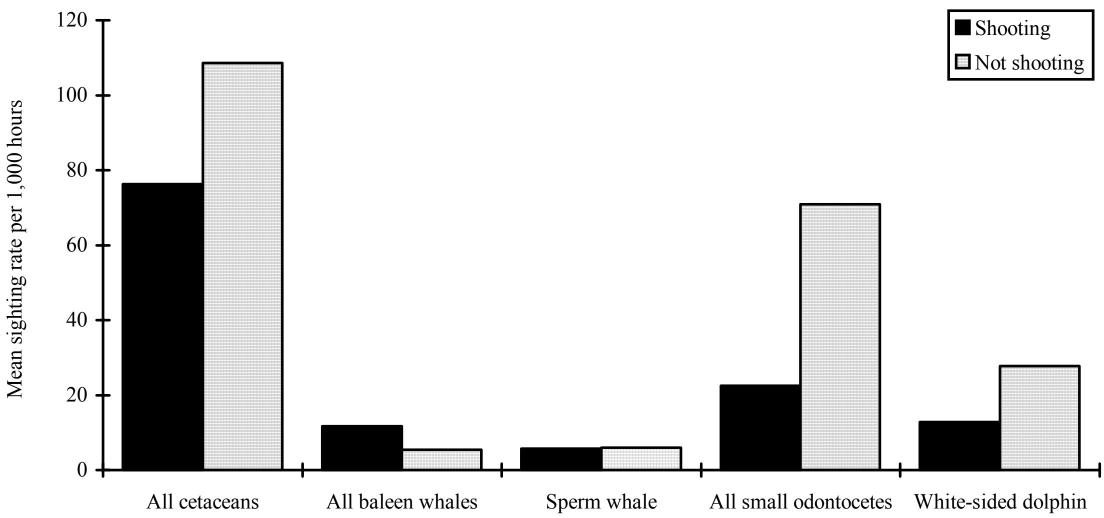

Figure 8 Sighting rates of marine mammals in relation to seismic activity during site surveys

Sighting rates for each week of each survey were examined to see whether there was any evidence of short-term exclusion from the survey area due to continued seismic activity, again using only data from periods of good weather conditions. Data from 18 weeks were tested for surveys with large arrays of airguns, while for site surveys data from five weeks were tested. There were considerable variations in sighting rates between the weeks, but with no apparent trends. The variations in sighting rate during surveys with large airgun arrays were found to be non-significant for all species tested, while for site surveys the results were only significant for all small odontocetes combined (Table 4). Sighting rates of small odontocetes during site surveys peaked in week 3, with a secondary peak in week 1.

Table 4 Statistical significance of variation in sighting rate throughout the course of surveys, using Kruskal-Wallis one-way analysis of variance (KW = Kruskal-Wallis statistic; n = sample size; d.f. = degrees of freedom; P = probability; n.s. = not significant; - = insufficient data).

	Surveys with large airgun arrays				*Site surveys*			
Species	***KW***	***n***	***d.f.***	***P***	***KW***	***n***	***d.f.***	***P***
All cetaceans combined	8.619	284	17	n.s.	7.282	28	4	n.s.
All baleen whales combined	12.228	284	17	n.s.	1.800	28	4	n.s.
Fin whale	14.955	284	17	n.s.	-	-	-	-
Fin/ sei whale	16.122	284	17	n.s.	-	-	-	-
Minke whale	14.901	284	17	n.s.	-	-	-	-
Sperm whale	13.439	284	17	n.s.	1.800	28	4	n.s.
Pilot whale	19.214	284	17	n.s.	-	-	-	-
Killer whale	19.545	284	17	n.s.	-	-	-	-
All small odontocetes combined	9.572	284	17	n.s.	9.890	28	4	<0.05
Dolphins (not *Lagenorhynchus*)	24.043	284	17	n.s.	-	-	-	-
Bottlenose dolphin	17.804	284	17	n.s.	-	-	-	-
Lagenorhynchus spp.	11.841	284	17	n.s.	3.958	28	4	n.s.
White-beaked dolphin	10.542	284	17	n.s.	1.800	28	4	n.s.
White-sided dolphin	13.618	284	17	n.s.	4.406	28	4	n.s.
Harbour porpoise	22.713	284	17	n.s.	-	-	-	-

Sighting rates were also compared between years for the more frequently seen species to examine whether there was any evidence of a longer-term change in the use of an area by marine mammals due to continued seismic activity. For each species, only data from known areas and months of peak abundance (established using various sources of effort-related data, e.g. Bloor *et al.* 1996; Clark and Charif 1998; JNCC 1995; NERC 1998; Northridge *et al.* 1995; Pollock *et al.* 1997, 2000; Skov *et al.* 1995), and during good weather conditions, were used. Fin whales, sperm whales and white-beaked dolphins showed significant fluctuations in sighting rate, but with neither an upwards nor downwards trend (Figure 9; Table 5). The sighting rate of white-sided dolphins increased significantly in 2000, while there was a significant decline in sightings of pilot whales after 1998. Although surveys in the Rockall area (where pilot whales were commonly seen) declined after 1998, the decline in sightings of pilot whales was apparently not a consequence of a geographical shift in effort - sightings of pilot whales in area West of Shetland alone also declined. There were no common patterns indicating that the annual variations in sighting rates were linked to the variation in the amount of seismic activity in each year. Sighting rates of minke whales did not vary significantly.

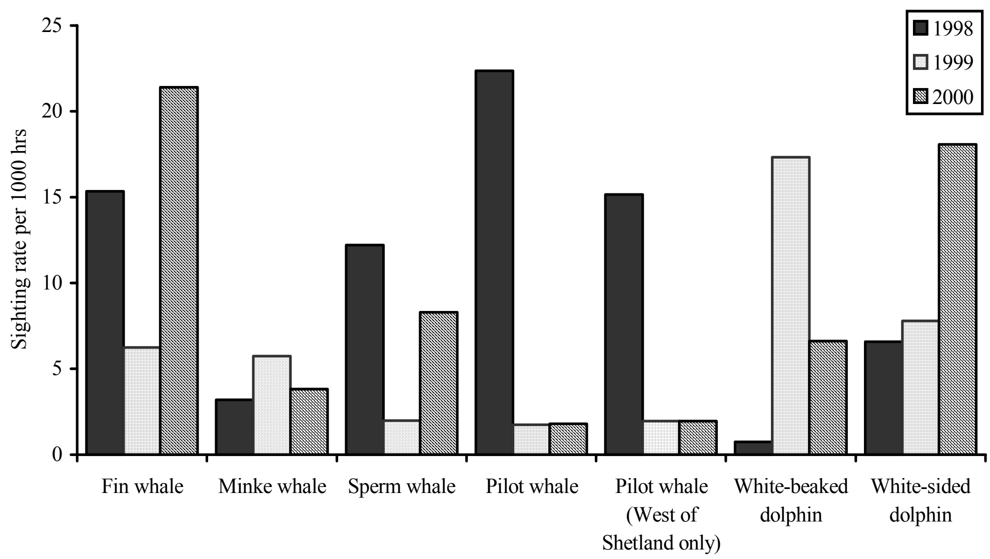

Figure 9 Annual variation in sighting rate of marine mammals

Table 5 Statistical significance of annual variation in sighting rates of marine mammals (n = sample size; d.f. = degrees of freedom; P = probability; n.s. = not significant).

Species	*Months*	*Areas*	χ^2	*n*	*d.f.*	*P*
Fin whale	Jun - Sep	West of Shetland Rockall	7.477	47	2	<0.05
Minke whale	Jun - Sep	West of Shetland Rockall Northern North Sea West of Ireland	1.907	30	2	n.s.
Sperm whale	May - Aug	West of Shetland Rockall West of Ireland	12.467	46	2	<0.01
Pilot whale	May - Sep	West of Shetland Rockall West of Ireland South-West Approaches	39.130	49	2	<0.001
Pilot whale	May - Sep	West of Shetland	18.426	19	2	<0.001
White-beaked dolphin	Jun - Sep	West of Shetland Northern North Sea	27.518	56	2	<0.001
White-sided dolphin	Jun - Sep	West of Shetland Rockall Northern North Sea	16.410	73	2	<0.001

6.2 Distance of marine mammals from the airguns

The median closest distance of approach to the airguns by marine mammals was compared between periods of shooting and periods when the airguns were not firing. Weather conditions can affect an observer's ability to detect marine mammals at greater distances, so only sightings occurring during better weather conditions were selected. Only those species where the sample size equalled or exceeded ten pods were used.

All of the small odontocete species tested, all baleen whales combined, and killer whales were found to remain significantly further from the airguns during periods of shooting on surveys with large airgun arrays (Figure 10; Table 6). The apparent displacement of the median distance was around 0.5 km or more for most of the species or species groups affected. During site surveys no significant differences in the distance of animals from the airguns were found (Figure 11; Table 6).

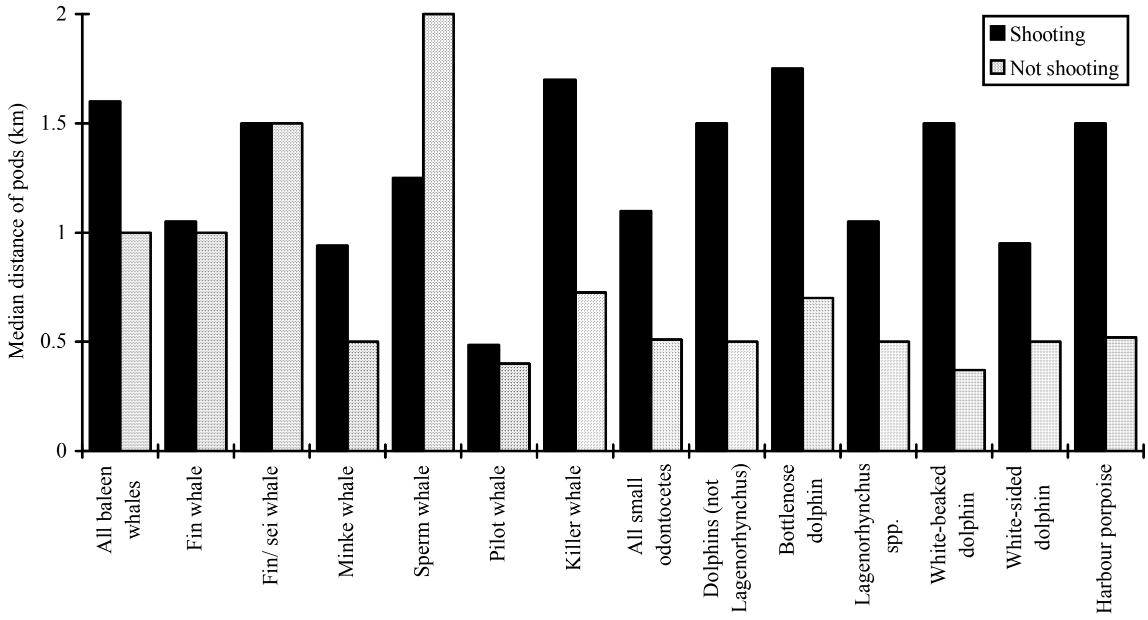

Figure 10 Median distance of marine mammals from the airguns in relation to seismic activity (excluding site surveys).

Table 6 Statistical significance of difference in distance of marine mammals from the airguns in relation to seismic activity (z = Wilcoxon statistic; n = sample size; P = probability; n.s. = not significant; - = insufficient data).

	Surveys with large airgun arrays			*Site surveys*		
Species	***z***	***n***	***P***	***z***	***n***	***P***
All baleen whales combined	2.529	148	0.0057	-	-	-
Fin whale	1.546	57	n.s.	-	-	-
Fin/ sei whale	1.226	78	n.s.	-	-	-
Minke whale	1.206	42	n.s.	-	-	-
Sperm whale	-0.445	51	n.s.	-	-	-
Pilot whale	-0.243	59	n.s.	-	-	-
Killer whale	1.843	14	0.0329	-	-	-
All small odontocetes combined	4.707	292	< 0.0001	0.516	37	n.s.
Dolphins (not *Lagenorhynchus*)	-2.377	21	0.0087	-	-	-
Bottlenose dolphin	-1.701	14	0.0446	-	-	-
Lagenorhynchus spp.	4.464	164	< 0.0001	1.164	17	n.s.
White-beaked dolphin	3.702	71	0.00011	-	-	-
White-sided dolphin	2.428	80	0.0075	0.123	15	n.s.
Harbour porpoise	2.503	21	0.0062	-	-	-

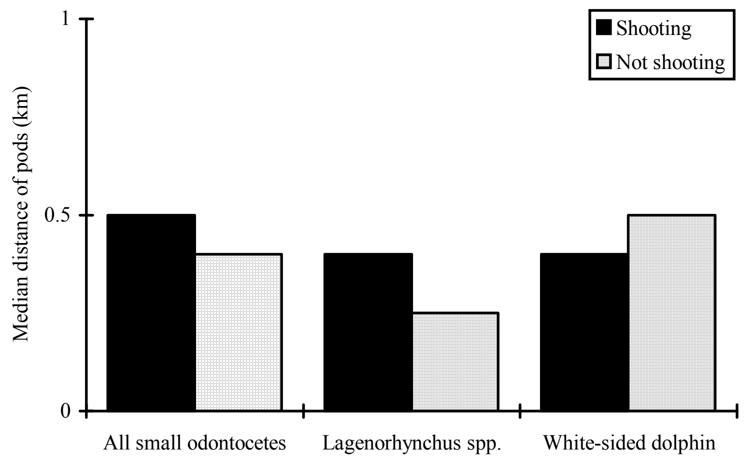

Figure 11 Median distance of marine mammals from the airguns in relation to seismic activity during site surveys

The proportion of sightings of small odontocetes occurring within a given range of large airgun arrays was reduced during periods of shooting for distances out to several kilometres from the source (Figure 12). The Kolmogorov-Smirnov test showed that these differences were statistically significant (χ^2 approximation = 21.021, d.f. = 1, $p < 0.001$). For medium and large cetaceans there were no significant differences in the proportion of sightings within a given range of large airgun arrays (χ^2 approximation = 3.056, d.f. = 1). During site surveys (Figure 13) there were no significant differences in the proportion of sightings within a given range of the airguns for any cetaceans (small odontocetes: χ^2 approximation = 0.097, d.f. = 1; medium and large cetaceans: χ^2 approximation = 1.214, d.f. = 1).

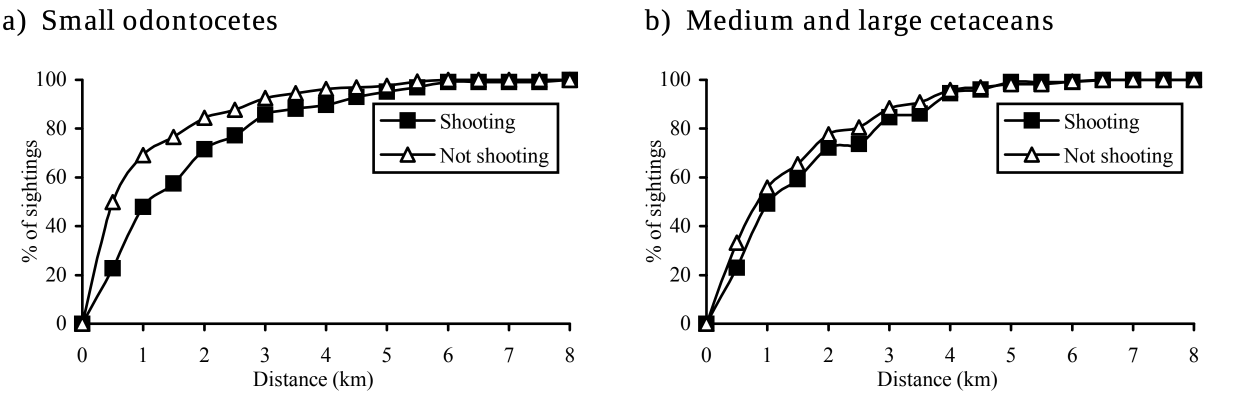

Figure 12 Proportion of marine mammal sightings occurring within specified distances of the airguns, in relation to seismic activity (excluding site surveys).

a) Small odontocetes b) Medium and large cetaceans

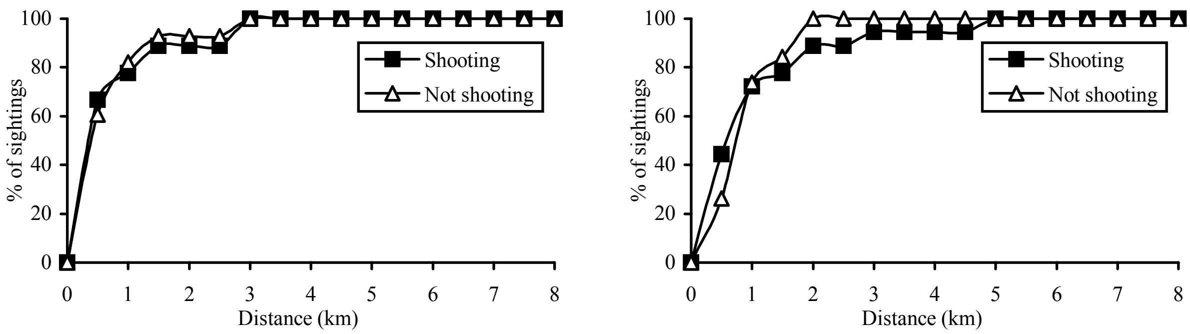

Figure 13 Proportion of marine mammal sightings occurring within specified distances of the airguns during site surveys, in relation to seismic activity.

6.3 Behaviour of marine mammals

Observers recorded any types of behaviour that were apparent at any time during encounters with marine mammals. For 21% of encounters, nothing other than 'normal swimming' was recorded. In the remaining encounters 44 other types of behaviour were recorded, some being observed more frequently than others. Comparisons with normal behaviour were not made, as normal behaviour can be difficult to establish in cetaceans. Instead, the frequency of occurrence of each recorded behaviour was compared between periods of shooting and not shooting. The results were tested for all behaviours and species where sample sizes were sufficient. Similar behaviours, such as breaching, jumping and somersaulting, were combined. The number of encounters where each behaviour was exhibited during periods of shooting or not shooting is expressed as a percentage of the total number of encounters at the respective seismic activity. The resulting percentage thus indicates the tendency of animals to engage in a particular behaviour in relation to seismic activity. Where types of behaviour were exhibited more frequently by particular species, the results for those individual species are shown; otherwise species are combined as appropriate.

For surveys with large airgun arrays there were a number of behavioural effects of seismic activity (Table 7). There were significantly fewer positive interactions with the survey vessel or its equipment (e.g. bow-riding, approaching close to the vessel, swimming alongside the vessel or its associated equipment, following the vessel or swimming close ahead of the vessel) during periods of shooting for all species tested except pilot whale. Similarly, when all cetaceans or all small odontocetes were combined there were more negative interactions (e.g. obvious avoidance) during periods of shooting. Alterations of course were more frequent during periods of shooting for all cetaceans combined and all baleen whales combined. Alterations of course during periods of shooting were more often away from the vessel than towards it, but this was not the case when the airguns were not firing (Table 8). It was not known whether the same individuals remained in an area throughout the course of surveys, so it was not possible to assess whether there was any degree of habituation or increased sensitisation to seismic activity.

Table 7 Behaviour of marine mammals in relation to seismic activity, excluding site surveys (n = sample size; P = probability; n.s. = not significant).

