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Cetacean observations during seismic surveys in 1997.

Carolyn J. Stone

April 1998

For further information please contact:
Joint Nature Conservation Committee
Dunnet House
7, Thistle Place
Aberdeen
AB10 1UZ

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Report Distribution

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Report title:	Cetacean observations during seismic surveys in 1997.
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Contents

1. Summary

1. Recording of cetaceans during 1997 operations in UK waters and some adjacent areas, in compliance with the *Guidelines for minimising acoustic disturbance to small cetaceans*, yielded a total of 730 sightings comprising 8,528 individuals.

2. The most frequently seen species were pilot whales, fin whales, sperm whales, white-sided dolphins, common dolphins, white-beaked dolphins and minke whales. Sightings peaked during July and August and were particularly concentrated in deep waters to the north-west of the UK.

3. After taking account of various factors such as geographical distribution, seasonal variations in sightings, weather conditions and the power output of the airguns, the sighting rate of pilot whales was found to be significantly higher while the airguns were firing during seismic surveys, while white-sided dolphins, white-beaked dolphins and all dolphin species combined were seen significantly less often during periods of shooting. Sighting rates of fin whales, fin/ sei whales, sperm whales and all large whales combined did not differ significantly between periods of shooting and not shooting.

4. Allowing for weather conditions at the time of sighting, white-sided dolphins, unidentified dolphins, minke whales and fin/ sei whales were found to be significantly further from the airguns when they were firing during seismic surveys than when they were not. Most other species were also further from the airguns during periods of shooting, but not significantly so. Although white-sided dolphins remained further from the airguns during periods of shooting, they were less far away if they were in association with pilot whales than if they were on their own.

5. There were some behavioural responses to seismic activity. Pilot whales and fin whales were more likely to swim at an increased speed during periods of shooting. Cetaceans altered course more often when the airguns were firing than when they were not firing. A significantly greater number of pods of pilot whales were seen to be heading away from the ship when the airguns were firing. Sperm whales dived more often during periods of shooting. Positive interactions of cetaceans with the survey vessel (bow-riding, swimming alongside the paravanes, following the vessel or approaching the vessel) were more frequent when the airguns were not firing, although some individuals were sufficiently tolerant of seismic activity to engage in positive interactions with the vessel while the airguns were firing.

6. There were indications that in deeper water the effects of seismic activity may be reduced. Relatively more cetaceans were seen during periods of shooting in deeper waters than during these periods in shallower waters.

7. Sample sizes from site surveys (small scale localised surveys, usually made prior to drilling) were small, therefore results from these surveys should be treated with particular caution. There were indications from site surveys that sighting rates of dolphins were higher when the airguns were not firing, while sighting rates of pilot whales and unidentified large whales were higher when the airguns were firing. However, sample sizes were too small to test the statistical significance of these results. No significant differences were found in the distance of cetaceans from the airguns between periods of shooting and not shooting.

8. The results presented here confirm many of the findings of previous analyses of data collected during seismic surveys. The only exception is that pilot whales have on some occasions previously been seen less frequently during periods of shooting, whereas in the present study the opposite situation was found.

9. Recommendations are made for minor revisions to the existing recording forms, and an additional form is proposed.

2. Introduction

As part of the UK's response to the Agreement on the Conservation of Small Cetaceans in the Baltic and North Seas (ASCOBANS), in February 1995 the then Department of the Environment issued the *Guidelines for minimising acoustic disturbance to small cetaceans*, which aimed to minimise disturbance to cetaceans from seismic surveys (a revised version of the guidelines is included in Appendix 1). The airguns used during seismic surveys generate sound that is mostly of low frequency, overlapping with the frequencies produced by baleen whales. These animals are therefore considered to be vulnerable to disturbance from seismic surveys (e.g. Moscrop & Simmonds 1994 and references therein). Although toothed whales and dolphins use higher frequency sound for communication and echolocation, there is some evidence that they may also be vulnerable to disturbance from seismic surveys (Goold 1996; Stone 1996, 1997a,b).

The guidelines were revised by the Joint Nature Conservation Committee (JNCC) in early 1996. Under the version of the guidelines which has been operative since 1996, operators are required to consult the Joint Nature Conservation Committee when planning seismic surveys in the UK and, if necessary, discuss precautions which can be taken to reduce disturbance. When conducting a survey, operators are required to check for the presence of cetaceans before starting a survey line, and delay the start of the survey by at least 20 minutes if cetaceans are within 500 m. Whenever possible, a soft-start procedure should be employed, gradually building up the airgun power over 20 minutes from a low energy starting level; in addition, the lowest practicable energy levels should be used throughout the survey. Operators are also required to send a report of the implementation of the guidelines to JNCC after the survey. Details of the time spent watching for cetaceans and any sightings that occurred are recorded by on-board observers using standard forms designed by JNCC (Appendix 2). The results of an analysis of the data recorded during 1997 are presented here.

3. Methods

Watches for cetaceans were carried out on seismic survey vessels throughout daylight hours on surveys conducted between February and December 1997 (there were no surveys in January). Details of the watch and any sightings were recorded on standard recording forms. Data from 58 surveys were forwarded to JNCC, covering 101 quadrants (Figure 1).