Behaviour	*Species*	*% of encounters while shooting when behaviour was exhibited*	*% of encounters while not shooting when behaviour was exhibited*	χ^2	*n*	*P*
Feeding	All cetaceans combined	3.64	8.29	10.784	91	< 0.01
	All baleen whales combined	2.88	8.14	3.686	18	n.s.
	Fin whale	6.12	16.95	2.610	13	n.s.
	All small odontocetes combined	5.16	8.15	1.797	48	n.s.
	Lagenorhynchus spp.	10.10	6.30	1.400	26	n.s.
+ve interactions	All cetaceans combined	4.79	12.67	20.862	135	< 0.001
	Pilot whale	10.39	16.09	0.991	22	n.s.
	All small odontocetes combined	5.63	18.94	17.485	98	< 0.001
	Lagenorhynchus spp.	7.07	25.59	11.845	72	< 0.001
	White-beaked dolphin	8.16	43.93	13.149	51	< 0.001
-ve interactions	All cetaceans combined	3.64	0.81	14.005	26	< 0.001
	All small odontocetes combined	5.16	1.54	7.043	18	< 0.01
Alteration of course	All cetaceans combined	6.13	2.42	11.781	53	< 0.001
	All baleen whales combined	8.63	2.33	5.948	16	< 0.05
	Pilot whale	14.29	5.75	3.056	16	n.s.
	All small odontocetes combined	3.76	2.20	1.294	18	n.s.
Breaching, jumping or somersaulting	All cetaceans combined	19.54	20.05	0.042	276	n.s.
	All small odontocetes combined	43.19	34.58	2.878	249	n.s.
	Dolphins (not *Lagenorhynchus*)	42.11	47.06	0.075	32	n.s.
	Bottlenose dolphin	50.00	38.89	0.205	13	n.s.
	Lagenorhynchus spp.	51.52	42.13	1.404	158	n.s.
	White-beaked dolphin	53.06	33.64	3.193	62	n.s.
	White-sided dolphin	55.00	51.72	0.060	82	n.s.
Tail- or flipper-slapping	All cetaceans combined	2.11	1.38	1.032	22	n.s.
Spy-hopping	Pilot whale	6.49	9.20	0.374	13	n.s.
Porpoising	All cetaceans combined	8.81	10.60	1.047	138	n.s.
	Pilot whale	5.19	9.20	0.889	12	n.s.
	All small odontocetes combined	19.72	17.84	0.277	123	n.s.
	Lagenorhynchus spp.	26.26	21.65	0.658	81	n.s.
	White-beaked dolphin	28.57	14.02	3.827	29	n.s.
	White-sided dolphin	25.00	35.34	0.975	51	n.s.
Fast swimming	All cetaceans combined	24.71	21.20	1.789	313	n.s.
	All baleen whales combined	8.63	6.98	0.272	24	n.s.
	Fin/ sei whale	8.33	6.59	0.178	13	n.s.
	Pilot whale	15.58	12.64	0.251	23	n.s.
	All small odontocetes combined	46.48	32.38	7.813	246	< 0.01
	Dolphins (not *Lagenorhynchus*)	68.42	33.33	3.982	30	< 0.05
	Lagenorhynchus spp.	50.51	33.46	5.410	135	< 0.05
	White-beaked dolphin	51.02	23.36	8.010	50	< 0.01
	White-sided dolphin	52.50	45.69	0.292	74	n.s.
Slow swimming	All cetaceans combined	20.69	20.85	0.004	289	n.s.
	All baleen whales combined	15.11	18.60	0.552	53	n.s.
	Fin/ sei whale	7.14	13.19	1.551	18	n.s.
	Minke whale	38.46	23.40	1.319	21	n.s.
	Sperm whale	32.50	29.69	0.063	32	n.s.
	Pilot whale	57.14	44.83	1.224	83	n.s.
	All small odontocetes combined	11.74	16.30	2.031	99	n.s.
	Lagenorhynchus spp.	8.08	18.50	4.961	55	< 0.05
	White-beaked dolphin	12.24	13.08	0.018	20	n.s.
	White-sided dolphin	5.00	18.10	3.467	23	n.s.
Milling	All cetaceans combined	2.49	2.19	0.018	32	n.s.
Surfacing frequently	All cetaceans combined	1.92	1.27	0.904	21	n.s.
	All baleen whales combined	5.04	2.91	0.907	12	n.s.
Surfacing infrequently	All cetaceans combined	9.77	11.64	1.037	152	n.s.
	All baleen whales combined	12.23	20.35	3.029	52	n.s.
	Fin whale	10.20	13.56	0.251	13	n.s.
	Fin/ sei whale	5.95	17.58	4.923	21	< 0.05
	Minke whale	23.08	19.15	0.127	15	n.s.
	All small odontocetes combined	9.39	10.13	0.081	66	n.s.
	Lagenorhynchus spp.	6.06	5.51	0.038	20	n.s.
Diving	All cetaceans combined	8.05	7.72	0.045	109	n.s.
	All baleen whales combined	7.91	12.21	1.377	32	n.s.
	Fin/ sei whale	7.14	7.69	0.018	13	n.s.
	Sperm whale	47.50	51.56	0.081	52	n.s.
Logging/ "resting"	All cetaceans combined	4.60	3.00	2.324	50	n.s.
	Sperm whale	37.50	20.31	2.700	28	n.s.
	Pilot whale	5.19	11.49	1.894	14	n.s.

Table 7 continued

Behaviour	*Species*	*% of encounters while shooting when behaviour was exhibited*	*% of encounters while not shooting when behaviour was exhibited*	χ^2	*n*	*P*
Widely dispersed group	All cetaceans combined	2.11	2.65	0.393	34	n.s.
	All small odontocetes combined	2.82	4.19	0.722	25	n.s.
	Lagenorhynchus spp.	3.03	7.48	2.263	22	n.s.

Table 8 Alterations of course by marine mammals during surveys with large airgun arrays (n = sample size).

	Shooting			*Not shooting*		
	Proportion towards vessel (%)	*Proportion away from vessel (%)*	*n*	*Proportion towards vessel (%)*	*Proportion away from vessel (%)*	*n*
All cetaceans combined	12.50	46.88	32	47.62	19.05	21
All baleen whales combined	16.67	41.67	12	50.00	50.00	4

There were some observed effects of seismic activity on the swimming characteristics of cetaceans. Small odontocetes showed a tendency to swim faster during periods of shooting (white-beaked dolphins, *Lagenorhynchus* spp., dolphins (not *Lagenorhynchus*) and all small odontocetes combined), and one dolphin species group was also observed to swim more slowly when the airguns were not firing (*Lagenorhynchus* spp.). The swimming characteristics of baleen whales were also affected in one case; fin/ sei whales were more often recorded as surfacing infrequently when the airguns were not firing (i.e. they spent less time at the surface when the airguns were not firing than during periods of shooting). However, there was no apparent effect of seismic activity on the tendency of animals to dive.

Feeding in cetaceans can be difficult to detect, as not all feeding occurs at the surface. However, feeding was recorded whenever it was apparent (lunge-feeding in baleen whales; fast, erratic swimming in odontocetes, often with diving birds associated). Fewer cetaceans were recorded as feeding during periods of shooting than when the airguns were not firing. This was statistically significant when all cetaceans were combined.

Sample sizes during site surveys did not permit testing of such a wide range of behaviours or species as for surveys with large airgun arrays. Nevertheless, some effects were observed (Table 9). On site surveys, as with surveys with large airgun arrays, positive interactions with the survey vessel or its equipment were seen mostly when the airguns were not firing. There was a greater tendency to breach, jump or somersault during periods of shooting for all cetaceans combined and all small odontocetes combined. However, in contrast to surveys with large airgun arrays, cetaceans were more often recorded as surfacing infrequently (i.e. remaining submerged) during periods of shooting.

The direction of travel of marine mammals relative to the survey vessel was recorded by observers in a diagram and was subsequently assigned to one of six categories. Table 10 presents the results for surveys with large airgun arrays for all species where sample sizes were sufficient for testing. During these surveys the direction of travel of individual species of baleen whale did not differ significantly with seismic activity, but when all baleen whales were combined the difference was found to be significant. The results for all cetaceans and all small odontocetes combined were also significant. Both white-beaked dolphin and *Lagenorhynchus* spp. showed significant results, as did harbour porpoise and pilot whale. In all cases where the results were significant, partitioning showed that fewer animals were travelling towards the vessel and/ or more were travelling away from the vessel during periods of shooting.

Table 9 Behaviour of marine mammals in relation to seismic activity during site surveys (n = sample size; P = probability; n.s. = not significant).

Behaviour	*Species*	*% of encounters while shooting when behaviour was exhibited*	*% of encounters while not shooting when behaviour was exhibited*	χ^2	*n*	*P*
+ve interactions	All cetaceans combined	1.64	16.86	8.096	30	< 0.01
	All small odontocetes combined	0.00	26.32	7.895	25	< 0.01
	Lagenorhynchus spp.	0.00	32.50	6.183	13	< 0.05
Breaching, jumping or somersaulting	All cetaceans combined	24.59	12.79	3.942	37	< 0.05
	All small odontocetes combined	46.67	22.11	4.912	35	< 0.05
	Lagenorhynchus spp.	52.63	27.50	2.290	21	n.s.
	White-sided dolphin	47.06	28.00	1.031	15	n.s.
Porpoising	White-sided dolphin	23.53	44.00	1.186	15	n.s.
Fast swimming	All cetaceans combined	22.95	19.19	0.318	47	n.s.
	All small odontocetes combined	36.67	29.47	0.378	39	n.s.
	Lagenorhynchus spp.	42.11	40.00	0.014	24	n.s.
	White-sided dolphin	47.06	40.00	0.116	18	n.s.
Slow swimming	All cetaceans combined	27.87	15.70	3.531	44	n.s.
	All small odontocetes combined	36.67	21.05	2.241	31	n.s.
	Lagenorhynchus spp.	36.84	22.50	0.980	16	n.s.
	White-sided dolphin	29.41	32.00	0.022	13	n.s.
Surfacing infrequently	All cetaceans combined	18.03	6.98	5.580	23	< 0.05
Diving	All cetaceans combined	9.84	11.63	0.131	26	n.s.
Widely dispersed group	White-sided dolphin	23.53	36.00	0.507	13	n.s.

Table 10 Direction of travel of marine mammals relative to the survey vessel in relation to seismic activity, excluding site surveys (n = sample size; d.f. = degrees of freedom; P = probability; n.s. = not significant).

Species	*Seismic activity*	*Towards ship*	*Away from ship*	*Crossing path of ship*	*Parallel to ship in same direction*	*Parallel to ship in opposite direction*	*Milling or variable*	χ^2	*n*	*d.f.*	*P*
All cetaceans combined	Shooting	6.81%	20.43%	22.57%	10.89%	30.74%	8.56%	58.933	1,368	5	< 0.001
	Not shooting	19.20%	10.19%	20.49%	11.12%	31.38%	7.61%				
All baleen whales combined	Shooting	4.35%	21.74%	18.84%	10.87%	34.78%	9.42%	12.037	304	5	< 0.05
	Not shooting	9.64%	9.64%	21.69%	11.45%	40.96%	6.63%				
Fin whale	Shooting	6.12%	26.53%	16.33%	10.20%	32.65%	8.16%	3.955	108	2	n.s.
	Not shooting	6.78%	11.86%	16.95%	3.39%	54.24%	6.78%				
Fin/ sei whale	Shooting	3.61%	24.10%	13.25%	13.25%	37.35%	8.43%	6.605	174	5	n.s.
	Not shooting	4.40%	13.19%	17.58%	7.69%	50.55%	6.59%				
Minke whale	Shooting	7.69%	11.54%	34.62%	7.69%	34.62%	3.85%	3.160	73	2	n.s.
	Not shooting	21.28%	6.38%	23.40%	10.64%	31.91%	6.38%				
Sperm whale	Shooting	10.00%	25.00%	7.50%	25.00%	25.00%	7.50%	3.732	104	5	n.s.
	Not shooting	9.38%	21.88%	18.75%	15.63%	23.44%	10.94%				
Pilot whale	Shooting	7.89%	14.47%	22.37%	10.53%	43.42%	1.32%	12.031	162	5	< 0.05
	Not shooting	19.77%	4.65%	13.95%	10.47%	45.35%	5.81%				
All small odontocetes combined	Shooting	8.10%	20.95%	28.57%	7.62%	22.86%	11.90%	45.035	646	5	< 0.001
	Not shooting	25.23%	8.49%	22.48%	11.01%	24.77%	8.03%				
Dolphins (not *Lagenorhynchus*)	Shooting	10.53%	26.32%	36.84%	0.00%	21.05%	5.26%	5.803	67	2	n.s.
	Not shooting	22.92%	6.25%	25.00%	8.33%	31.25%	6.25%				
Bottlenose dolphin	Shooting	8.33%	33.33%	25.00%	0.00%	25.00%	8.33%	2.556	30	1	n.s.
	Not shooting	22.22%	5.56%	22.22%	11.11%	27.78%	11.11%				
Lagenorhynchus spp.	Shooting	11.11%	18.18%	28.28%	9.09%	21.21%	12.12%	29.676	350	5	< 0.001
	Not shooting	32.27%	4.78%	25.50%	9.96%	20.72%	6.77%				
White-beaked dolphin	Shooting	6.12%	26.53%	28.57%	8.16%	16.33%	14.29%	33.081	153	5	< 0.001
	Not shooting	48.08%	4.81%	21.15%	6.73%	10.58%	8.65%				
White-sided dolphin	Shooting	12.50%	12.50%	30.00%	7.50%	27.50%	10.00%	5.211	154	4	n.s.
	Not shooting	21.93%	5.26%	30.70%	8.77%	28.95%	4.39%				
Harbour porpoise	Shooting	0.00%	45.45%	27.27%	0.00%	27.27%	0.00%	4.289	34	1	< 0.05
	Not shooting	4.35%	30.43%	4.35%	13.04%	47.83%	0.00%				

For site surveys (Table 11) there were fewer species or species groups where sample sizes were sufficient to test the results, but in all cases the direction of travel was found to differ significantly with seismic activity. Again, partitioning showed that in all cases fewer animals were travelling towards the vessel and/ or more were travelling away from the vessel during periods of shooting.

Table 11 Direction of travel of marine mammals relative to the survey vessel in relation to seismic activity during site surveys (n = sample size; d.f. = degrees of freedom; P = probability; n.s. = not significant).

Species	*Seismic activity*	*Towards ship*	*Away from ship*	*Crossing path of ship*	*Parallel to ship in same direction*	*Parallel to ship in opposite direction*	*Milling or variable*	χ^2	*n*	*d.f.*	*P*
All cetaceans combined	Shooting	3.29%	14.75%	14.75%	11.48%	45.90%	9.84%	19.380	230	5	< 0.01
	Not shooting	23.08%	7.69%	15.98%	15.98%	25.44%	11.83%				
All small odontocetes combined	Shooting	0.00%	16.67%	10.00%	13.33%	50.00%	10.00%	21.783	124	4	< 0.001
	Not shooting	31.91%	6.38%	20.21%	11.70%	19.15%	10.64%				
Lagenorhynchus spp.	Shooting	0.00%	15.79%	15.79%	10.53%	47.37%	10.53%	10.127	59	1	< 0.01
	Not shooting	37.50%	10.00%	22.50%	7.50%	12.50%	10.00%				
White-sided dolphin	Shooting	0.00%	17.65%	11.76%	11.76%	47.06%	11.76%	8.410	42	1	< 0.01
	Not shooting	20.00%	12.00%	36.00%	8.00%	16.00%	8.00%				

6.4 The influence of depth on the level of disturbance of marine mammals

Depth of the water column is one of many factors that could influence the propagation of sound underwater, and therefore influence the response of marine mammals to seismic activity. The depth of water was normally recorded whenever marine mammals were seen. Some species (blue whale, beaked whales) were only seen in deep waters (Table 12). Seals were only seen in continental shelf waters. Other species were seen in a range of depths, but usually predominantly in either deeper or shallower waters. For example, fin whales, sei whales, sperm whales and pilot whales were predominantly found in deep waters, while white-beaked dolphins, minke whales and harbour porpoises occurred mostly in shelf waters.

Table 12 Median and range of depth of marine mammals encountered during seismic surveys

Species	*Median depth of pods (m)*	*Minimum depth (m)*	*Maximum depth (m)*	*Number of pods*
All seals combined	71	17	137	26
Grey seal	68	38	137	14
Common seal	92.5	49	109	6
All cetaceans combined	818	5	3,830	1,655
All baleen whales combined	995	16	3,830	335
Northern right whale (probable)	950	950	950	1
Humpback whale	1,046	104	2,000	8
Blue whale	1,554.5	1,200	1,769	4
Fin whale	1,003	90	2,168	115
Sei whale	1,503	859	3,000	13
Fin/ sei whale	1,038.5	90	3,000	184
Minke whale	141	16	3,830	78
Sperm whale	1,456	99	2,163	123
All beaked whales combined	1,224.5	1,062	1,285	6
Northern bottlenose whale	1,073.5	1,062	1,085	2
Sowerby's beaked whale	1,196	1,196	1,196	1
Pilot whale	1,321	85	2,500	170
Killer whale	215	10	2,000	61
All small odontocetes combined	172	5	3,000	791
Dolphins (not *Lagenorhynchus*)	457.5	5	3,000	78
Risso's dolphin	251.5	76	911	10
Bottlenose dolphin	166	5	1,867	34
Lagenorhynchus spp.	152	20	2,500	413
White-beaked dolphin	88	20	1,719	171
White-sided dolphin	863.5	66	2,500	198
Common dolphin	725.5	76	3,000	24
Striped dolphin	1,315	24	1,800	5
Harbour porpoise	130	19	1,537	37

Seismic surveys were conducted in varying locations covering a range of depths. The location recorded on the 'Location and Effort' forms (where these were completed correctly) was used to assign each day to one of three depth categories: 1) continental shelf (0-200 m); 2) shelf slope (200-1,000 m); 3) deep waters (> 1,000 m). More surveys took place on the continental shelf than in deeper waters. A slightly higher proportion of time was spent shooting in deep waters than over the continental shelf or shelf slope during surveys with large airgun arrays, while very little time was spent shooting over the continental shelf during site surveys (Table 13).

Table 13 Proportion of time spent shooting at different depths

	Proportion of time spent shooting	
Depth	*Surveys with large airgun arrays*	*Site surveys*
0-200 m	36.81%	11.15%
200-1,000 m	37.84%	34.37%
> 1,000 m	41.08%	38.77%

For killer whales and all cetaceans combined, median tests showed that relatively more pods were encountered during periods of shooting in deeper waters than was the case in shallower waters, during surveys with large airgun arrays (Table 14). For all other species the results were non-significant. It was not possible to examine the effects of depth for site surveys, as the proportion of time spent shooting in waters of different depths varied greatly.

Table 14 Proportion of marine mammal encounters while shooting, at depths exceeding or not exceeding the median depth for each species, excluding site surveys (n = sample size; d.f. = degrees of freedom; P = probability; n.s. = not significant).

Species	*Sightings at depths not exceeding median depth - percentage of sightings encountered while shooting*	*Sightings at depths exceeding median depth - percentage of sightings encountered while shooting*	χ^2	*n*	*d.f.*	*P*
All seals combined	0.00	16.67	0.545	24	1	n.s.
All cetaceans combined	29.42	46.01	39.684	1,379	1	< 0.001
All baleen whales combined	40.65	48.70	1.716	309	1	n.s.
Fin whale	51.85	37.74	1.622	107	1	n.s.
Fin/ sei whale	45.98	49.43	0.092	174	1	n.s.
Minke whale	33.33	38.89	0.060	72	1	n.s.
Sperm whale	40.38	36.54	0.041	104	1	n.s.
Pilot whale	45.68	49.38	0.099	162	1	n.s.
Killer whale	3.33	27.59	4.964	59	1	< 0.05
All small odontocetes combined	32.24	31.74	0.012	661	1	n.s.
Dolphins (not *Lagenorhynchus*)	26.47	29.41	0.000	68	1	n.s.
Bottlenose dolphin	40.00	40.00	0.139	30	1	n.s.
Lagenorhynchus spp.	26.14	30.11	0.506	352	1	n.s.
White-beaked dolphin	28.21	35.06	0.556	155	1	n.s.
White-sided dolphin	21.79	29.49	0.841	156	1	n.s.
Common dolphin	0.00	36.36	2.750	22	1	n.s.
Harbour porpoise	17.65	47.06	2.150	34	1	n.s.

6.5 Sightings during the soft-start

There were 43 sightings of marine mammals during the soft-start; 12 were first seen prior to the soft-start commencing but were still present as the soft-start commenced, while 31 were first detected once the soft-start was underway. All encounters during the soft-start occurred on surveys with large airgun arrays.

Sightings occurring only during the soft-start were compared with those occurring only when the airguns were not firing or only when the airguns were firing at full power levels during surveys with large airgun arrays. As sample sizes for individual species were small, all cetaceans were combined.

It was not possible to compare sighting rates, as no distinction was made between effort at full power and effort during the soft-start.

The influence of weather on the ability to detect marine mammals at distance was taken into account when comparing the median distance of cetaceans from the airguns. A Kruskal-Wallis one-way analysis of variance showed that the median distance of cetaceans varied significantly according to the power level of the airguns (Figure 14; KW = 18.970, n = 569, d.f. = 2, $p < 0.001$). Multiple comparisons revealed that while there were significant differences between the distance of cetaceans when the airguns were not firing and their distance during shooting at full power levels, the distance of cetaceans during the soft-start did not differ significantly from either shooting at full power or not shooting.

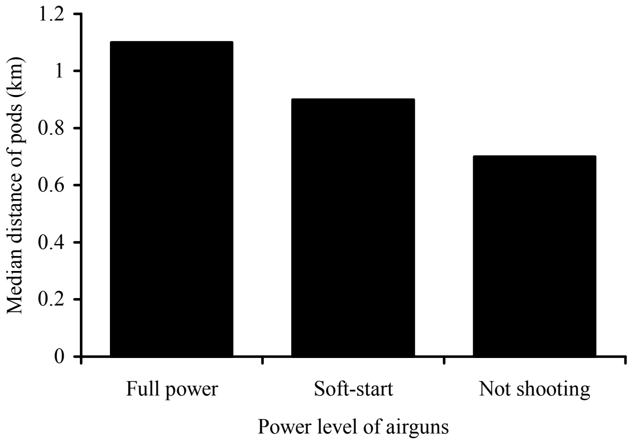

Figure 14 Median distance of cetaceans (all species combined) in relation to the power level of the airguns.

The median distance of cetaceans increased during the first half of the soft-start, then decreased again towards the end (Figure 15). However, sample sizes were very small in each category, so this result should be treated with caution.

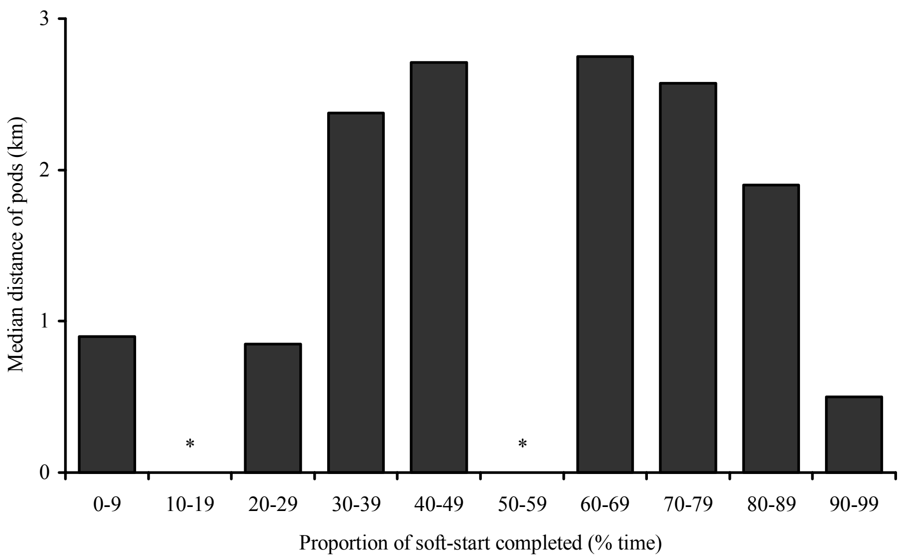

Figure 15 Median distance of cetaceans (all species combined) throughout the soft-start (* = no data).

The frequency of occurrence of some behaviours during the soft-start was closely aligned to that during firing at full power levels (e.g. feeding, negative interactions, fast swimming). Conversely, the frequency of positive interactions was similar to that during periods when the airguns were not firing - there were reported instances of white-beaked dolphins bow-riding during the soft-start. However, where sample sizes were sufficient to permit testing, the frequency of occurrence of behaviours was not found to differ significantly with the power level of the airguns (Table 15). The most frequently recorded behaviour during the soft-start (other than 'normal swimming', which was reported for 25.93% of encounters) was fast swimming.

Table 15 Behaviour of cetaceans (all species combined) in relation to the power level of the airguns (n = sample size; P = probability; n.s. = not significant; - = insufficient data).

Behaviour	*% of encounters while shooting at full power when behaviour was exhibited*	*% of encounters during soft-start when behaviour was exhibited*	*% of encounters while not shooting when behaviour was exhibited*	χ^2	*n*	*P*
Feeding	3.54	3.70	8.29	-	90	-
+ve interactions	4.38	14.81	12.67	-	135	-
-ve interactions	3.75	3.70	0.81	-	26	-
Alteration of course	6.04	3.70	2.42	-	51	-
Breaching, jumping or somersaulting	19.79	14.81	20.05	0.362	273	n.s.
Porpoising	8.96	7.41	10.60	-	137	-
Fast swimming	24.79	25.93	21.20	1.908	310	n.s.
Slow swimming	21.25	14.81	20.85	0.510	287	n.s.
Milling	2.29	3.70	2.19	-	31	-
Surfacing infrequently	9.38	18.52	11.64	-	151	-
Diving	7.71	14.81	7.72	-	108	-

Sample sizes were too low to permit statistical testing of the direction of travel of animals relative to the vessel during the soft-start. However, small odontocetes and baleen whales were more often observed heading away from the vessel than towards it, while pilot whales tended to head towards the vessel (Table 16).

Table 16 Direction of travel of cetaceans relative to the survey vessel during the soft-start (n = sample size).

Species	*Towards ship*	*Away from ship*	*Crossing path of ship*	*Parallel to ship in same direction*	*Parallel to ship in opposite direction*	*Milling or variable*	*n*
All cetaceans combined	25.93%	18.52%	3.70%	14.81%	29.63%	7.41%	27
All baleen whales combined	11.11%	22.22%	0.00%	11.11%	55.56%	0.00%	9
Pilot whale	66.67%	0.00%	0.00%	0.00%	33.33%	0.00%	3
All small odontocetes combined	21.43%	28.57%	7.14%	14.29%	14.29%	14.29%	14

Of the 12 sightings that were detected prior to the soft-start but were still present as the soft-start commenced, two exhibited behaviours that could be described as a startle response. In one case a pod of pilot whales at a distance of 290 m from the airguns altered course and swam away from the vessel when the soft-start commenced. In another case, a sperm whale that had previously been swimming slowly and had dived, resurfaced as the soft-start commenced and proceeded to swim rapidly at the surface; in this case the animal was 2 km from the airguns. In the remaining ten cases where animals were observed as the soft-start commenced there was no apparent reaction (or observers did not differentiate between behaviours prior to the soft-start and those during the soft-start).

7. The use of dedicated marine mammal observers

The term 'dedicated marine mammal observer', from here onwards, is taken to mean someone with experience of marine mammal observations, dedicated to that task alone during the survey, and whose normal role on seismic surveys is that of marine mammal observer. It does not include those personnel who are normally fishery liaison officers, but who may on occasion be dedicated to the task of marine mammal observations.

Dedicated marine mammal observers were used on 19% of the surveys reported here. For the majority of surveys (56%) fishery liaison officers undertook observations of marine mammals (in only 1% of surveys were fishery liaison officers dedicated to this task), while 20% of surveys relied on members of the ships' crews. For a small proportion of surveys (5%) observers were anonymous.

7.1 Effect on the operation of surveys

The operational procedures laid down in the *Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys* require that for 30 minutes immediately prior to any use of the airguns a search for marine mammals is carried out, that shooting is delayed if marine mammals are detected within 500 m of the airguns (until at least 20 minutes after the last sighting), and that in all cases the airguns commence firing at low power levels, gradually increasing to full power levels over a period of at least 20 minutes (the soft-start). The level of compliance with these requirements was assessed for each type of observer. Due to differences in regulatory requirements, reports received from surveys outside UK waters were excluded from these comparisons. When considering the use of a soft-start, site surveys were analysed separately from other surveys; the guidelines indicate that some site surveys may be exempt from a soft-start, although in March 2000 JNCC issued a guidance note clarifying that such exemptions would only exist with the prior agreement of JNCC.

Compliance with all aspects of the guidelines was found to be greatest when dedicated marine mammal observers were on board (Table 17). Use of members of ships' crews to perform the role of marine mammal observer was the least effective alternative. The greatest discrepancy in performance arose during situations when shooting had to be delayed due to the close proximity of marine mammals. In some cases where the guidelines were not complied with some attempt was made to minimise disturbance to the animals, but the action taken was insufficient (either the delay or the subsequent soft-start was too short). In other cases no action was taken.

Table 17 Compliance with the *Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys* in relation to type of observer (n = sample size).

Requirement	*Dedicated marine mammal observer*		*Fishery liaison officer*		*Ship's crew*	
	Level of compliance	*n*	*Level of compliance*	*n*	*Level of compliance*	*n*
Pre-shooting search of minimum duration 30 minutes	90.5%	1,727	78.2%	3,042	54.4%	574
Delays in shooting when marine mammals detected within 500 m	70.0%	20	0.0%	6	0.0%	1
Soft-start of minimum duration 20 minutes (surveys with large airgun arrays)	93.2%	1,868	80.1%	3,767	32.1%	28
Soft-start of minimum duration 20 minutes (site surveys)	31.1%	530	3.1%	683	1.0%	774

7.2 Effect on information received

The guidelines require that reports are submitted after surveys, and standard recording forms are available for this purpose. 'Location and Effort' forms should have been submitted for all surveys, while 'Record of Operations' forms should have been submitted for all surveys where airguns were used. Observers were assessed on their ability to complete these forms correctly, and on some of the information supplied on the 'Record of Sighting' forms. Only reports from surveys in UK waters were used for these comparisons. When comparing sighting rates of different types of observers only data from June to August in areas West of Shetland and Rockall were used (i.e. areas and months of peak marine mammal occurrence), and periods of poor weather were disregarded.

Dedicated marine mammal observers were better at completing the recording forms correctly, particularly the 'Location and Effort' form (Table 18). They were also much better at detecting marine mammals than other observers, with sighting rates double that of fishery liaison officers and six times that of members of ships' crews. There was a slight difference in the median distance at which marine mammals were seen by the various types of observer, with dedicated marine mammal observers having the greatest median distance. However, the maximum distance at which marine mammals were detected varied much more, with the average for dedicated marine mammal observers being greatest.

Table 18 Information supplied in relation to type of observer, and ability of observer.

	Dedicated marine mammal observer	*Fishery liaison officer*	*Ship's crew*
All recording forms completed correctly	93.3%	67.9%	31.6%
Location and Effort form completed correctly	93.5%	74.0%	36.8%
Record of Operations form completed correctly	93.1%	90.4%	69.4%
Mean sighting rate per 1,000 hours survey	150.6	71.0	26.9
Distance of sighting:			
Median	900 m	850 m	700 m
Mean maximum	3,688 m	1,819 m	1,578 m
Species identification:			
Proportion of sightings downgraded	14.9%	26.5%	30.7%
Proportion of sightings wrong	0.9%	0.9%	0.0%
Proportion of records with no description	3.9%	2.0%	10.9%
Identified to species level	68.3%	60.2%	43.6%
Identified as one of a narrow group of similar species	15.5%	10.5%	6.9%
Identified as one of a broad group of species	16.2%	29.3%	49.5%
Behaviour:			
Mean range of behavioural categories used per observer	12.1	6.2	2.3
Mean number of behaviours recorded per sighting	1.8	1.4	1.2

The level of detail of information provided by dedicated marine mammal observers was also better than by other personnel. Their identification skills were generally better - fewer identifications by dedicated marine mammal observers were downgraded when compared to those of other types of personnel. However, fishery liaison officers were better at routinely providing descriptions of marine mammals, although these descriptions were not always sufficient to confirm their identification. After downgrading had been performed where necessary, the proportion of sightings that were identified to species level or as being one of a narrow group of similar species (e.g. fin/ sei whale, or white-beaked/ white-sided dolphin) was highest for dedicated marine mammal observers and lowest for members of ships' crews, while the reverse was true for use of the broad identification categories ('cetacean', 'whale', 'large whale', 'medium whale', 'dolphin' or 'seal'). Dedicated marine mammal observers used a broad range of categories of behaviour and recorded a slightly higher number of behaviours per sighting on average, while members of ships' crews generally recorded a limited range of behaviours.

8. Discussion

Baleen whales have often been considered to be more vulnerable to disturbance from seismic activity than odontocetes (e.g. Evans and Nice 1996), as the frequencies they use overlap with those produced by seismic airguns. Although the auditory sensitivities of baleen whales are not known, there is an assumption that hearing will occupy approximately the same range of frequencies that these animals produce sounds at. Fin whales, for example, produce constant calls at 20-40 Hz and would be expected to be very sensitive to sounds at these frequencies (Evans and Nice 1996). Seismic exploration generally utilises frequencies up to 220 Hz, thus directly overlapping with the frequencies used by baleen whales such as the fin whale.

Few effects of seismic activity have been observed in baleen whales in UK waters. Fin whales and minke whales were the species of baleen whale most often observed, but no effects on the occurrence or behaviour of these individual species were found. Humpback whales were seen only occasionally during seismic surveys, but no effect of seismic activity on their occurrence was found. However, when all species of baleen whale were combined it was found that they stayed further from the airguns during periods of shooting. They were also found to alter course more often during periods of shooting and more were heading away from the vessel at these times. These results indicate that there may be at least some level of localised avoidance of seismic activity by baleen whales. Avoidance of seismic activity has sometimes been observed in baleen whales previously (Ljungblad *et al.* 1988; Richardson and Greene 1993; Richardson *et al.* 1985). The fact that fin/ sei whales were less often recorded as surfacing infrequently during periods of shooting implies that they tended to remain at or near the surface then. Received sound levels near the surface are generally lower than at greater depths (Richardson *et al.* 1995; Urick 1983). McCauley *et al.* (1998, 2000) suggested that this may provide an explanation for humpback whales spending much time at the surface during a period of seismic activity.

A tendency to remain near the surface during periods of seismic activity may have led to fin/ sei whales being more easily detected at these times, thus falsely inflating sighting rates when compared to periods when the airguns were silent. The absence of any reduction in the number of sightings of baleen whales therefore should not be taken as confirmation that there was no or minimal disturbance, as sighting rate may be influenced by the animals' behaviour. As discussed above, there were other indications of localised avoidance, and in addition there may be effects not able to be detected using the current data. For example, effects on vocalisations would not be apparent from visual observations. A reduction in vocalisations in response to seismic activity has been found in bowhead whales (Richardson 1997). Effects of seismic activity on the physiology of the baleen whales found around the UK are largely unknown. An increase in the respiration rate of fin whales within 1 km of the airguns during periods of shooting has been indicated by shorter blow intervals when compared to periods when the airguns were silent (Stone 1998b). Other studies have also indicated alterations in surfacing, respiration and dive cycles in other baleen whales in response to seismic activity, sometimes at considerable distances from the source (Ljungblad *et al.* 1988; Richardson *et al.* 1985, 1986, 1995).

Sperm whales around the UK showed no observable effects of seismic activity. However, in the Gulf of Mexico seismic activity has been found to result in a decrease in abundance of sperm whales and negative effects on their communication and orientation behaviour (Mate *et al.* 1994; Rankin and Evans 1998). Cetaceans hear as well at depth as they do near the surface (Ridgway *et al.* 1998), so deep-diving species such as sperm whales will be vulnerable to acoustic disturbance throughout the water column. It may be difficult to observe effects on their occurrence or behaviour simply from surface observations due to the relatively small proportion of time they spend at the surface.

Pilot whales also showed little effect of seismic activity. The only observed effect was on their orientation, with more heading away from and fewer towards the vessel during periods of shooting. However, any avoidance appeared to be relatively minor as there was no difference in their closest distance of approach to the airguns in relation to seismic activity. It is not known whether the decline in sighting rates of pilot whales over the three-year period was related to continued seismic activity or to some other factor, e.g. a shift in prey distribution. Most of the pilot whales seen during seismic surveys occurred in the Faroes-Shetland Channel or in the Rockall area. Zachariassen (1993) notes that climatic and biological parameters, including sea surface temperature and squid abundance, may be of importance to the abundance of pilot whales in the Faroese area. However, the possibility that continued seismic activity may be playing some part in influencing the temporal changes in pilot whale occurrence, perhaps in combination with other factors, cannot be dismissed.

For the first time some effects of seismic activity on killer whales have been assessed. As with the baleen whales and other large and medium-sized odontocetes, no reduction in sighting rate was found in response to seismic activity. However, killer whales were found to remain further from the source when it was active, which may indicate some level of localised avoidance.

Most of the energy from seismic airguns is at frequencies below the optimum hearing range of small odontocetes, whose greatest auditory sensitivities lie within the range 10-150 kHz (Evans and Nice 1996, from various sources). Consequently odontocetes are sometimes regarded as being relatively insensitive to seismic sounds (Evans and Nice 1996; Richardson *et al.* 1995). However, high frequency noise is emitted incidentally during seismic operations. Goold and Fish (1998) found that noise from seismic airguns dominated the 200 Hz - 22 kHz bandwidth at ranges of up to 2 km from the source, and that even at 8 km from the source seismic emissions exceeded background noise at frequencies of up to 8 kHz. They concluded that noise from seismic airguns would be clearly audible to dolphins out to ranges of at least 8 km from the source. Furthermore, there is the possibility that dolphins may also be able to detect low frequency sounds, by using some mechanism other than conventional hearing. Turl (1993) found that a bottlenose dolphin responded to sounds of 50-100 Hz and suggested that this was due to detection of particle velocity or some combination of pressure and velocity in the near-field.

Whether they are responding to high or low frequencies, and by whatever mechanism, it is nevertheless clear that small odontocetes do react to seismic activity. The small odontocetes tested showed a much greater range of effects than baleen whales or larger odontocetes. The *Lagenorhynchus* species showed significant declines in sighting rates during periods when the airguns were firing, as did all small odontocete species combined. All categories (individual species or species groups) of small odontocetes tested were found to remain further from the airguns during periods of shooting. Several of the small odontocete species or species groups were more often heading away from the vessel during periods of shooting. Other behavioural effects of seismic activity were also noted amongst the small odontocetes, with fewer dolphins engaging in positive interactions (e.g. bow-riding) with the vessel or its equipment during periods of shooting, more displaying obvious avoidance, and an increase in swimming speed at these times (and occasionally a corresponding decrease in swimming speed when the airguns were not firing).

In previous analyses (Stone 1997, 1998a, 2000, 2001, 2003) similar trends have been found, with baleen whales increasing their distance from the source, changing their orientation and sometimes remaining nearer the surface in response to seismic activity, while sperm whales showed no observable effects and pilot whales only exhibited a difference in orientation; small odontocetes, on the other hand, have shown a reduction in sighting rates in response to seismic activity, as well as an increase in distance from the source, a change in orientation and some behavioural effects. In addition to confirming previous results, by combining data over several years the present study has enabled examination of the effects of seismic activity on a greater range of individual species and a greater range of behaviours. For example, some parameters have been tested for killer whales, bottlenose dolphin and harbour porpoise, all species for which there has been no previous knowledge of the effects of seismic activity; all three species were found to remain further from the source when it was active, and the orientation of harbour porpoise was also affected. Many more behaviours were able to be examined than has been the case previously for most species. The current analysis demonstrates some behavioural effects previously unconfirmed in small odontocetes, such as a greater incidence of obvious avoidance and faster swimming speeds during periods of shooting. The results for the new species and behaviours tested have maintained the pattern of a higher number of significant observed effects for small odontocetes than for baleen whales and larger odontocetes.

Other studies on the effects of seismic activity on small odontocetes are rare, with most work concentrating on baleen whales and large odontocetes, although one study found that common dolphin populations were temporarily disturbed by seismic activity (Goold 1996). Perhaps because of the generally-held belief that small odontocetes are not sensitive to the frequencies produced by seismic airguns, and the lack of research into effects on these species, small odontocetes are often overlooked when considering mitigation strategies for seismic operations. Recent guidelines for seismic exploration in Australia, for example, only cover larger cetaceans (Environment Australia 2001). Small odontocetes should be considered for inclusion in any mitigation strategies against acoustic disturbance.

It is possible that the different cetacean species react to seismic activity in different ways. Most of the taxonomic groups examined have shown at least some response during periods of shooting. It seems that baleen whales orient away from the survey vessel and increase their distance from the source, but do not move away from the area completely. It is possible that these slower moving species, rather than moving out of the area, have perhaps adopted a strategy of remaining nearer the surface where received sound levels may be less, whilst slowly moving further from the source. Other studies (Ljungblad *et al.* 1988; Richardson *et al.* 1985, 1986, 1995; Stone 1998b) have also suggested there may be changes in the respiration rate of baleen whales such as bowhead and fin whales during periods of seismic activity, which may indicate some level of stress - this feature was not able to be assessed using the data from the surveys reported here. The faster moving small odontocetes, it seems, not only orient away from the source and increase their distance from it, but also increase their speed and are better able to move out of the immediate area (as indicated by reduced sighting rates during periods of shooting). Numbers of small odontocetes are reduced within the limits of visual detection, but how far beyond this the displacement extends is not known.