Observers were asked to provide descriptions of cetaceans sighted to support their identification. Where descriptions were missing or inadequate, or did not correspond with the identification given, then identifications were amended on the basis of the information available. This usually involved down-grading of identifications from a species to a group of similar species which the animal could have been, based on the description given. For example, if an observer identified a cetacean as a common dolphin, but the only description was of a "small animal with a sickle shaped fin", then this sighting would have been entered into the database as dolphin sp., i.e. an unidentified dolphin. In some cases cetaceans were filmed and the videos were forwarded to JNCC and used to confirm identification. In these cases, videos were viewed prior to examining the corresponding recording forms, to allow an independent assessment of identification without knowledge of what the observer believed the species to be. Where this independent assessment of identification differed considerably from the identification recorded by the observer, the videos were viewed again as a final check before amending the identification recorded by the observer.

Some of the analyses involved calculating numbers of sightings per unit effort (i.e. per 1,000 hours survey). For these analyses, only those sightings from surveys where effort was correctly recorded were used (72% of surveys). There were several potential sources of variation in sighting rate: 1) geographical variation in abundance of cetaceans; 2) seasonal variation in abundance of cetaceans; 3) the influence of weather on the ability to detect cetaceans. As the proportion of time spent shooting also varied according to location, time of year and weather conditions, it was important to take account of these potential sources of bias when assessing the effects of seismic (= airgun) activity. Therefore, for some aspects of the analysis, subsets of data from selected areas and months were used, and periods of poor weather were disregarded. Accordingly, each quadrant was assigned to one of seven broad areas (Figure 1). Weather conditions were recorded daily by observers, with sea state classed as glassy, slight, choppy or rough, and visibility categorised as poor, moderate or good.

Sample sizes were small for many species. The extraction of subsets of data to eliminate bias reduced sample sizes even further, so this was done only for the more frequently seen species. The non-parametric statistical tests employed were those appropriate for small sample sizes (Siegel & Castellan 1988). Maps were plotted using DMAP for Windows, and show the 1,000 m isobath. Species maps were drawn after summing the number of individuals of a species in each ¼ ICES square (15' latitude x 30' longitude).

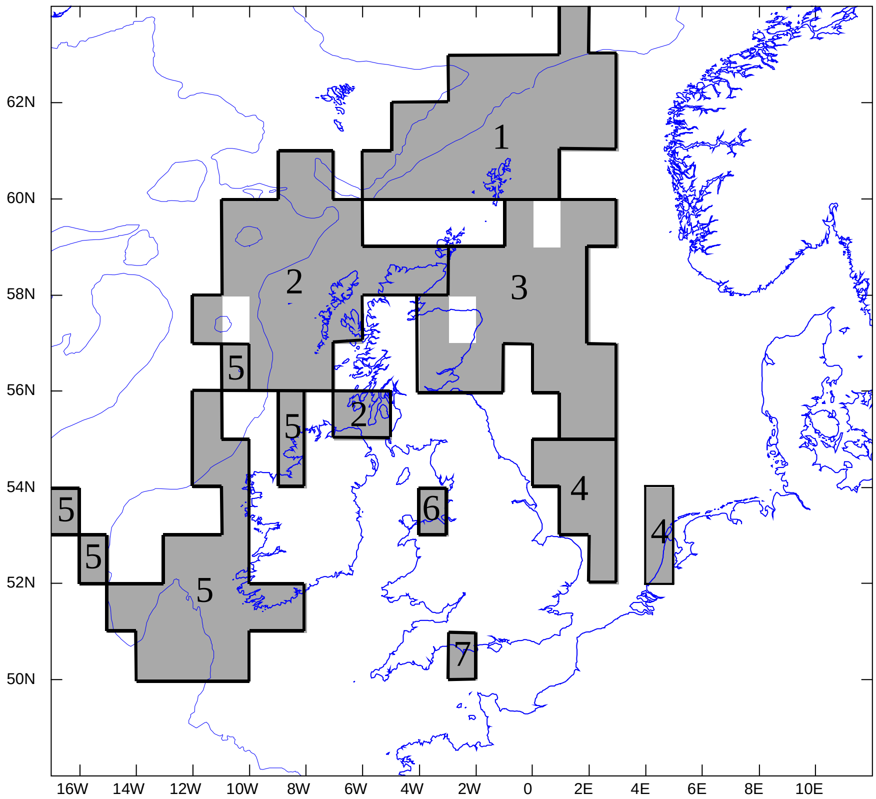

Figure 1 Quadrants surveyed for cetaceans from seismic survey vessels in 1997, and areas used in analysis: 1) West of Shetland; 2) Rockall; 3) Northern North Sea; 4) Southern North Sea; 5) West of Ireland; 6) Irish Sea; 7) English Channel.

4. An overview of cetacean sightings and survey effort

Cetaceans were sighted on 730 occasions during 1997, with a total of 8,528 individuals being seen. The most frequently seen species were pilot whales and fin whales, with reasonable numbers also of sperm whales, white-sided dolphins, common dolphins, white-beaked dolphins and minke whales (Table 1). 65% of sightings were identified to species level, and a further 17% were identified as being one of a pair or group of similar species. The larger whales tended to occur as individuals or small groups; the mean number of animals per pod was 2.00 for fin whales and 1.53 for sperm whales. Dolphins and pilot whales, while occasionally being seen singly or in pairs, were mostly seen in larger groups (mean pod size = 17.26 for pilot whales; mean pod size = 27.69 for white-sided dolphins). Sightings of cetaceans peaked during July and August (Figure 2).