The avoidance exhibited by small odontocetes, and to a lesser extent other cetacean species, appears to be mostly temporary. There was no evidence of declining sighting rates throughout the course of seismic surveys (although sightings of pilot whales declined over a three-year period). However, it is not known whether the animals seen later in a survey are the same individuals that were present earlier (photo-identification studies generally not being feasible from seismic survey vessels), or whether they have moved and new animals have come in to the area. It is also possible that animals may have no choice but to remain in an area, if there is some reason (e.g. food) that they need to be there.

Most of the responses observed could be classed as avoidance reactions. However, another effect of seismic activity was that fewer cetaceans were observed feeding during periods of shooting. The possibility that cetaceans are prevented from feeding by seismic activity has the potential to be a serious threat to the wellbeing of both individuals and populations. It is also possible that seismic activity may effect prey species (e.g. Engås *et al.* 1996; Turnpenny and Nedwell 1994), thus indirectly affecting marine mammals.

Site surveys and other similar low power surveys had some effects on cetaceans, although rather less than on surveys with large airgun arrays, as might be expected. All species tested showed an effect on their orientation when the airguns were firing during site surveys, with fewer heading towards the vessel and/ or more heading away from the vessel, and all species tested also engaged in fewer positive interactions with the vessel or its equipment at these times. However, in spite of this apparent reluctance to head towards or approach close to the vessel, none of the species tested were found to be significantly further from the source during periods of shooting. Sighting rates were reduced when all small odontocete species were combined, but not in other cases. One behavioural reaction to shooting during site surveys was a tendency to breach or jump more often. The meaning of such behaviours can be difficult to interpret - various roles have been suggested as an explanation for breaching, most involving the assumption that it serves as some form of non-vocal signalling. There was an apparent tendency for cetaceans to surface infrequently (i.e. remain submerged) during periods of shooting on site surveys, which was opposite to the situation found on surveys with larger arrays where fin/ sei whales remained submerged more when the airguns were not firing. There was no apparent effect of site surveys on swimming speed.

Previously, the only effect noted from site surveys was a difference in orientation (Stone 2003). It is now apparent that there are some additional effects. Although it is impossible to assess the level of disturbance that such responses might be indicative of, it is important that site surveys continue to apply the guidelines as a precautionary measure.

More data are needed to assess whether the soft-start is effective as a mitigating measure. Some cetaceans swam away from the vessel during the soft-start, thus reducing the potential for disturbance, although from the limited data available this did not seem to be the case for pilot whales. Conversely, some dolphins engaged in bow-riding. Noise levels ahead of the vessel may be less than those abeam of it (Richardson *et al.* 1995; McCauley *et al.* 2000), but animals bow-riding during low power shooting may be vulnerable to disturbance if they have insufficient time to move away before full power levels are reached. As well as minimising disturbance, the aim of the soft-start is to reduce the risk of physical injury to undetected animals close to the source, and this risk may increase if shooting were to commence at full power levels with no soft-start. The soft-start procedure should therefore continue to be employed, with further data being gathered to enable a better assessment of its effectiveness.

The responses observed here indicate that there is some level of disturbance of cetaceans from seismic activity, although to what extent this poses a serious threat to the health of marine mammals is not known. In summary, the observations suggest that small odontocetes (particularly the *Lagenorhynchus* species) show the strongest avoidance of seismic activity, with baleen whales and killer whales showing some localised avoidance, pilot whales showing few effects (unless the decline in sightings of this species is in any way linked to seismic activity) and sperm whales showing no observed effects from these data. Other potential effects of seismic activity remain largely unknown, for example long-term effects, effects on vocalisations, social behaviour and physiology, consequences of auditory masking and the potential for damage to hearing. It is essential, therefore, that the precautionary guidelines to minimise disturbance continue to be applied. In order to achieve the highest level of compliance with the guidelines it is recommended that dedicated marine mammal observers are used. The comparative lack of compliance with the guidelines when members of ships' crews were responsible for marine mammal observations may indicate the importance of having an observer who is independent. The use of dedicated marine mammal observers will also ensure that high quality data are gathered enabling further assessment of the effects of seismic activity on marine mammals.

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11. Appendices

Appendix 1	Species distribution maps (although the majority of sightings occurred during the years 1998 to 2000, some sightings recorded on these maps occurred during the two surveys in 1997 that are also included in this report)
Appendix 2	*Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys (April 1998)* and *Guidance note on the implementation of the guidelines for minimising acoustic disturbance to marine mammals from seismic surveys (March 2000)*
Appendix 3	Marine mammal recording forms used during 1998-2000
Appendix 4	Current marine mammal recording forms and *Guide to using marine mammal recording forms*
Appendix 5	Scientific names of species mentioned in the text

Appendix 1

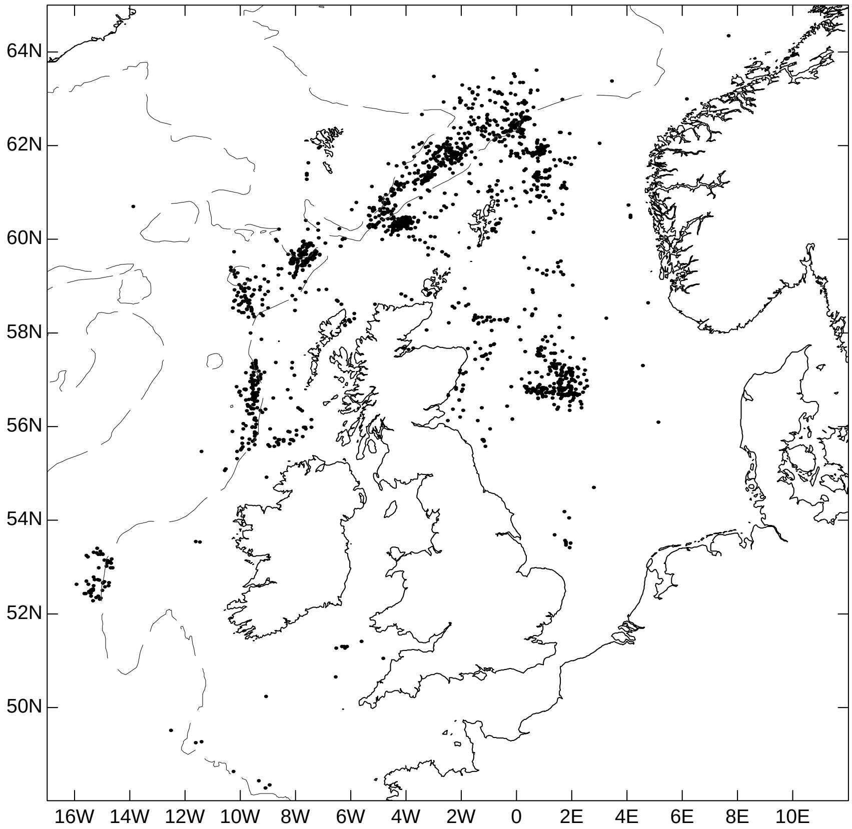

Figure 16 Marine mammal sightings from seismic survey vessels, 1998-2000.

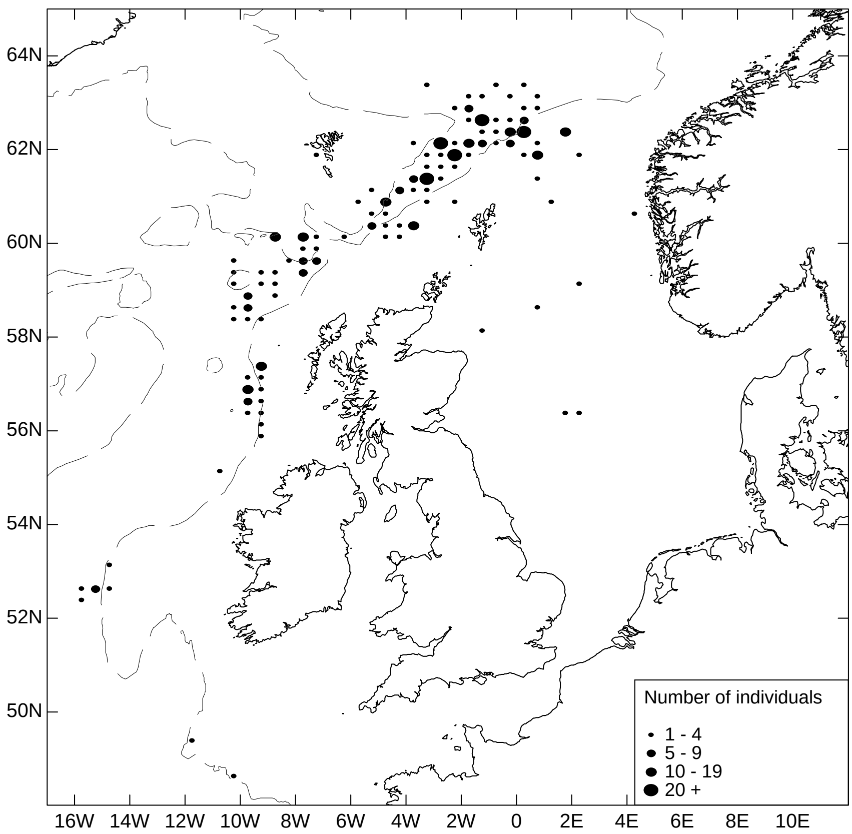

Figure 17 Distribution of unidentified whales seen from seismic survey vessels, 1998-2000.

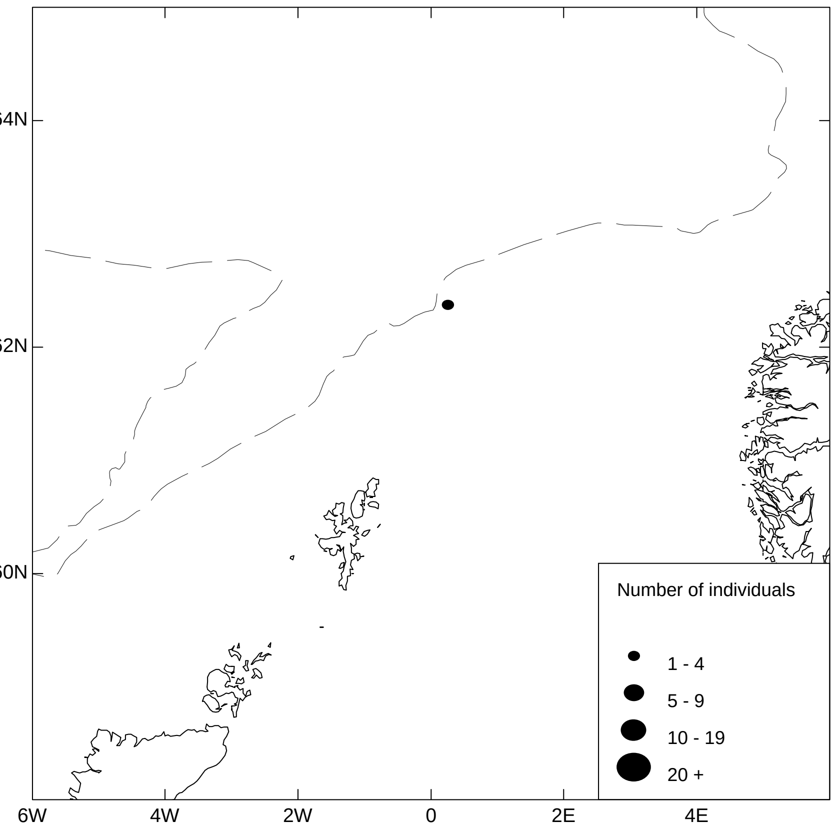

Figure 18 Location of probable northern right whale seen from seismic survey vessels, 1998-2000.

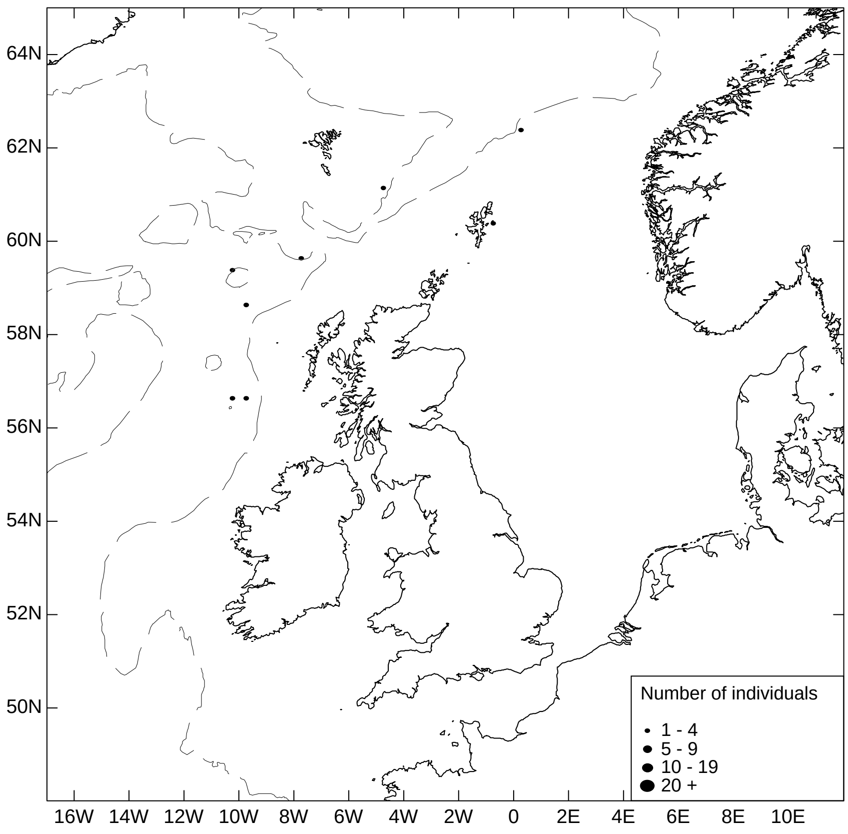

Figure 19 Distribution of humpback whales seen from seismic survey vessels, 1998-2000.

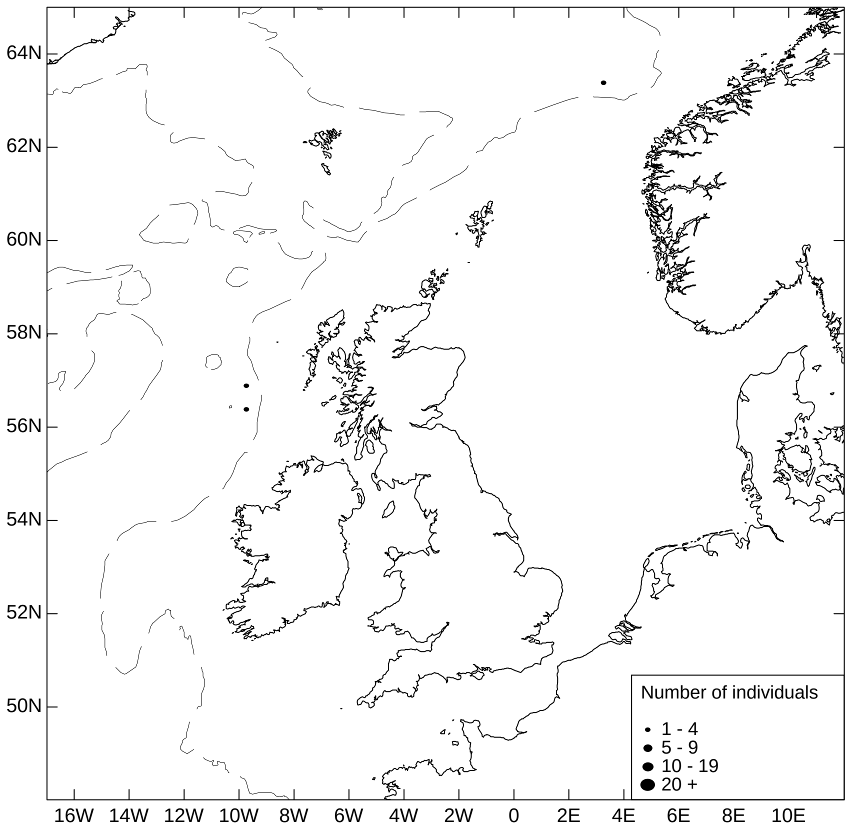

Figure 20 Distribution of blue whales seen from seismic survey vessels, 1998-2000.

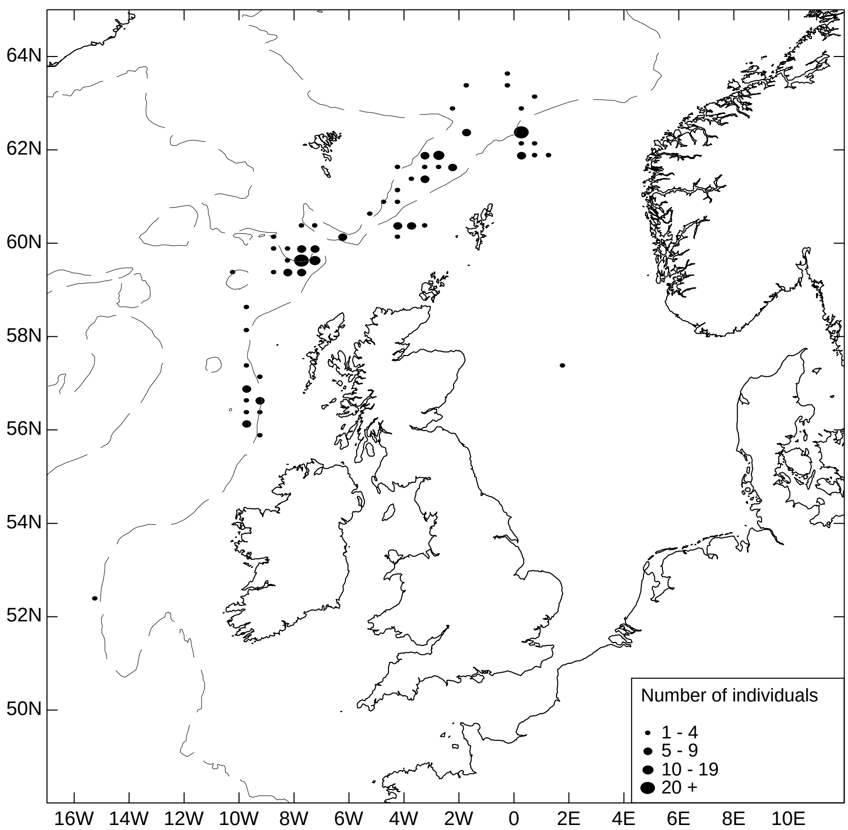

Figure 21 Distribution of fin whales seen from seismic survey vessels, 1998-2000.

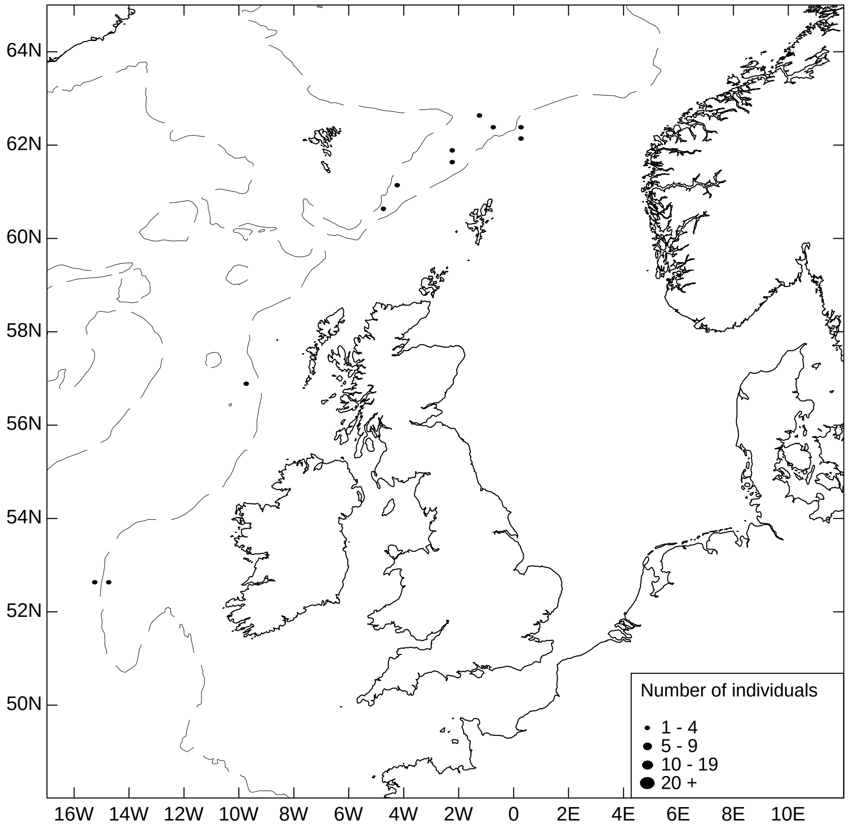

Figure 22 Distribution of sei whales seen from seismic survey vessels, 1998-2000.