"Location and Effort" recording forms were completed correctly for 42 of the 58 surveys, although five of these used earlier versions of the forms where details of weather conditions were not recorded. During these 42 surveys a total of 17,474 hrs 20 mins were spent watching for cetaceans, of which the airguns were firing for a total of 6,231 hrs 37 mins (36% of time on watch). During periods when the airguns were not firing the vessels were engaged in a variety of other 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. Nine of the 58 surveys from which reports were received were site surveys, during which a total of 1,456 hrs 30 mins were spent watching for cetaceans, with 293 hrs 26 mins spent shooting (20% of time on watch). The time spent watching peaked in August, although the proportion of time spent shooting peaked earlier in June and July (Figure 3). Most survey effort was concentrated to the West of Shetland and in the northern North Sea (Figure 4).

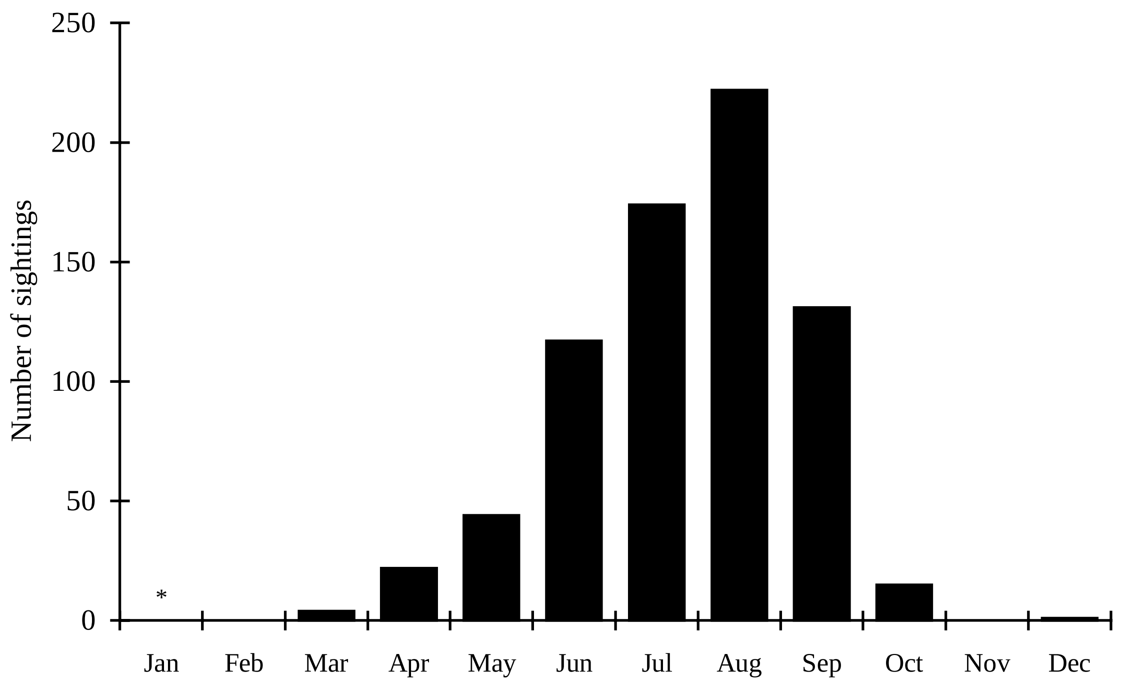

Figure 2 Number of cetacean sightings per month (* = no surveys).

Table 1 Summary of cetacean sightings from seismic surveys in 1997.

Species	No. sightings	No. individuals
Cetacean sp.	26 [i]	740
Whale sp.	24	50
Large whale sp.	41 [g,h]	96
Humpback whale	3	16
Blue whale	4	5
Fin whale	81 [c,i]	162
Sei whale	1	3
Sperm whale	57 [f]	87
Fin/ sei whale	44 [d]	96
Fin/ sei/ blue whale	1	1
Fin/ sei/ humpback whale	15	43
Fin/ sei/ blue/ humpback whale	3	4
Humpback/ sperm whale	3	3
Medium whale sp.	1	1
Minke whale	38	78
Northern bottlenose whale	2	7
Pilot whale	146 [a,b,c,d,e,f,g]	2,520
Killer whale	17	111
Dolphin sp.	83 [b,f]	1,127
Dolphin sp. not porpoise	1	3
Risso's dolphin	3	14
Bottlenose dolphin	10 [g]	176
White-beaked dolphin	38 [e]	805
White-sided dolphin	49 [a]	1,357
Lagenorhynchus sp.*	15 [g,h]	585
Common dolphin	40	372
Common/ white-sided dolphin	3	45
Patterned dolphin sp.	1	3
Harbour porpoise	5	18
Total	**730**	**8,528**

* *Lagenorhynchus* sp. = white-beaked or white-sided dolphin
a includes 8 sightings of pilot whales associated with white-sided dolphins
b includes 4 sightings of pilot whales associated with dolphin sp.
c includes 3 sightings of pilot whales associated with fin whales
d includes 2 sightings of pilot whales associated with fin/ sei whales
e includes 1 sighting of pilot whales associated with white-beaked dolphins
f includes 1 sighting of pilot whales associated with sperm whales and dolphin sp.
g includes 1 sighting of pilot whales associated with bottlenose dolphins, *Lagenorhynchus* sp. and large whale sp.
h includes 1 sighting of *Lagenorhynchus* sp. associated with large whale sp.
i includes 1 sighting of fin whales associated with cetacean sp.

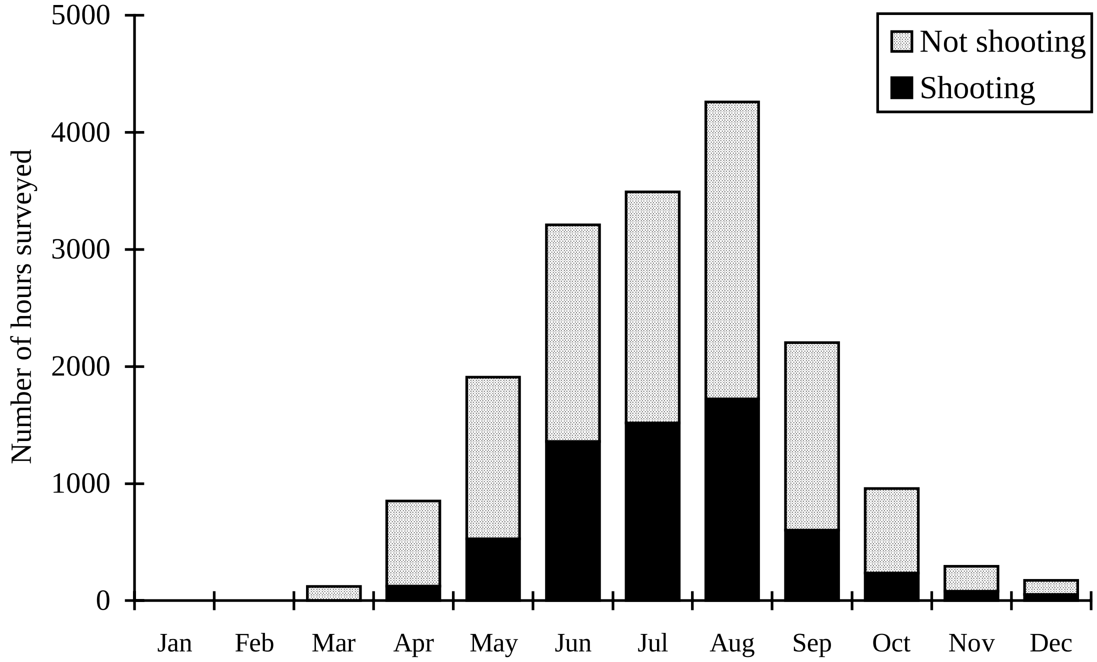

Figure 3 Length of time spent watching for cetaceans throughout 1997, and seismic activity during watches (only includes surveys where effort was correctly recorded).

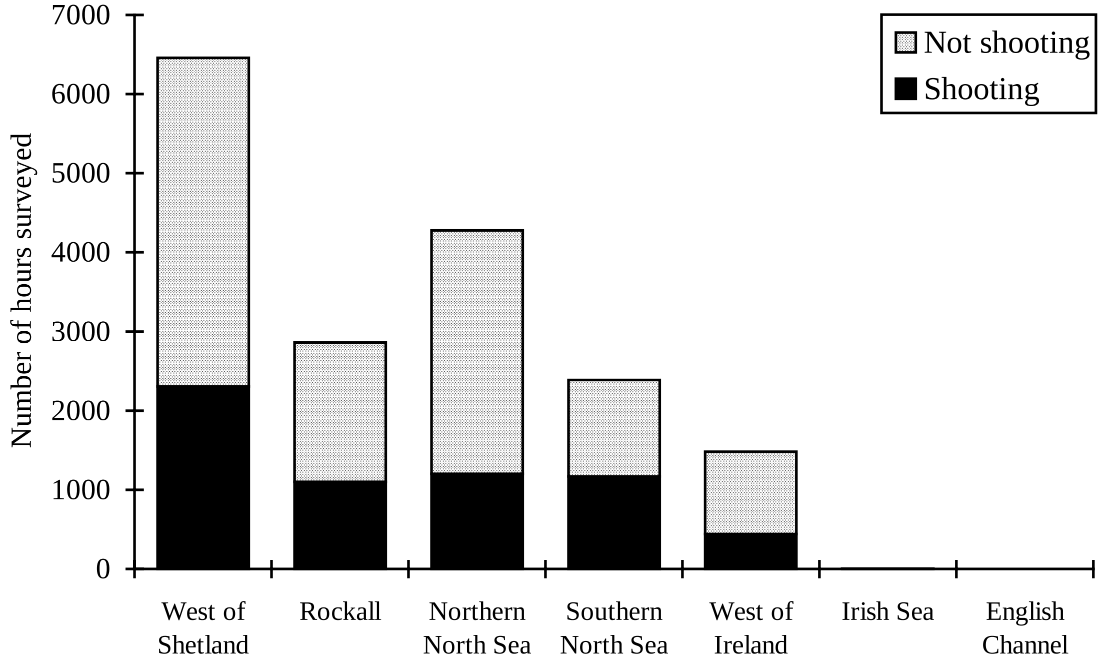

Figure 4 Length of time spent watching for cetaceans in each area, and seismic activity during watches (only includes surveys where effort was correctly recorded).