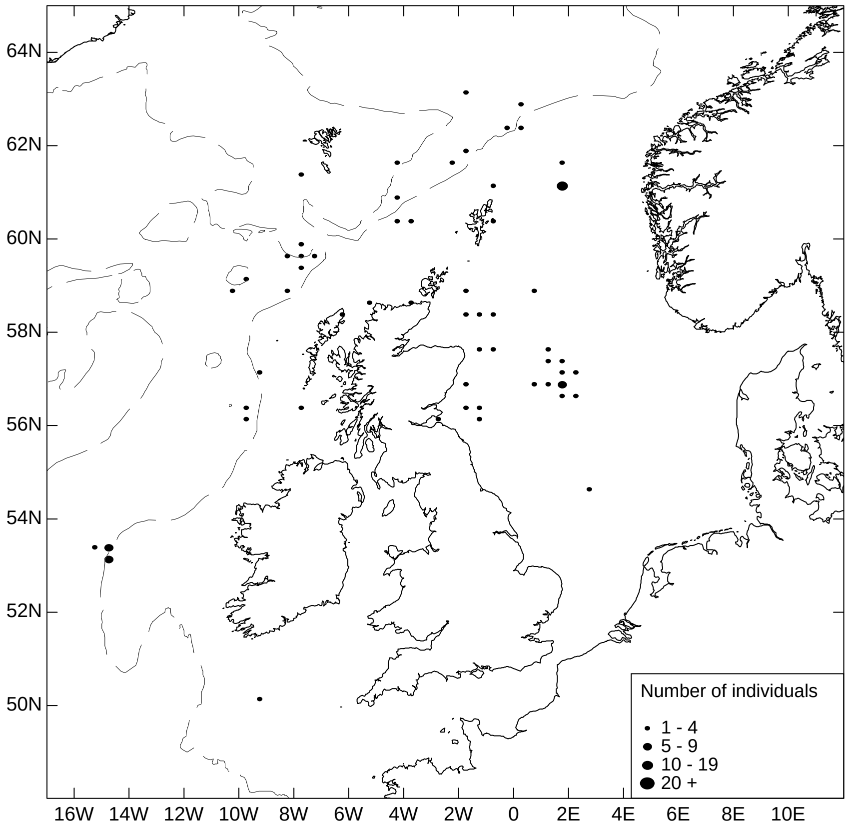

Figure 23 Distribution of minke whales seen from seismic survey vessels, 1998-2000.

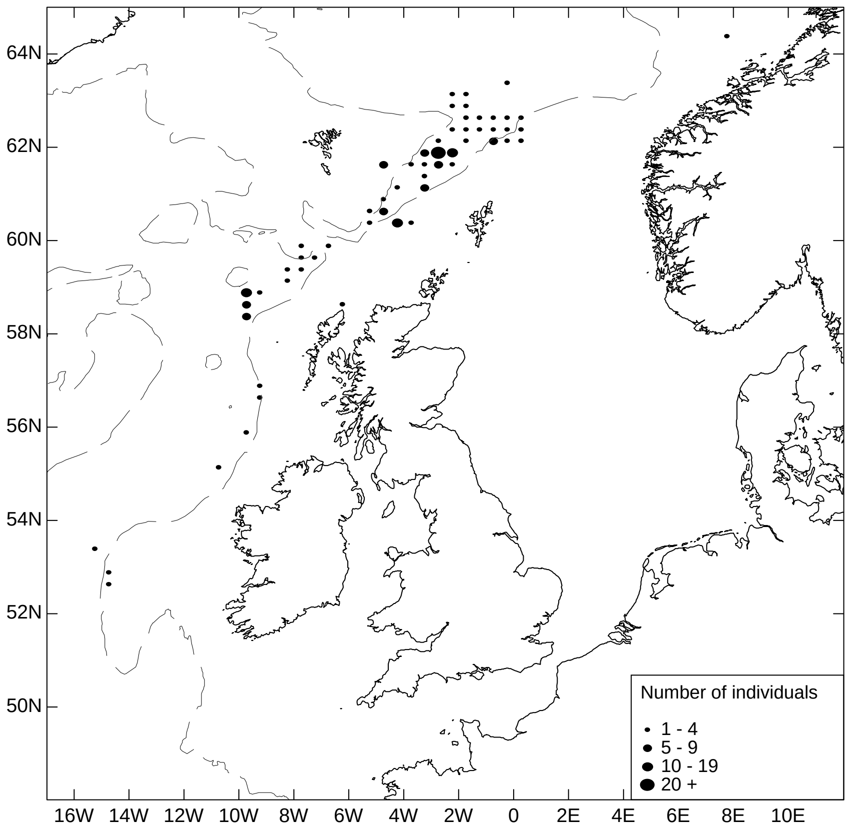

Figure 24 Distribution of sperm whales seen from seismic survey vessels, 1998-2000.

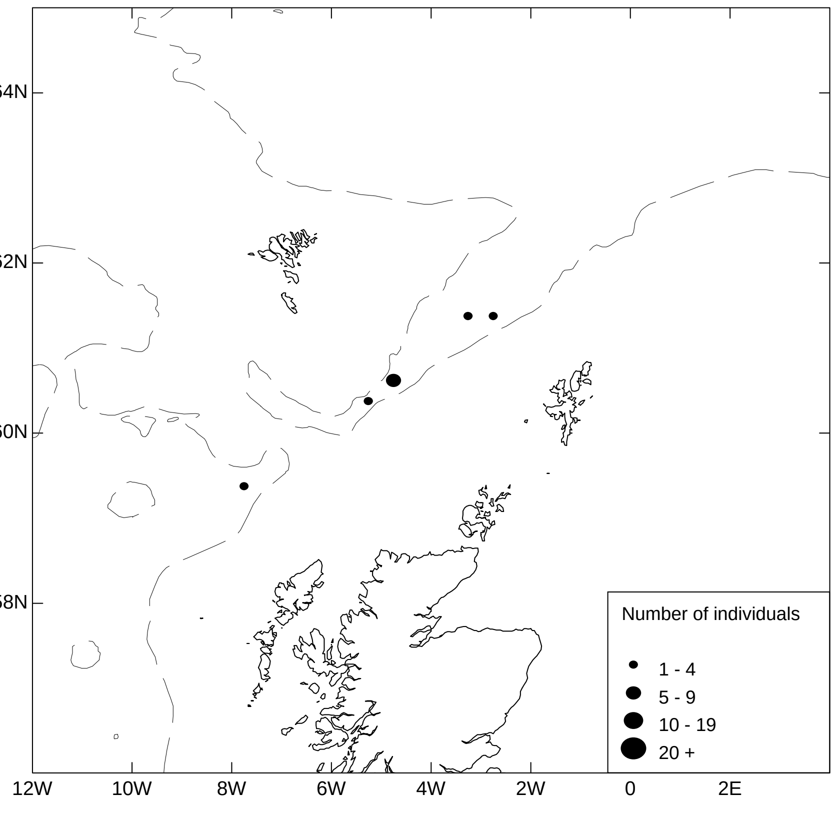

Figure 25 Distribution of unidentified beaked whales seen from seismic survey vessels, 1998-2000.

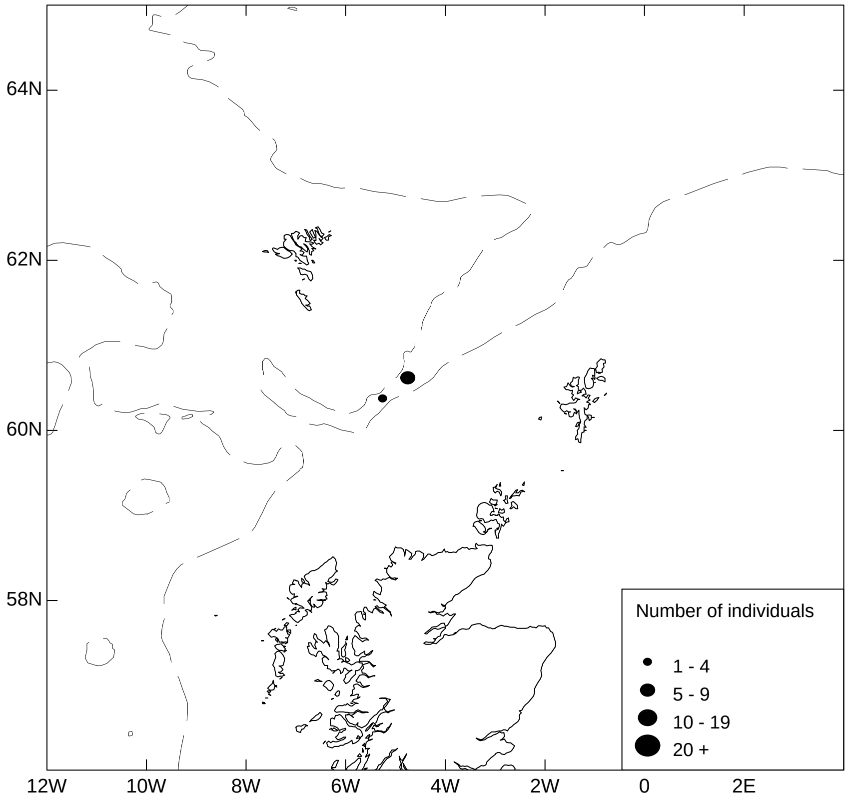

Figure 26 Distribution of northern bottlenose whales seen from seismic survey vessels, 1998-2000.

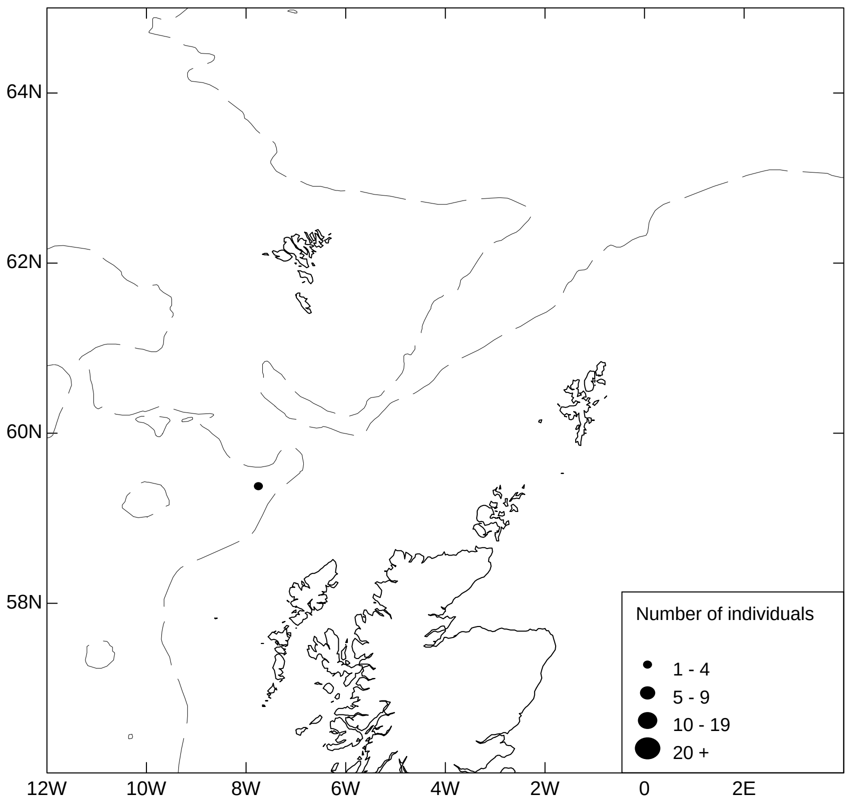

Figure 27 Location of Sowerby's beaked whale seen from seismic survey vessels, 1998-2000.

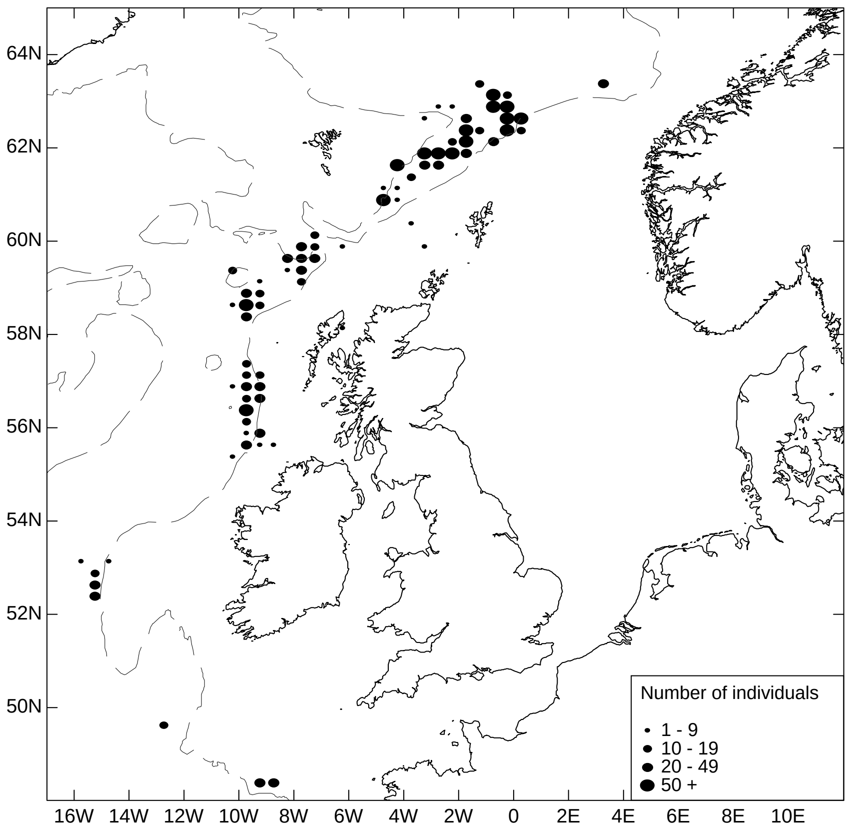

Figure 28 Distribution of pilot whales seen from seismic survey vessels, 1998-2000.

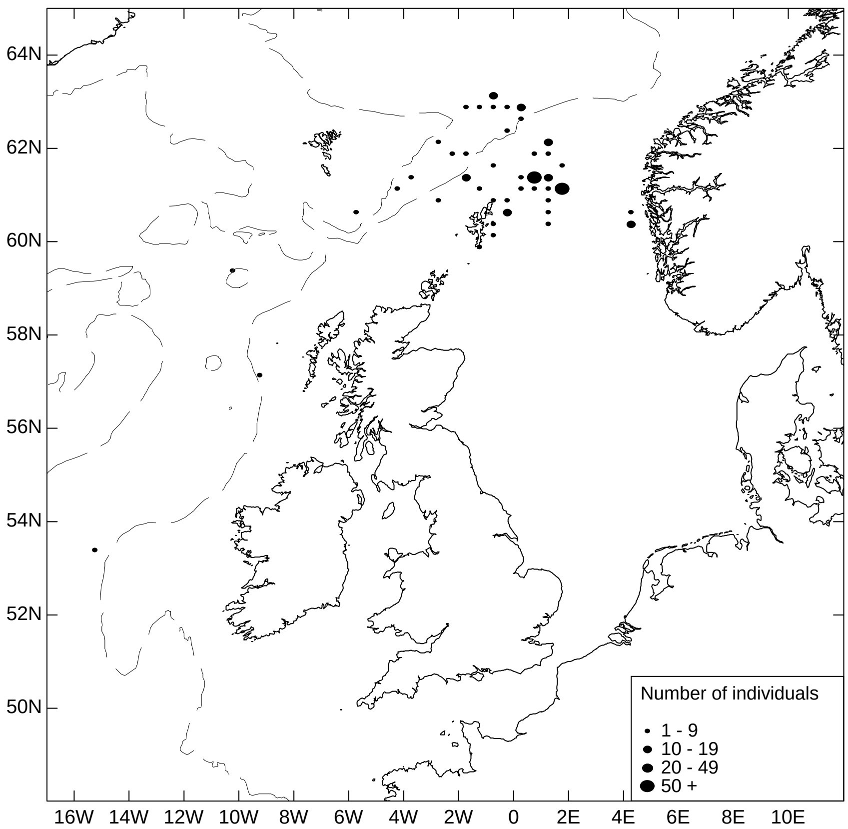

Figure 29 Distribution of killer whales seen from seismic survey vessels, 1998-2000.

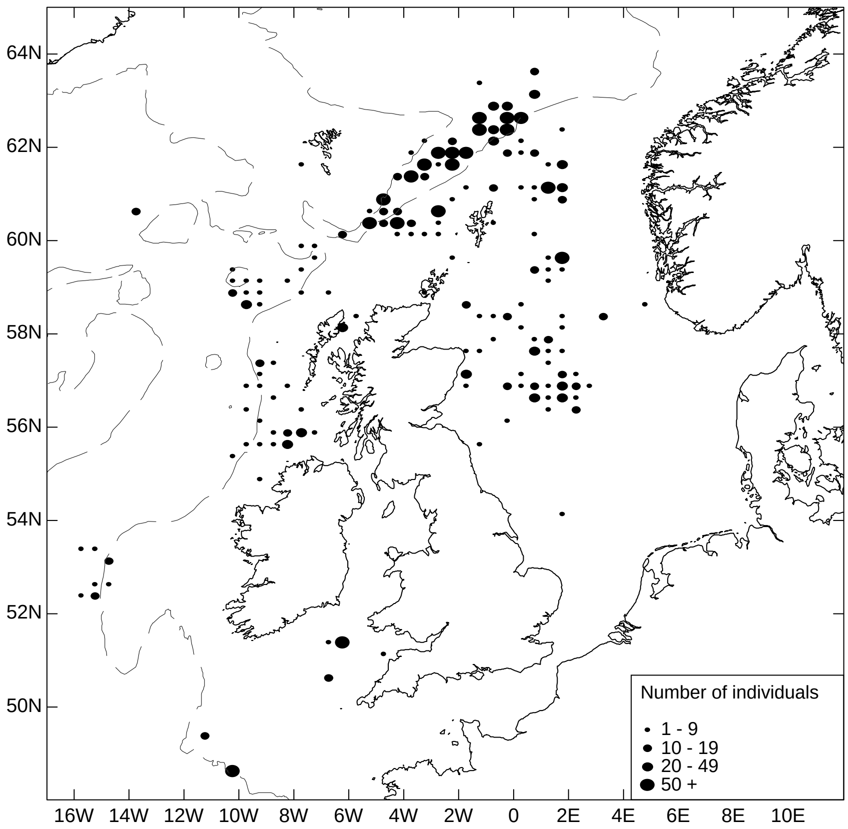

Figure 30 Distribution of unidentified dolphins seen from seismic survey vessels, 1998-2000.

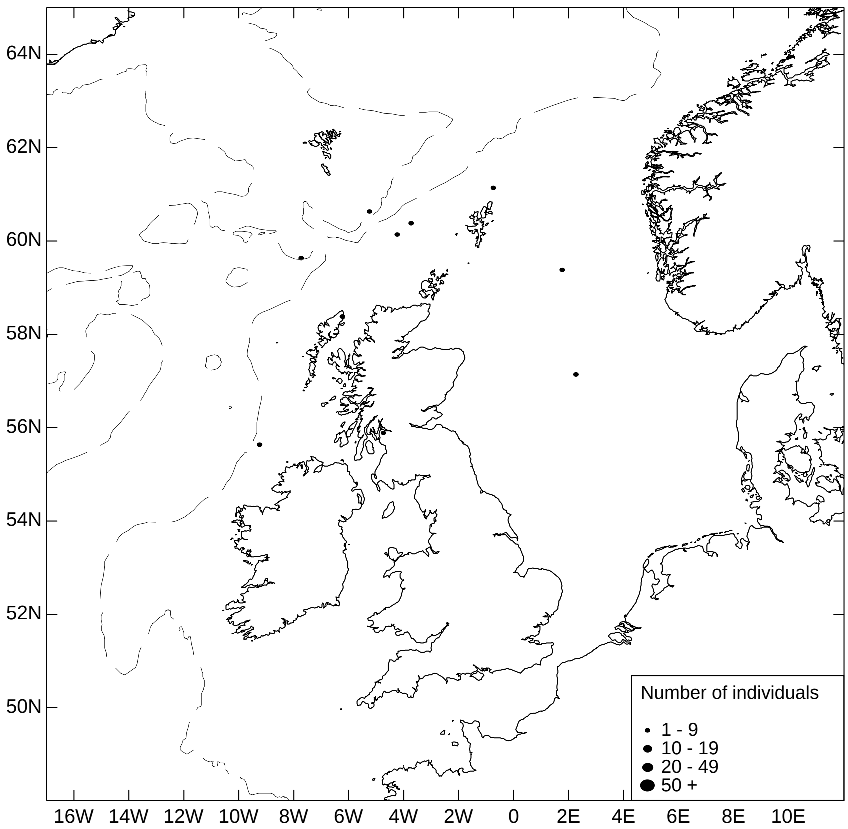

Figure 31 Distribution of Risso's dolphins seen from seismic survey vessels, 1998-2000.