5. Distribution of cetaceans

The majority of cetacean sightings occurred along the 1,000 m isobath to the north-west of the UK, in a broad area encompassing waters from Rockall to the north of Shetland (Figure 5). Although most time was spent in the area West of Shetland, there were also sightings elsewhere, with small concentrations in the northern North Sea and to the west of Ireland. Species maps (Figures 6 - 22) showed that many species were seen exclusively in north-western waters, including fin whales, sei whales, humpback whales, blue whales, northern bottlenose whales and Risso's dolphins. All but one sighting of sperm whales also occurred in north-western waters, the exception being one individual seen in the northern North Sea in late August (Figure 11). Most fin and sperm whales were seen in waters of over 1,000 m depth (Figures 9 & 11).

Several other species were also seen mainly in north-western waters, including pilot whales, killer whales, white-sided dolphins and bottlenose dolphins. There was a large concentration of pilot whales in an area to the north-west of the Hebrides (Figure 14). Pilot whales also occurred to the north of Shetland and in low numbers to the west of Ireland. There was also a single sighting of pilot whales in the northern North Sea in April. Most white-sided dolphins were seen in deep waters to the north-west of the UK, but some were found over the continental shelf around the Hebrides and Shetland. Killer whales were seen mainly in waters north of 59ºN, although some were seen to the west of Ireland (Figure 15). Seven out of ten sightings of bottlenose dolphins during seismic surveys in 1997 occurred in waters over 1,000 m deep (Figure 18). There were only two inshore sightings of bottlenose dolphins, both occurring in the northern Minch.

Two species whose distribution did not centre on north-western waters were the white-beaked dolphin and the common dolphin. White-beaked dolphins were seen to the north of Shetland and in the North Sea, with some additional sightings in shelf waters close to the Hebrides (Figure 19). Common dolphins were seen mainly in deep waters to the west of Ireland and to the south-west of the Hebrides (Figure 21).

Some species had a more widespread distribution. Minke whales occurred in north-western waters, in the North Sea and to the west of Ireland, although most occurred to the north-west of Shetland (Figure 12). Harbour porpoises, although not seen very often, were seen in various locations. Although they were occasionally seen beyond the continental shelf edge, most sightings of harbour porpoises occurred in shelf waters (Figure 22).

Whilst the distribution of most species concurs to a large extent with previous knowledge of cetacean distribution, the distribution maps should not be interpreted as being representative of a species' range in UK waters. Although watches for cetaceans encompassed many quadrants (Figure 1), survey effort in these quadrants was unequal. As "Location and Effort" forms were not completed for all surveys, it was impossible to calculate the effort in each quadrant. From those surveys where effort was correctly recorded, indications were that more time was spent in the area West of Shetland than in any other area (Figure 4). Although the concentration of sightings in north-western waters reflects the importance of these waters for cetaceans, it is also likely to be partly due to greater survey effort in these areas.

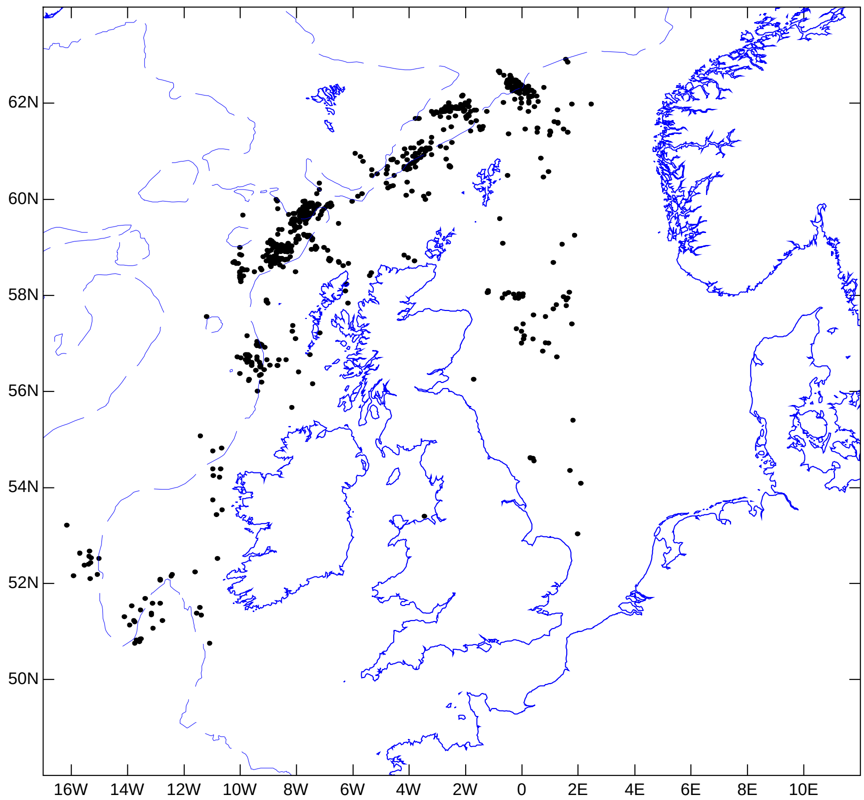

Figure 5 Cetacean sightings (all species) from seismic survey vessels during 1997.