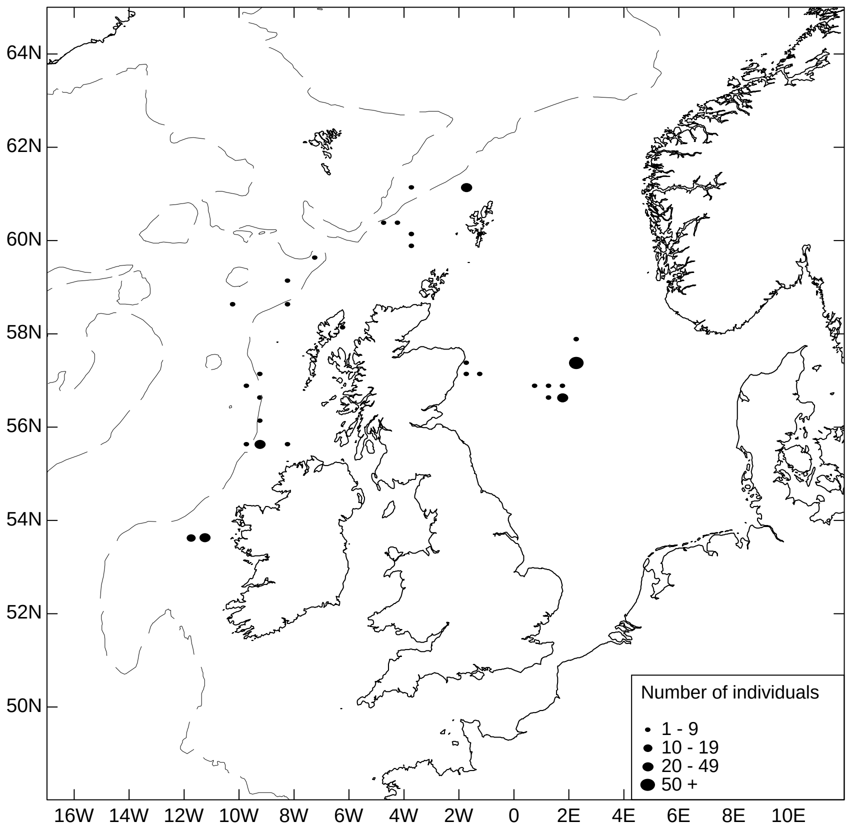

Figure 32 Distribution of bottlenose dolphins seen from seismic survey vessels, 1998-2000.

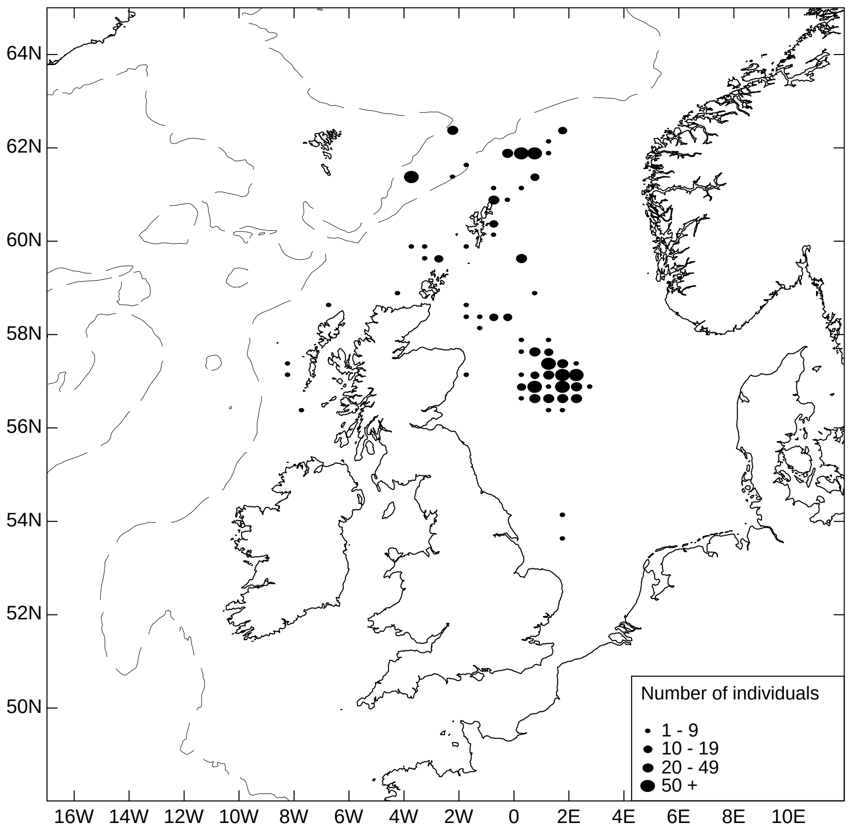

Figure 33 Distribution of white-beaked dolphins seen from seismic survey vessels, 1998-2000.

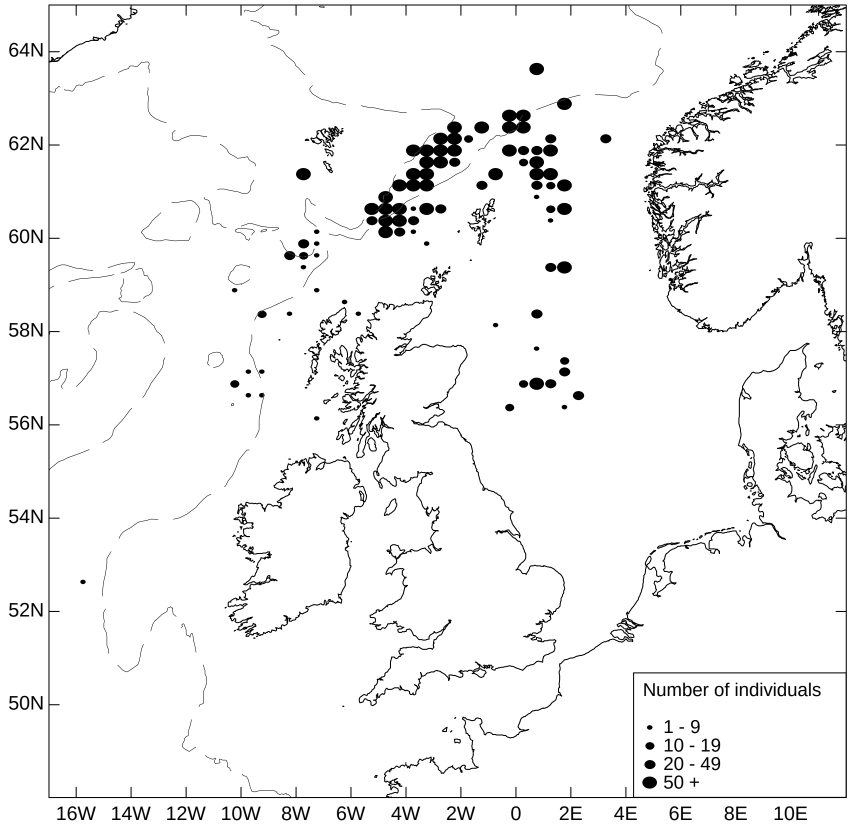

Figure 34 Distribution of white-sided dolphins seen from seismic survey vessels, 1998-2000.

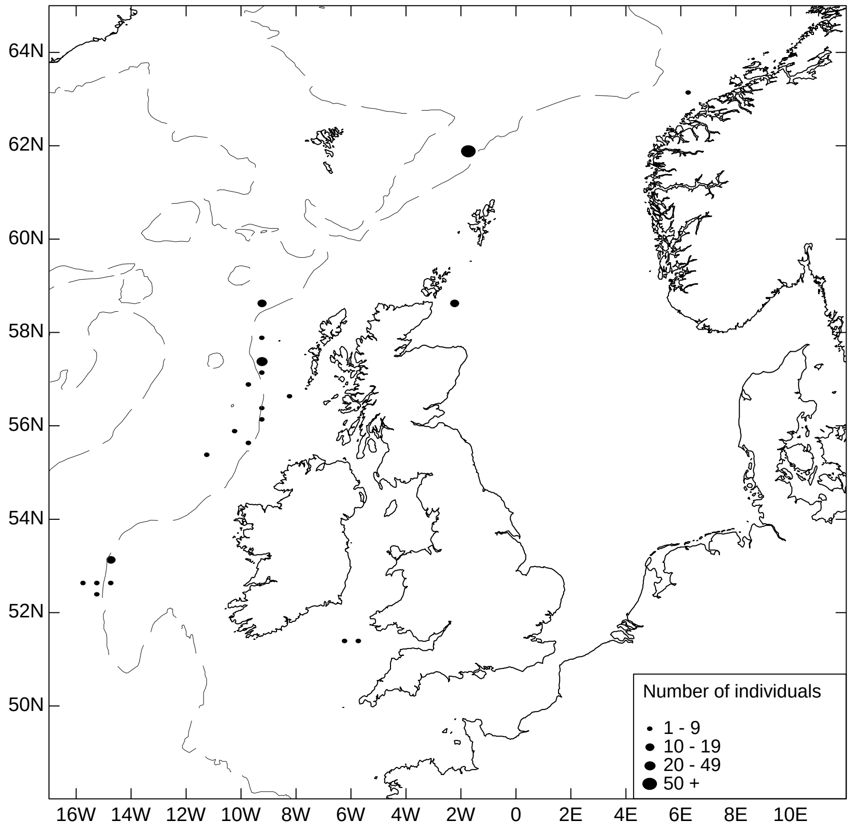

Figure 35 Distribution of common dolphins seen from seismic survey vessels, 1998-2000.

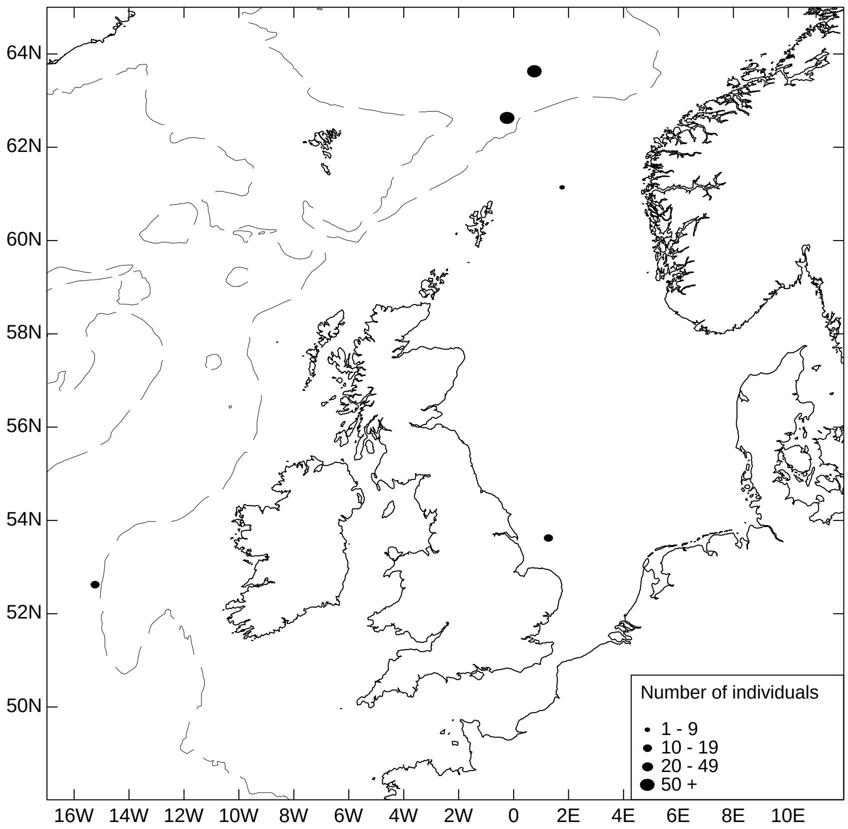

Figure 36 Distribution of striped dolphins seen from seismic survey vessels, 1998-2000.

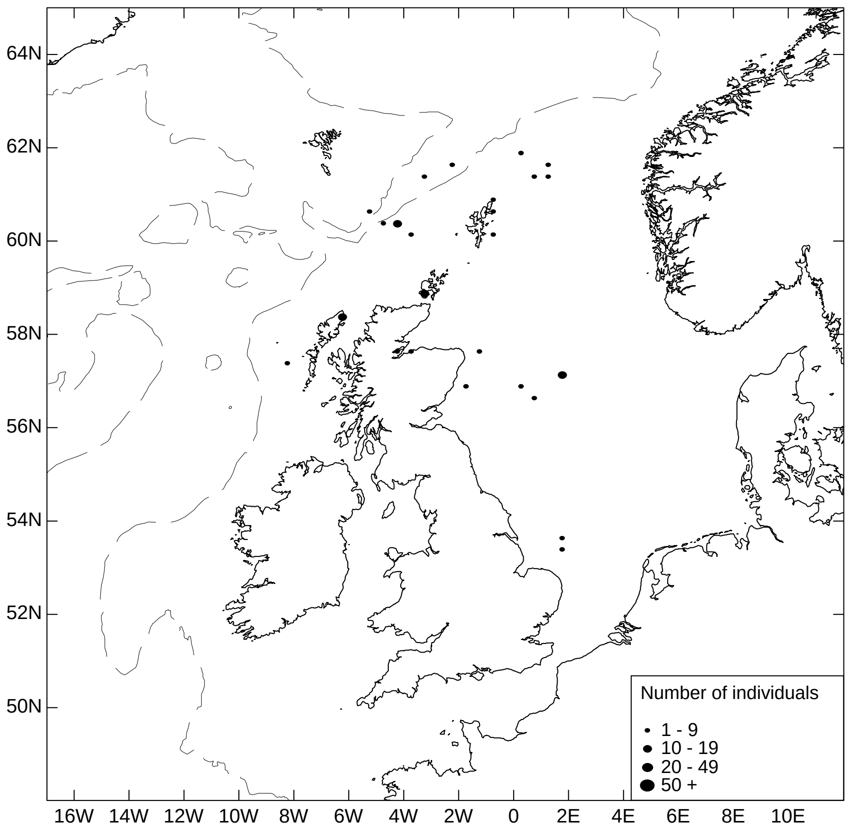

Figure 37 Distribution of harbour porpoises seen from seismic survey vessels, 1998-2000.

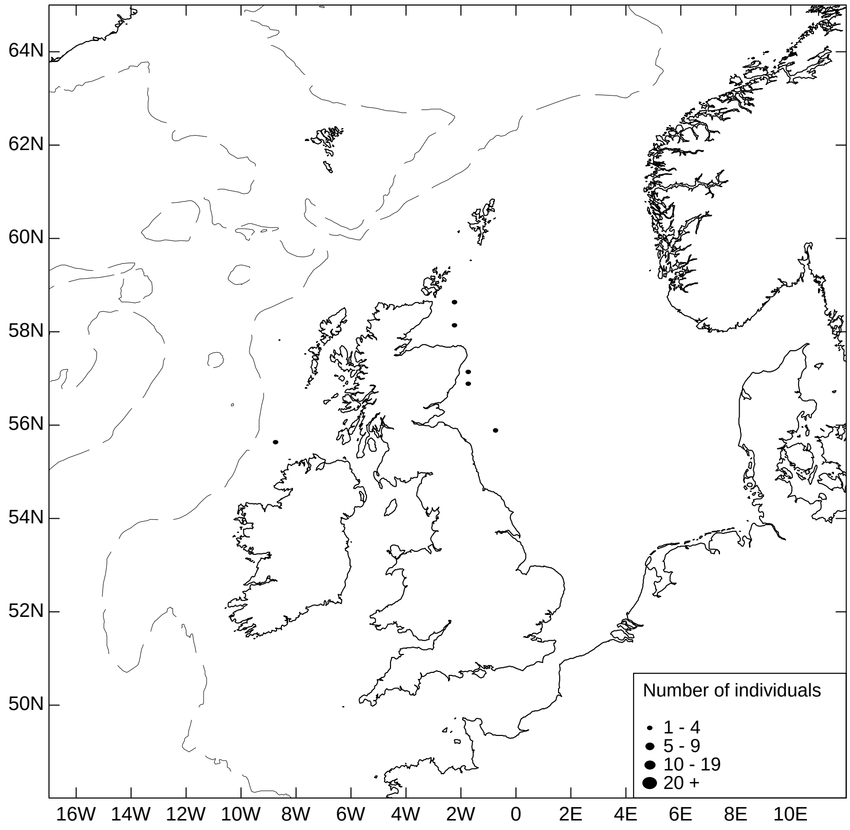

Figure 38 Distribution of unidentified seals seen from seismic survey vessels, 1998-2000.

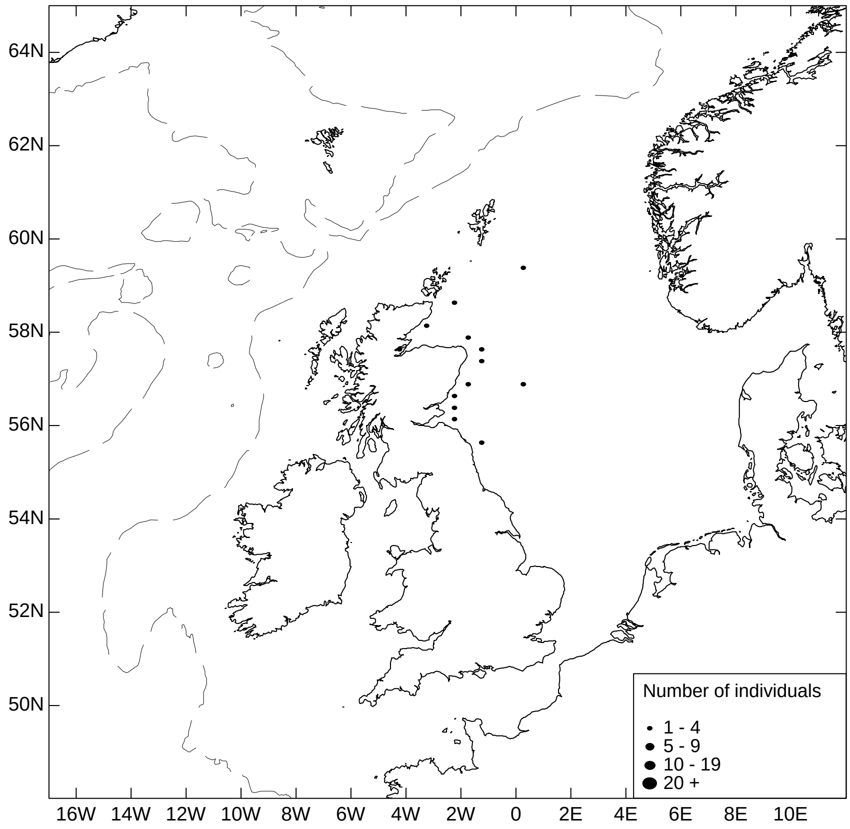

Figure 39 Distribution of grey seals seen from seismic survey vessels, 1998-2000.