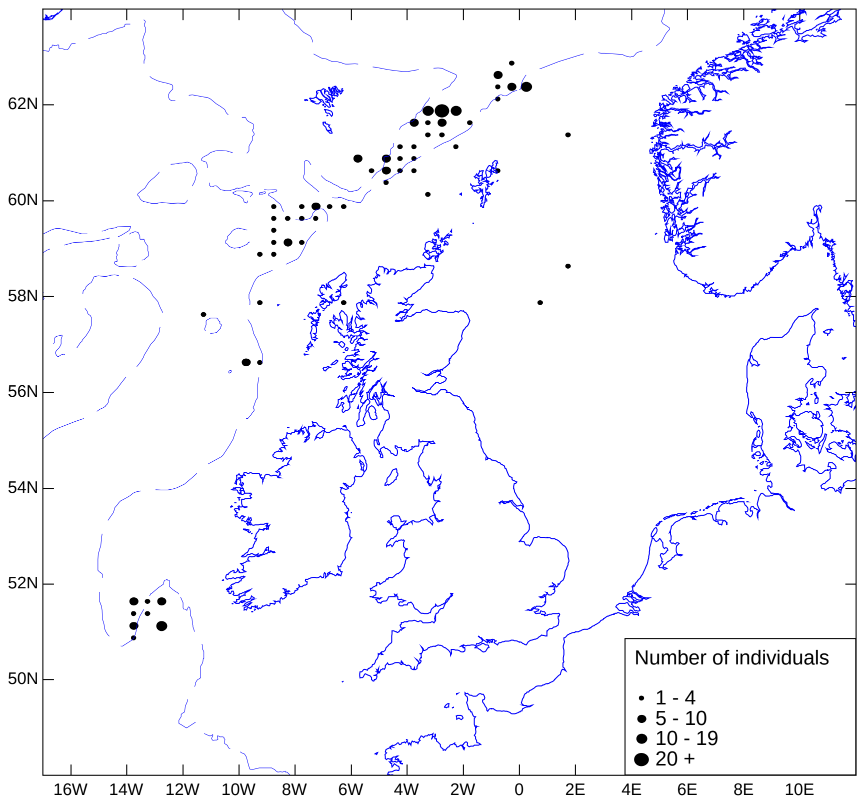

Figure 6 Distribution of unidentified whales seen during seismic surveys in 1997.

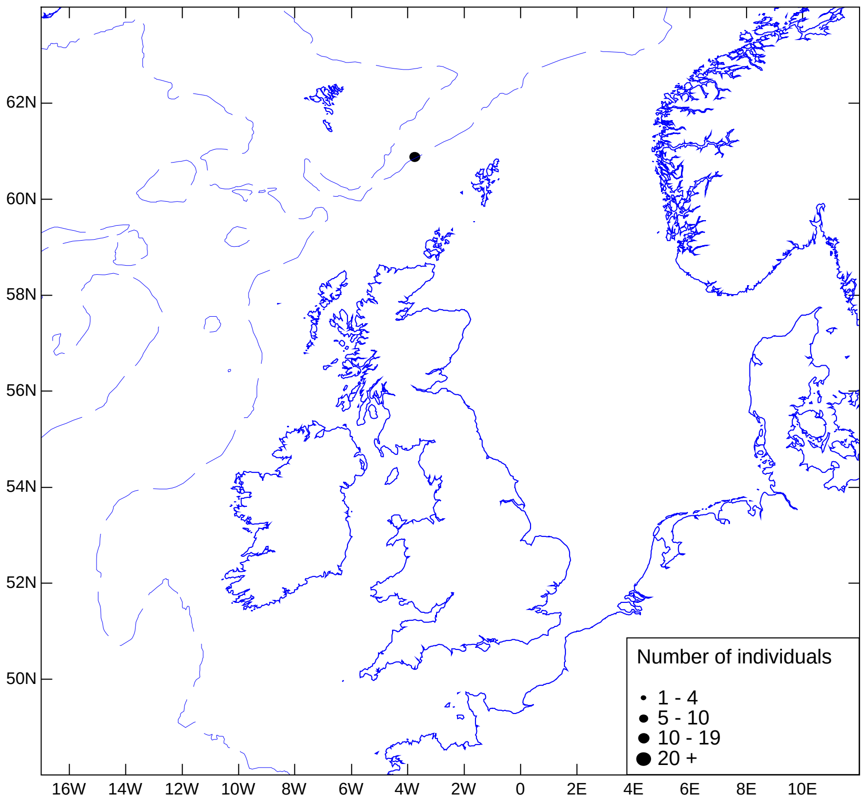

Figure 7 Distribution of humpback whales seen during seismic surveys in 1997.

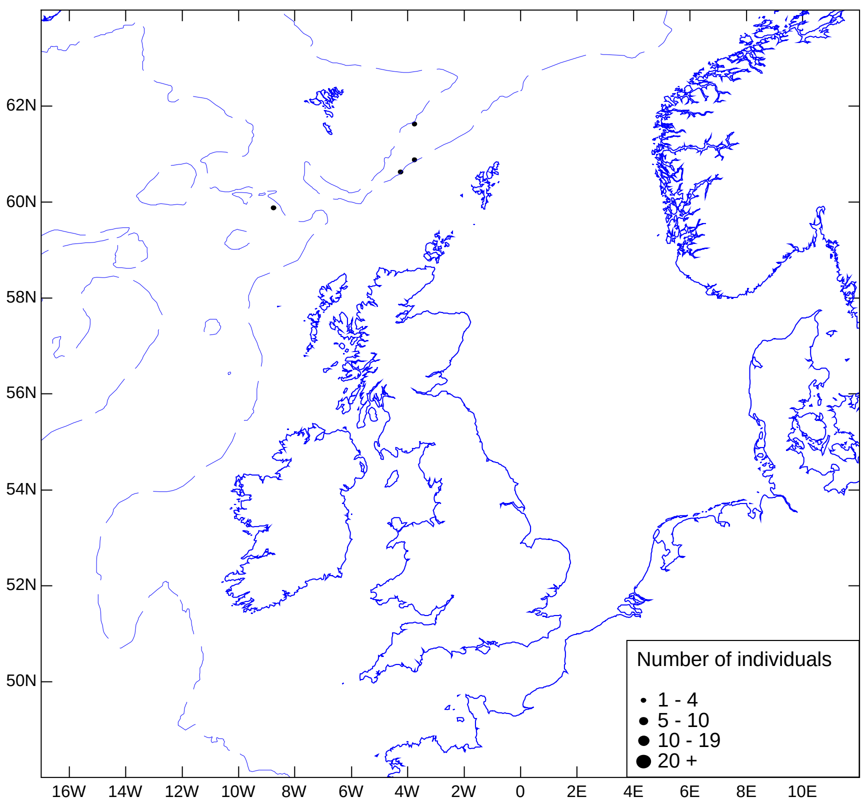

Figure 8 Distribution of blue whales seen during seismic surveys in 1997.

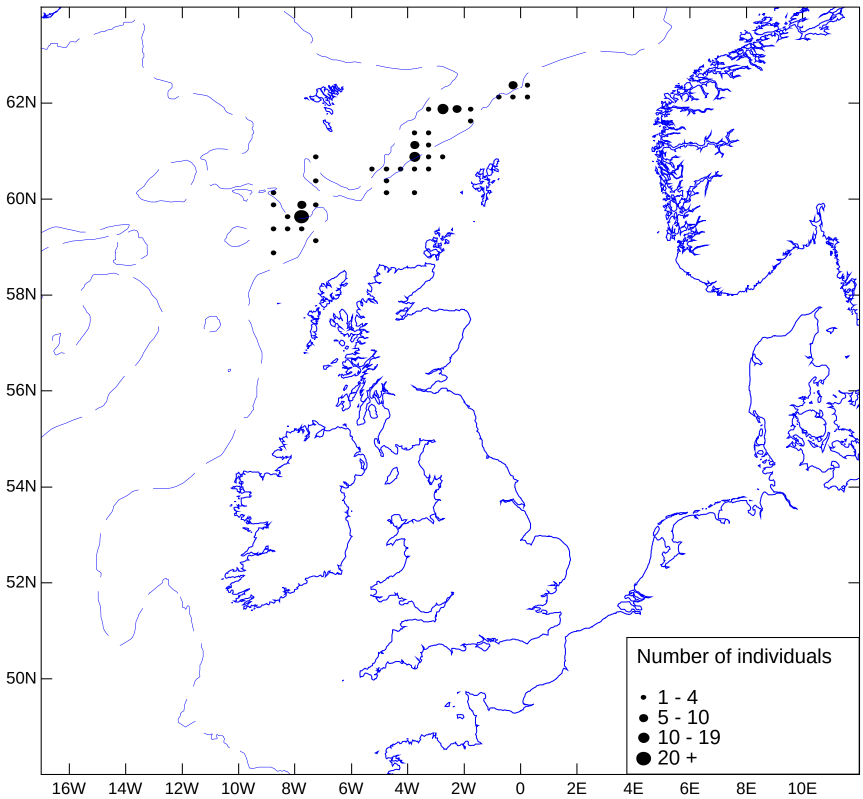

Figure 9 Distribution of fin whales seen during seismic surveys in 1997.

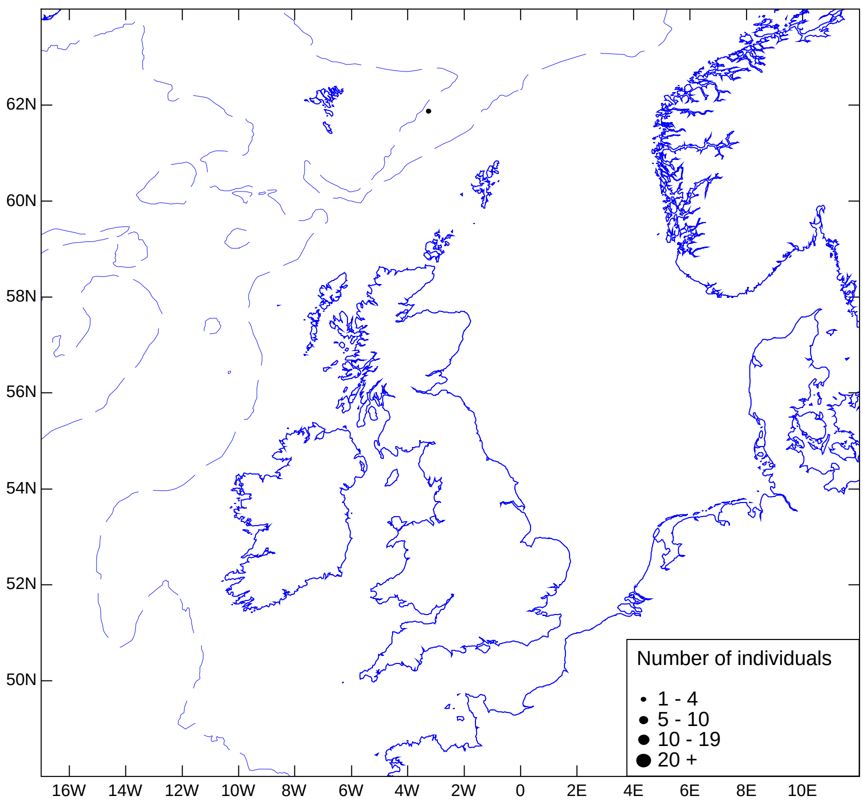

Figure 10 Distribution of sei whales seen during seismic surveys in 1997.