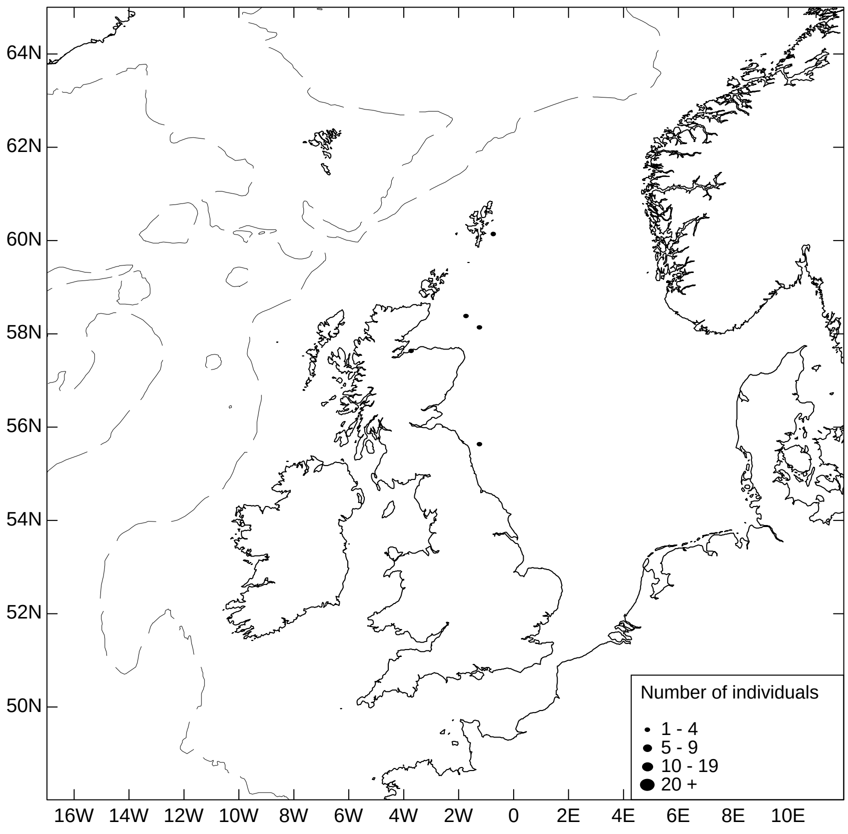

Figure 40 Distribution of common seals seen from seismic survey vessels, 1998-2000.

Appendix 2

GUIDELINES FOR MINIMISING ACOUSTIC DISTURBANCE TO MARINE MAMMALS FROM SEISMIC SURVEYS

April 1998 Version

These guidelines are aimed at minimising acoustic disturbance to marine mammals from seismic surveys and other operations where acoustic energy is released. Application of the guidelines is required under licence conditions in blocks licensed under the 16th and 17th rounds of offshore licensing. However, member companies of the UK Offshore Operators Association (UKOOA) and the International Association of Geophysical Contractors (IAGC) have indicated that they will comply with these guidelines in all areas of the UK Continental Shelf (UKCS) and in some cases elsewhere. The guidelines apply to all marine mammals, including seals, whales, dolphins and porpoises. All surveys using higher energy seismic sources (including site surveys as well as large scale seismic surveys) should comply with these guidelines.

Precautions to reduce the disturbance caused by seismic surveys

Seismic surveys at sea do not necessarily constitute a threat to marine mammals, if care is taken to avoid situations which could potentially harm the animals.

A. The Planning Stage

When a seismic survey is being planned, operators should:

- Contact the Joint Nature Conservation Committee (JNCC - see Further Information for address) to determine the likelihood that marine mammals will be encountered. In sensitive areas, the JNCC may request precautions in addition to those outlined below (for example, the special conditions attached to some oil and gas licences).

- In areas which are important for marine mammals (as indicated in consultation with the JNCC) operators should seek to provide the most appropriately qualified and experienced personnel to act as marine mammal observers on board the seismic survey vessel. If possible, such observers should be experienced cetacean biologists. As a minimum, it is recommended that observers should have attended an appropriate training course.

- If advised to do so by the JNCC, discuss the precautions which can be taken to reduce disturbance, and the design of any scientific studies with the Sea Mammal Research Unit (see Annex for address). In areas where marine mammals are abundant, properly conducted observation and recordings using qualified observers (see above) carried out before, during and after the seismic survey, can provide valuable information on its effect.

- Operators should plan surveys so that their timing will reduce the likelihood of encounters with marine mammals, although at present there is limited information on their distribution in some areas.

- Operators should seek to reduce and/or baffle unnecessary high frequency noise produced by air-guns or other acoustic energy sources.

B. During the Seismic Survey

When conducting a seismic survey, the following guidelines should be followed:

- LOOK AND LISTEN

  Beginning at least 30 minutes before commencement of any use of the seismic sources, the operator and observers should carefully make a visual check from a suitable high observation platform to see if there are any marine mammals within 500 metres, using the cues mentioned later in these guidelines to detect the presence of cetaceans. Hydrophones and other listening equipment may provide additional information on the presence of inconspicuous species, such as harbour porpoises, or submerged animals, and should be used whenever possible. This will be particularly appropriate in poor weather, when visual evidence of marine mammal presence cannot be obtained.

- DELAY

  If marine mammals are present, the start of the seismic sources should be delayed until they have moved away, allowing adequate time after the last sighting (at least 20 minutes) for the animals to move well out of range. Hydrophones may also be useful in determining when cetaceans have moved. In situations where seal(s) are congregating immediately around a platform, it is recommended that commencement of the seismic sources begins at least 500 m from the platform.

- THE SLOW BUILD UP

  Where equipment allows, power should be built up slowly from a low energy start-up (e.g. starting with the smallest air-gun in the array and gradually adding in others) over at least 20 minutes to give adequate time for marine mammals to leave the vicinity. There should be a soft start every time the air-guns are used, even if no marine mammals have been seen. The soft start may only be waived for surveys where the seismic sources always remain at low power levels e.g. some site surveys.

- KEEP IT LOW

  Throughout the survey, the lowest practicable power levels should be used.

C. Report after the survey

A report detailing marine mammals sighted (standard forms are available from JNCC), the methods used to detect them, problems encountered, and any other comments will help increase our knowledge and allow us to improve these guidelines. Reports should be sent to the JNCC (see Further Information for address). Reports should include the following information:

- Date and location of survey
- Number and volume of airguns used
- Nature of air-gun discharge frequency (in Hz), intensity (in dB re. 1µPa or bar metres) and firing interval (seconds), or details of other acoustic energy used
- Number and types of vessels involved in the survey
- A record of all occasions when the air-guns were used, including the watch beforehand and the duration of the soft-start (using standard forms)
- Details of any problems encountered during marine mammal detection procedures, or during the survey
- Marine mammal sightings (using standard forms)
- Details of watches made for marine mammals and the seismic activity during watches (using standard forms)
- Reports from any observers on board

Background to the guidelines

These guidelines reflect principles which could be used by anyone planning marine operations that could cause acoustic or physical disturbance to marine mammals. The recommendations contained in the guidelines should assist in ensuring that all marine mammals in areas of proposed seismic survey activity are protected against possible injury, and disturbance is minimised.

The guidelines were originally prepared by a Working Group convened at the request of the Department of the Environment, developed from a draft prepared by the Sea Mammal Research Unit. The guidelines have been reviewed twice by the Joint Nature Conservation Committee following consultation with interested parties and in the light of experience after their use since 1995.

Please note: As these guidelines are concerned with reducing risks to marine mammals, all other notifications should be given as normal.

Existing protection

Section 9 of the Wildlife and Countryside Act 1981 prohibits deliberate killing, injuring or disturbance of any cetacean (equivalent in Northern Ireland is Article 10 of the Wildlife (Northern Ireland) Order 1985). This reflects the requirements of the Convention on the Conservation of European Wildlife and Habitats (the Bern Convention) and Article 12 of the EC Habitats and

Species Directive (92/43/EEC), implemented by The Conservation (Natural Habitats, etc.) Regulations 1994 and The Conservation (Natural Habitats, etc.) Regulations Northern Ireland 1995.

In addition, the UK is a signatory to the Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas and has applied its provisions in all UK waters. Amongst other actions required to conserve and manage populations of small cetaceans, the Agreement requires range states to "work towards....the prevention of ...disturbance, especially of an acoustic nature".

Marine mammal presence in UK waters

Records indicate there may be 22 species of cetacean either resident in, or passing through, UK waters. There are 9 regular visitors seen in coastal waters, the most common species of which are harbour porpoise, white-beaked dolphin, bottlenose dolphin and common dolphin; the most common seen in deeper offshore seas are the long-finned pilot whale, common dolphin, harbour porpoise and killer whale. Northern right whales are very rare - they are an endangered species, having been hunted very close to extinction.

There are two species of seal which are resident in UK waters, the common or harbour seal and the grey seal. Both species breed in the UK, with common seals pupping in June/ July, and grey seals pupping from September to December, the exact timing depending on their location. Seals may be particularly vulnerable to disturbance during the pupping season. Other species, such as the hooded seal, may occasionally be seen in waters to the north of the UK.

Cues for detecting the presence of cetaceans

Even when quite close to vessels, cetaceans are often difficult to detect. The following points should help in ensuring that an adequate search has been made.

- Seismic operators should allow adequate time (at least 30 minutes) for sightings to be made prior to commencement of any use of the seismic sources

- The ease of detecting cetaceans declines with increasing sea state, so care should be taken to ensure an adequate search has been made in the prevailing conditions.

- Searches should be made from a high vantage point with a clear all-round view, e.g. the bridge roof or crow's nest. If necessary use two or more vantage points to give an all-round view.

- The sea should first be scanned slowly with the naked eye and then scanned slowly with binoculars.

- Hydrophones are a useful aid to detecting cetaceans. Cetaceans communicate with each other using whistles, creaks, chirps and moans which may be heard over considerable distances. Trains of clicks are used for echolocation and while foraging. They may be heard with a hydrophone at distances of several kilometres. In areas which are known to be frequented by small cetaceans, any hydrophones used should be capable of receiving the high frequency sounds used by these animals.

- Submerged cetaceans are much more at risk than those on the surface. This makes it particularly important to use a hydrophone whenever possible to detect vocally active animals that may be invisible from the surface.

- Dolphins and porpoises generally surface 2-3 times per minute in order to breathe. Dive times and surfacing behaviour are more erratic when they are feeding, but most dives are unlikely to exceed 5 minutes. Large whales surface less often and may remain submerged for some time.

- Splashes may be a cue to the presence of cetaceans, although in seas rougher than sea state 2 cetacean splashes may be difficult to detect and distinguish from wave splashes.

- Blows of large whales may be more obvious, but still may be difficult to detect in strong winds.

- Some species may be attracted to boats from some distance away, probably by engine noise. They may accompany a vessel for a considerable period and even bowride if it is fast-moving. If possible, look over the bow of the ship to check for cetaceans close in to the ship which may be hidden from view from the normal vantage points. The arrays of hydrophones which are towed by survey vessels may also be attractive to dolphins.

- Feeding seabirds can sometimes be evidence of the presence of cetaceans. Species which are likely to associate with cetaceans include gannets, kittiwakes and Manx shearwaters, although any flock of birds should be checked for the possible presence of cetaceans.

- An oily slick at the sea surface may signify the presence of cetaceans. These slicks may also be attractive to birds such as fulmars and storm petrels.

Cetaceans are capable of brief swimming speeds of 30 knots (34 mph), and sustained movement at 8 knots (10 mph), although some may swim at much slower speeds. If disturbed, they may alter their heading rapidly.

Seismic surveys

Modern large-scale surveys are conducted using towed arrays of "air-guns" - cylinders of compressed air. Each cylinder contains a small volume (typically between 10 and 100 cubic inches) at a pressure of about 2000 psi. The array, typically containing some tens of such cylinders, is discharged simultaneously, to generate a pressure pulse which travels downwards into the sea bed. Some of this acoustic energy is emitted into the wider marine environment; however, the designers of air-gun arrays seek to maximise the transmission of energy into the sea bed, with the result that the energy dissipated into the wider environment is reduced. As a survey proceeds, the air-gun array is recharged with air from a compressor on board the towing vessel. The process is repeated at intervals of approximately ten seconds - the timing dependent on the objectives of the survey.

Potential effects of acoustic disturbance on cetaceans

The most prevalent form of acoustic disturbance in UK waters is probably the noise generated by boats; however, the noise caused by boat traffic is so widespread that many cetacean populations may have become used to it, although this does not necessarily mean that the animals are unaffected. The limited research on the effects of disturbance due to the passage of vessels shows there is some evidence that cetaceans will avoid approaching ships and alter migration routes in response to marine traffic.

Effects of seismic surveys

The extent to which seismic disturbance from airguns affects cetaceans is not well known for all species, since only a limited amount of research has been done (see Annex for further details). Most published research relates to the effect on large whales (particularly bowhead whales) of older air-gun arrays, which were different from those currently in use.

Seismic air-guns are designed to produce low frequency noise, generally below 200 Hz, used to build up a picture of the seabed and the underlying strata. However, recent research has shown that high frequency noise is also produced (Goold 1996a). Low frequency noise is more likely to disturb baleen whales than toothed dolphins; baleen whales communicate at frequencies mostly below 3 kHz, which are likely to overlap with the dominant frequencies used by seismic air-guns. The sensitivity of toothed dolphins to sound falls sharply below 1 kHz, and sounds below 0.2 kHz are probably inaudible to them. The sounds used by dolphins for communication are often above 4.8 kHz, and echolocation sounds can occur up to 200 kHz. Goold (1996a) found significant levels of energy across the recorded bandwidth up to 22 kHz. This high frequency noise, incidental to seismic operations, will overlap with the frequencies used by toothed dolphins, and could potentially cause disturbance. There is some evidence of disturbance of dolphins by seismic activity (Goold 1996b, Stone 1997, 1998).

Seismic activity could have a number of different effects on small cetaceans: it may interfere with communication or alter behaviour. In the worst case, there is some risk of physical damage in the immediate vicinity of air-guns. There is no evidence to suggest that injury has occurred to any cetacean in UK waters as a result of seismic activity, although such injuries may be difficult to detect. Seismic surveys may have indirect effects on local cetacean populations because of changes they may cause in the distribution of prey species.

The risk to cetaceans is increased by their natural inquisitiveness, and the fact that they may be attracted to areas of human activity where seismic surveying is about to take place.

Further information and comments on these guidelines

If you have any comments or questions on these guidelines, or suggestions on how they may be improved, please contact:

Mark Tasker
Joint Nature Conservation Committee
Dunnet House
7, Thistle Place
ABERDEEN
AB10 1UZ

Telephone 01224 655701
Fax 01224 621488
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ANNEX

CONTACT NAMES AND ADDRESSES

Trevor Salmon
Department of the Environment
European Wildlife Division (TG 9/02)
Tollgate House
Houlton Street
BRISTOL
BS2 9DJ

Telephone 0117 987 8854
Fax 0117 987 8642

(And, if requested to contact the Sea Mammal Research Unit)

Prof. John Harwood
Sea Mammal Research Unit
Gatty Marine Laboratory
University of St Andrews
St. Andrews
FIFE
KY16 8LB

Telephone 01334 462630
Fax 01334 462632

FURTHER INFORMATION

Davis *et al.* 1990. *State of the Arctic Environment, Report on Underwater Noise.* Prepared by LGL Ltd, PO Box 280, King City, Ontario, Canada L0G 1K0. Prepared for the Finnish Initiative on Underwater Noise. Provides a useful summary of the available scientific information of the possible effects of acoustic disturbance on cetaceans.

Environmental Guidelines for Exploration Operations in Nearshore and Sensitive Areas, published by the UK Offshore Operators Association, 3 Hans Crescent, London SW1X 0LN.

Evans, P.G.H. & Nice, H. 1996. *Review of the effects of underwater sound generated by seismic surveys on cetaceans.* Report to UKOOA, Sea Watch Foundation, Oxford.

Goold, J.C. 1996a. Broadband characteristics and propagation of air gun acoustic emissions in the southern Irish Sea. *(in press).*

Goold, J.C. 1996b. Acoustic assessment of populations of common dolphin *Delphinus delphis* in conjunction with seismic surveying *Journal of the Marine Biological Association 76:* 811-820.

Moscrop, A. & Simmonds, M. 1994. *The threats posed by noise pollution and other disturbances to the health and integrity of cetacean populations around the UK.* A report for the Whale and Dolphin Conservation Society, pp. 1-8. (Includes a review of work on acoustic disturbance of cetaceans). Available from the Whale and Dolphin Conservation Society, Alexander House, James Street West, Bath, Avon, BA1 2BT.

Richardson, W.J., Fraker, M.A., Würsig, B. & Wells, R. 1985. Behaviour of bowhead whales *Balaena mysticetus* summering in the Beaufort Sea: reactions to industrial activities. *Biological Conservation 32:* 195-230.

Richardson, W.J., Greene, C.R. Jr., Malme, C.I. & Thomson, D.H. 1995. *Marine mammals and noise.* Academic Press, San Diego.

Stone, C.J. 1997. Cetacean observations during seismic surveys in 1996. *JNCC Reports, No. 228.*

Stone, C.J. 1998. Cetacean observations during seismic surveys in 1997. *JNCC Reports, No. 278.*

Turnpenny, A.W.H. & Nedwell, J.R. 1994. *The Effects on Marine Fish, Diving Mammals and Birds of Underwater Sound Generated by Seismic Surveys.* Fawley Aquatic Research Laboratories Ltd, Fawley, Southampton SO45 1TW. (This includes an extensive further bibliography). Available from United Kingdom Offshore Operators Association, 3 Hans Crescent, London, SW1X 0LN.

USEFUL CETACEAN IDENTIFICATION GUIDES:

Cawardine, M. 1995. *Eyewitness handbooks - Whales, dolphins and porpoises.* Dorling Kindersley. ISBN 0-7513-1030-1. Price £14.99. Available from bookshops.

Evans, P.G.H. 1995. *Guide to the identification of whales, dolphins and porpoises in European seas.* Sea Watch Foundation Publication, Oxford. Available from Sea Watch Foundation, Unit 29, Southwater Industrial Estate, Station Road, Southwater, West Sussex RH13 7UD. Price £5.00 + 50p p&p.

Leatherwood, S. & Reeves, R.R. 1983. *The Sierra Club handbook of whales and dolphins.* Sierra Club Books, San Francisco. ISBN 0-87156-341-X (hardback) ISBN 0-87156-340-1 (paperback). Available from some bookshops.

Sea Watch Foundation / BBC Wildlife 1994. *Identification guide to whales and dolphins of the British Isles.* Laminated wall chart available from Sea Watch Foundation Publication, Oxford. Available from Sea Watch Foundation, Unit 29, Southwater Industrial Estate, Station Road, Southwater, West Sussex RH13 7UD. Price £2.95 + £1.00 p&p.

To Statutory Nature Conservation Agencies, Department of Trade and Industry, Seismic Contractors, Oil Companies, Marine Mammal Observers, International Association of Geophysical Contractors, United Kingdom Offshore Operators Association.

GUIDANCE NOTE ON THE IMPLEMENTATION OF THE GUIDELINES FOR MINIMISING ACOUSTIC DISTURBANCE TO MARINE MAMMALS FROM SEISMIC SURVEYS

March 2000

The aim of this note is threefold; to clarify our position with respect to the use of Marine Mammal Observers; to respond to queries raised in relation to the application of the 'Guidelines for Minimising Acoustic Disturbance to Marine Mammals from Seismic Surveys' and to provide an update on the JNCC marine mammal web pages. The information below is complimentary to the Guidelines and should be used in conjunction with them. On points of detail it will provide supplementary Guidance.

Use of dedicated Marine Mammal Observers (MMOs) during seismic surveys.

This note has been produced ahead of the main period of United Kingdom Continental Shelf (UKCS) seismic activity in order to inform companies of the JNCC position with regard to the use of dedicated MMOs during seismic surveys. The JNCC will continue to look at PON 14 applications and assess the need for MMOs on a case by case basis, however this note is intended to provide advance notice of the advice the JNCC is likely to give. It is intended that this will enable companies to better plan the financial and logistical requirements that surveys will likely require and assist those companies supplying MMOs to better predict demand.

JNCC advise that MMOs be used in areas where cetacean sensitivities are sufficiently high to merit it. This varies temporally and geographically and also reflects the varying sensitivity of individual species to seismic sources and their conservation status. We advise that a prerequisite for MMOs is to have attended a short course. We are able to supply details of those carrying out these courses. This basic requirement is adequate for areas of moderate sensitivity where an MMO is requested. For more sensitive areas a suitably qualified and experienced cetacean biologist must be used. Cetacean biologists must have also attended an MMO training course.

In northerly latitudes daylight hours during the spring and summer months are long. Under these circumstances it is not practical to expect a single MMO to collect high quality data for all daylight hours. **Therefore all surveys requiring MMOs taking place between 1 April and 1 November north of 57^0 latitude will be required to use two MMOs.** Where this is in a sensitive area two trained cetacean biologists will be required. We do not anticipate there will normally be exceptions to this. The use of a second crewmember with other onboard responsibilities is not considered an adequate substitute.

Companies should be aware that the use of an MMO does not in itself waive licence conditions.

A summary of the likely requirements of the major UK sea areas where seismic surveying is currently conducted and their MMO requirements is given below.

i. Southern North Sea

Cetacean sensitivities are generally low to moderate. An MMO is usually not required. However, JNCC request that a watch be kept for marine mammals and a report containing location, effort and sightings forms be submitted

ii. Central and Northern North Sea

Cetacean sensitivities are highly variable and it is not possible to generalise. Some surveys will require an MMO, others will not. MMOs who are experienced, trained cetacean biologists will not normally be required but this is not invariably the case, particularly in northern latitudes. Also see below.

iii. Moray Firth

Cetacean sensitivities are high. Any seismic operation (including site surveys) conducted in the Moray Firth will require experienced, trained cetacean biologists.

iv. North and west of Shetland, west of the Hebrides

Cetacean sensitivities are high. Any seismic operation (including site surveys) will require experienced, trained cetacean biologists.

v. Irish Sea Basin

Cetacean sensitivities are generally low to moderate. An MMO is not always required. However, JNCC request that a watch is kept for marine mammals and a report containing location, effort and sightings forms is submitted. An exception to this is St George's Channel and the area off Cardigan Bay, which is of high sensitivity.

Companies proposing a survey outwith the above areas should consult JNCC as a matter of course. For any survey in a sensitive area we advise early consultation. Advice is provided on the basis of our current understanding of cetacean distribution and is subject to change in the light of new research.

Feedback to issues raised by MMOs and Companies

We would like to extend our thanks to MMOs and Companies that have been active in providing feedback to JNCC on issues arising from the implementation of the ‘Guidelines for Minimising acoustic Disturbance to marine mammals from Seismic Surveys’. We are grateful for your comments and would encourage more comments in future. We are not formally reviewing the Guidelines this year, but may do at the end of the 2000 season: this review will take account of these points.

i. Soft starts for ‘timeshare’ situations and for site surveys

In ‘timeshare’ situations and for site surveys the necessity for a soft start of the full 20 minutes duration has been questioned. We consider that in both situations the soft start should be for a minimum of 20 minutes as for all other surveys. The only exception to this is for a minority of site surveys where a waver has been agreed with the JNCC prior to the start of the survey.

ii. Continual shooting between lines

The practice of continuing to shoot whilst turning between lines is not encouraged. Firing should stop at the end of the line.

iii. Test firing of guns

The whole array should not be fired without a full soft start. Wherever possible, a gradual increase in capacity should be used, regardless of whether the test is at full capacity or not. In daylight hours where any seismic source, regardless of capacity is being test fired there needs to be a pre-firing scan as per the Guidelines. The MMO, if present, must be given advance warning.

iv. Redesign of JNCC reporting forms

We have received several comments suggesting improvements to the JNCC recording forms. We accept that they are not ideal but do not currently have the resources to update them. We would encourage suggestions on how best to improve them and intend to update them for the 2001 season. In the interim we request that reports be submitted on JNCC forms to prevent difficulties when performing analysis.

v. Gun use at night

We would advise that there is provision for the systematic recording of gun use during the hours of darkness when the MMO is not on duty. These records should be made available to the MMO.

vi. Use of hydrophones

Substantial progress has been made in the development of this detection technique and we anticipate that hydrophone use will increase when the technology becomes commercially available.

vii. Problems encountered implementing the Guidelines at sea.

The JNCC is willing to respond to queries where difficulties are encountered at sea.. Please contact the undersigned.

JNCC Website

We are currently developing marine mammal pages for the JNCC website. This project has been delayed due to lack of resources and the redesign of the entire site. We hope to run pages that present interesting information and images on marine mammals and provide a forum for feedback from MMOs and other interested parties. In the meantime please address any queries to the undersigned. The JNCC website may be viewed at www.jncc.gov.uk.

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Appendix 3

MARINE MAMMAL RECORDING FORM - RECORD OF OPERATIONS

Ship .... Client .... Contractor ....

Complete this form every time the airguns are used, whether for shooting a line or for testing or for any other purpose. Times should be in GMT.

Date	Who carried out a search for marine mammals? (Job title)	Time when pre-shooting search for marine mammals began	Time when search for marine mammals ended	Were hydro-phones used?	Were marine mammals seen before the airguns began firing?	Time when marine mammals were last seen	Was there any reason why marine mammals may not have been seen? (e.g. swell, fog, etc.)	If marine mammals were present, what action was taken? (e.g. delay shooting)	Time when soft start began	Time when airguns reached full power	Time when airguns stopped

Please return to JNCC, Dunnet House, 7 Thistle Place, Aberdeen, AB10 1UZ (fax. 01224 621488; e-mail seismic@jncc.gov.uk).

MARINE MAMMAL RECORDING FORM - LOCATION AND EFFORT DATA

Ship .... Ship type (seismic/guard etc.) ....

Observer(s) .... Survey type (site, 2D, 3D etc.) ....

Please record the following information every day, regardless of whether marine mammals are seen or not.

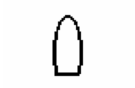
Date	Block number	Number of daylight hours during which a watch for marine mammals was kept	Length of time seismic guns were shooting during the watch	Wind force (Beaufort) and direction	Sea state Choose from: G = glassy S = slight C = choppy R = rough	Swell Choose from: O = low M = medium L = large	Visibility Choose from: P = poor M = moderate G = good

Return to: JNCC, Dunnet House, 7 Thistle Place, Aberdeen, AB10 1UZ (fax. 01224 621488; e-mail seimsic@jncc.gov.uk).

MARINE MAMMAL RECORDING FORM - RECORD OF SIGHTING

Options in italics should be circled or underlined as appropriate

<table>
<tr><td colspan="2">Date</td><td colspan="2">Time (GMT)</td></tr>
<tr><td colspan="4">How did this sighting occur? (please tick box)
While you were keeping a continuous watch for marine mammals □
Spotted incidentally by you or someone else □
Other (please specify) □</td></tr>
<tr><td colspan="2">Ship</td><td colspan="2">Observer</td></tr>
<tr><td colspan="3">Ship's position (latitude and longitude)</td><td>Water depth (metres)</td></tr>
<tr><td colspan="2">Species</td><td colspan="2">Certainty of identification
Definite / probable / possible</td></tr>
<tr><td colspan="2">Total number</td><td colspan="2">Number of adults

Number of juveniles</td></tr>
<tr><td colspan="3" rowspan="2">Description (include features such as overall size; shape of head; colour and pattern; size, shape and position of dorsal fin; height, direction and shape of blow)</td><td>Photograph or video taken
Yes / No</td></tr>
<tr><td>Direction of travel of animals in relation to ship (draw arrow)
</td></tr>
<tr><td colspan="3">Behaviour</td><td>Direction of travel of animals (compass points)</td></tr>
<tr><td>Activity of ship</td><td colspan="2">Airguns firing

Yes / No</td><td>Closest distance of animals from airguns (metres)
(Record even if not firing)</td></tr>
</table>

Please continue overleaf or on a separate sheet if necessary

Return to: JNCC, Dunnet House, 7 Thistle Place, Aberdeen, AB10 1UZ
(fax. 01224 621488; e-mail seismic@jncc.gov.uk).

Appendix 4

MARINE MAMMAL RECORDING FORM - RECORD OF OPERATIONS

Ship ....…… Client ....….. Seismic Contractor .... JNCC SS ref. no. ....

Complete this form every time the airguns are used, including overnight, whether for shooting a line or for testing or for any other purpose.

Times should be in GMT.

Date	Airgun activity			Pre-shooting search					Action necessary		
	Time when soft start began	Time when airguns reached full power	Time when airguns stopped	Who carried out a search for marine mammals? (Job title)	Time when pre-shooting search for marine mammals began	Time when search for marine mammals ended	Was there any reason why marine mammals may not have been seen? (e.g. dark, fog, swell, etc.)	Were hydro-phones used?	Were marine mammals present in the 30 minutes before the airguns began firing?	If yes, give time when marine mammals were last seen	If marine mammals were present, what action was taken? (e.g. delay shooting)

Please return to JNCC, Dunnet House, 7 Thistle Place, Aberdeen, AB10 1UZ (fax. 01224 621488; e-mail seismic@jncc.gov.uk).

MARINE MAMMAL RECORDING FORM - LOCATION AND EFFORT DATA

Ship .... Ship type (seismic/guard etc.) .... Survey type (site, 2D, 3D, 4C etc.) …..........… JNCC SS ref. no. ....

Please record the following information every day (as many lines per day as you wish), even if no marine mammals are seen.

Date	Observer	Time you started looking for marine mammals (GMT)	Time you stopped looking for marine mammals (GMT)	Duration of watch for marine mammals (hrs & mins)	Length of time airguns were shooting while you were looking for marine mammals (hrs & mins)	Blocks transited while looking for marine mammals (or start and end position if blocks not known)	Wind force and direction (use Beaufort scale)	Sea state Choose from: G = glassy (like mirror) S = slight (no or few white horses) C = choppy (many white horses) R = rough (large waves, foam crests, spray)	Swell Choose from: O = low (< 2 m) M = medium (2-4 m) L = large (> 4 m)	Visibility Choose from: P = poor (< 1 km) M = moderate (1-5 km) G = good (> 5 km)

Return to: JNCC, Dunnet House, 7 Thistle Place, Aberdeen, AB10 1UZ (fax. 01224 621488; e-mail seismic@jncc.gov.uk).

MARINE MAMMAL RECORDING FORM - RECORD OF SIGHTING

Options in italics should be circled or underlined as appropriate

Date	**Time** (GMT)	**JNCC SS ref. no.**	**Sighting no.**

How did this sighting occur? (please tick box)

- While you were keeping a continuous watch for marine mammals □
- Spotted incidentally by you or someone else □
- Other (please specify) □

Ship

Observer

Ship's position (latitude and longitude)

Water depth (metres)

Species

Certainty of identification
Definite / probable / possible

Total number

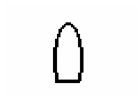
Number of adults

Number of juveniles

Description (include features such as overall size; shape of head; colour and pattern; size, shape and position of dorsal fin; height, direction and shape of blow)

Photograph or video taken
Yes / No

Direction of travel of animals in relation to ship (draw arrow)



Behaviour

Direction of travel of animals (compass points)

Activity of ship

Airguns firing (when animals first seen)
Yes / No / Soft-start

Closest distance of animals from airguns (metres)
(Record even if not firing)

Please continue overleaf or on a separate sheet if necessary

Return to: JNCC, Dunnet House, 7 Thistle Place, Aberdeen, AB10 1UZ
(fax. 01224 621488; e-mail seismic@jncc.gov.uk).

GUIDE TO USING MARINE MAMMAL RECORDING FORMS

Please read this before completing the marine mammal recording forms. If you are unclear about any aspect of using the recording forms, please seek advice from JNCC (contact details at end).

There are three forms to be completed:

1) Record of Operations - summary of seismic operations
2) Location and Effort Data - basic information on where you looked for marine mammals, how long you looked for, and what the weather conditions were
3) Record of Sighting - information on each sighting of marine mammals.

Each of the three forms is explained in more detail below. Even if you see no marine mammals during the entire survey Record of Operations and Location and Effort forms should be completed and returned to JNCC. These forms are designed so that you can provide, in a standard format, the minimum information that is needed. Please do not alter the forms, but do feel free to provide any additional information that you think would be of benefit.

Each form asks for a JNCC SS ref. no. (JNCC seismic survey reference number). This should be obtained from JNCC before the survey.

Record of Operations

This form asks for basic information on all uses of the airguns throughout the survey. JNCC will use this form to see how well your survey followed the *Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys*. You should complete one line on this form each time the airguns are used, whether for shooting a line, for testing, or for any other purpose (seismic crews do not routinely record test firing, so you will need to ask them to make a note of any times when they are testing the guns).

Airgun activity You should record all airgun activity at any time of day, including times when the airguns are firing overnight. You are asked to record the times of three key stages of airgun activity: a) when the soft-start began; b) when the airguns reached full power (this is not necessarily the same time as the start of line, as the airguns may reach full power before the start of line); and c) when they stopped firing. You should record this information for any uses of the guns, including testing - you may need to remind the seismic crew of the need for a soft-start when testing the guns. If the guns stop before reaching full power, put "No full power" (or "NFP") in the column headed "Time when the airguns reached full power" and record the time the airguns stopped as usual.

Pre-shooting search You are also asked to record the time you started looking for marine mammals before the airguns started firing (the pre-shooting search), and the time you stopped watching. You should record the times of all pre-shooting searches, but you do not have to provide details of other watches on this form (but include these if you are not sure whether they are relevant). A pre-shooting search should be carried out prior to all uses of the airguns during daylight hours (including test firing). You may leave the times of the pre-shooting search blank if you did not watch because it was dark, but the airgun activity should still be recorded. You are asked if there was any reason why marine mammals may have been missed (e.g. it was dark, or there was a large swell/ fog/ rough seas, etc.).

Action necessary You should record whether marine mammals were present in the 30 minutes prior to the airguns starting firing, and if they were, the time at which they were last seen. If they were present you will need to record what action was taken if necessary under the guidelines (e.g. delay shooting), or indicate a reason why no action was necessary (e.g. animals were more than 500 m away or were last seen more than 20 minutes before firing commenced).

Location and Effort Data

The Location and Effort form should be completed for every day of the survey, regardless of whether you actually see any marine mammals or not, and regardless of whether there is any seismic activity. You may fill in as many lines per day of this form as you wish.

This form includes basic information e.g. ship's name, survey type, date, observer's name, time of watch, duration of watch and duration of shooting, blocks transited and weather conditions during the watch. Further notes on some of these are given below.

Duration of watch You will need to record how long you spent looking for marine mammals, in hours and minutes. This should only include periods when you were actually concentrating on looking for marine mammals.

Length of time airguns were shooting while you were looking for marine mammals This information is important to assess the effects of seismic activity on marine mammal abundance. You should record how long the airguns were firing during each watch for marine mammals (not during a whole 24 hour period). The length of time the guns were shooting during the watch should include any uses of the guns (i.e. should include any run-in to a line, soft-start or test firing, as well as the time spent shooting a line). You must not include time spent firing when you were not watching for marine mammals (e.g. during hours of darkness).

Blocks transited while looking for marine mammals You should record the blocks passed through during each watch - block numbers are preferred, but if you are not sure of them you may give start and end positions in latitude and longitude instead (but please try to avoid giving just a prospect name in this column). You may find a map of quadrants and blocks somewhere on board the ship e.g. in the instrument room.

Weather conditions Weather conditions during the watch should also be recorded. Wind force should be on the Beaufort scale (1-12), e.g. W5. If you record it as speed in knots please make this clear, e.g. W 9 knots, so that JNCC can convert it to Beaufort later. Sea state should be classed as glassy (sea like a mirror, or small ripples), slight (small wavelets with no or few white horses), choppy (small to moderate waves with frequent white horses) or rough (larger waves, extensive white foam crests, perhaps breaking, probably some spray). Those observers who are familiar with Beaufort sea states may record these if they wish, bearing in mind that the sea state at any given time may not correspond to the wind force at that time. Swell should be recorded as low (0-2 m), medium (2-4 m) or large (more than 4 m). Visibility should be recorded as poor, moderate or good (poor = less than 1 km [½ mile]; moderate = 1-5 km [½-3 miles]; good = more than 5 km [3 miles]).

Record of Sighting

The sighting form need only be filled in when you see marine mammals. Most of the details you are asked to record are self-explanatory, but notes on some items are given below for clarification.

Time There is sufficient space in this box to put both a start and end time of the sighting if the animals are present for some time.

JNCC SS ref. no. This should be the same reference number as on the Record of Operations and Location and Effort forms, and should be obtained from JNCC prior to the survey commencing.

Sighting no. Use numbers in sequence, starting at 1 for the first sighting of the survey. Where more than one species occur together, these should be recorded together on the same form or on separate forms sharing the same sighting number.

How did this sighting occur You should indicate whether you spotted the marine mammals while you were keeping a continuous lookout. Sometimes someone else may call your attention to a marine mammal that you would otherwise not have seen, in which case you should tick the second box (spotted incidentally) - JNCC need to know this to make an accurate assessment of sighting rate.

Position This is the ship's position at the time of the sighting (please remember to include whether you are east or west of the Greenwich meridian). There is sufficient space in this box to enter a start and end position if the animals are around for some time.

Depth This is the depth of water at the position given, in metres.

Species Identify marine mammals as far as possible - if you cannot identify it to species level then put down what you can. For example, if you know it's a whale not a dolphin, but you can't tell what sort of whale, put down "whale". Useful categories are "whale", "large whale", "medium whale", "small whale", "dolphin", "patterned dolphin", "unpatterned dolphin" or groups of species of similar appearance e.g. "blue/fin/sei whale", "white-beaked/white-sided dolphin", "common/white-sided dolphin" etc. It can also be useful to eliminate species that you know it definitely isn't e.g. "medium-sized whale but not killer whale".

Total number If it is difficult to tell exactly how many marine mammals there are this can be an estimate of the minimum and maximum number, e.g. 5 - 8.

Number of adults / Number of juveniles If it is difficult to tell how many of each age there are this can be an estimate of the minimum e.g. at least 3 adults, at least 2 juveniles.

Description It is essential to include a description of the animal, even if you are certain which species it is. The identity of sightings without descriptions, or with poor descriptions, will be downgraded. If you are certain which species it is, describe the characteristic features you used to identify it e.g. "hourglass pattern on flanks" for common dolphin. If you are uncertain, then the more details you give, the better. Some features to describe are suggested on the form. A rough sketch may be useful (e.g. of the shape of fin, or pattern of colour).

Photograph or video taken If you have the opportunity to photograph or video the animal this may be used later to help confirm identification. Any photographs or videos should be sent to JNCC, clearly labelled with the date of the survey, the ship's name, the survey operator and seismic contractor. Where possible, use cameras where date and time can be recorded on the film so that photographs/ video footage can be matched to the correct Record of Sighting form.

Direction of travel of animals The direction of travel should be given in two ways - in relation to the boat (draw an arrow on the diagram), and in points of the compass.

Behaviour If there is more than one sort of behaviour then record all behaviours seen. Examples of behaviour are:

- normal swimming
- fast swimming
- slow swimming
- porpoising
- breaching (animal launches itself out of the water and falls back in)
- tail-slapping (animal slaps tail on the water surface)
- sky-pointing/ spy-hopping (animal almost vertical in the sea with head pointing towards the sky)
- feeding
- resting
- avoiding the ship
- approaching the ship
- bow-riding
- or any other behaviour you see.

Activity of ship e.g. steaming, on standby, deploying streamers, shooting a line, soft-start, etc.

Airguns firing This is important information - even if you think it's obvious from the activity of the ship, please fill in whether the airguns were firing or not when the marine mammals were first seen. If the animals were first seen during the soft-start, circle this option. If airgun activity changes while the animals are still present, add a note to say this.

Closest distance of animals from airguns This should be filled in whether or not the airguns are firing when marine mammals are seen. If the airguns are not out, then use the closest distance to the ship or to the normal position of the airguns (but please say which you are using).

If you have any queries regarding the use of these forms, please contact the JNCC (address below).

Completed forms should be returned to:

Joint Nature Conservation Committee,
Seabirds and Cetaceans Team,
Dunnet House,
7 Thistle Place,
Aberdeen,
AB10 1UZ.

Tel.	01224 655704
Fax.	01224 621488
E-mail	seismic@jncc.gov.uk

Appendix 5

Scientific names of species mentioned in the text

Common seal	*Phoca vitulina*
Grey seal	*Halichoerus grypus*
Bowhead whale	*Balaena mysticetus*
Northern right whale	*Eubalaena glacialis*
Humpback whale	*Megaptera novaeangliae*
Blue whale	*Balaenoptera musculus*
Fin whale	*Balaenoptera physalus*
Sei whale	*Balaenoptera borealis*
Minke whale	*Balaenoptera acutorostrata*
Sperm whale	*Physeter macrocephalus*
Beaked whale spp.	*Mesoplodon/ Ziphius/ Hyperoodon* spp.
Northern bottlenose whale	*Hyperoodon ampullatus*
Sowerby's beaked whale	*Mesoplodon bidens*
Pilot whale	*Globicephala melas*
Killer whale	*Orcinus orca*
Risso's dolphin	*Grampus griseus*
Bottlenose dolphin	*Tursiops truncatus*
White-beaked dolphin	*Lagenorhynchus albirostris*
White-sided dolphin	*Lagenorhynchus acutus*
Common dolphin	*Delphinus delphis*
Striped dolphin	*Stenella coeruleoalba*
Harbour porpoise	*Phocoena phocoena*