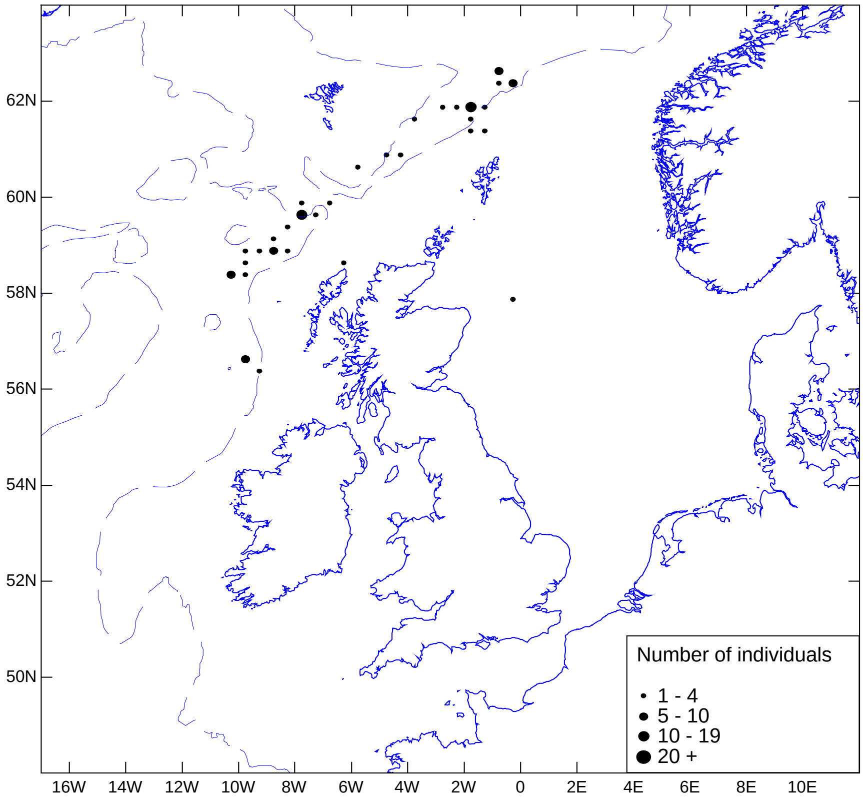

Figure 11 Distribution of sperm whales seen during seismic surveys in 1997.

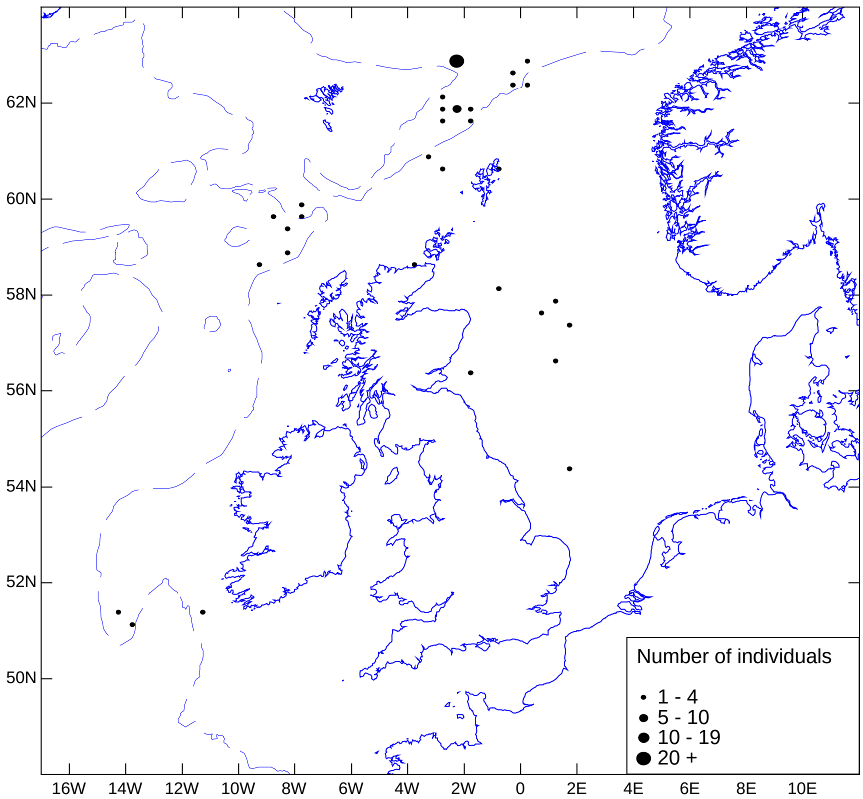

Figure 12 Distribution of minke whales seen during seismic surveys in 1997.

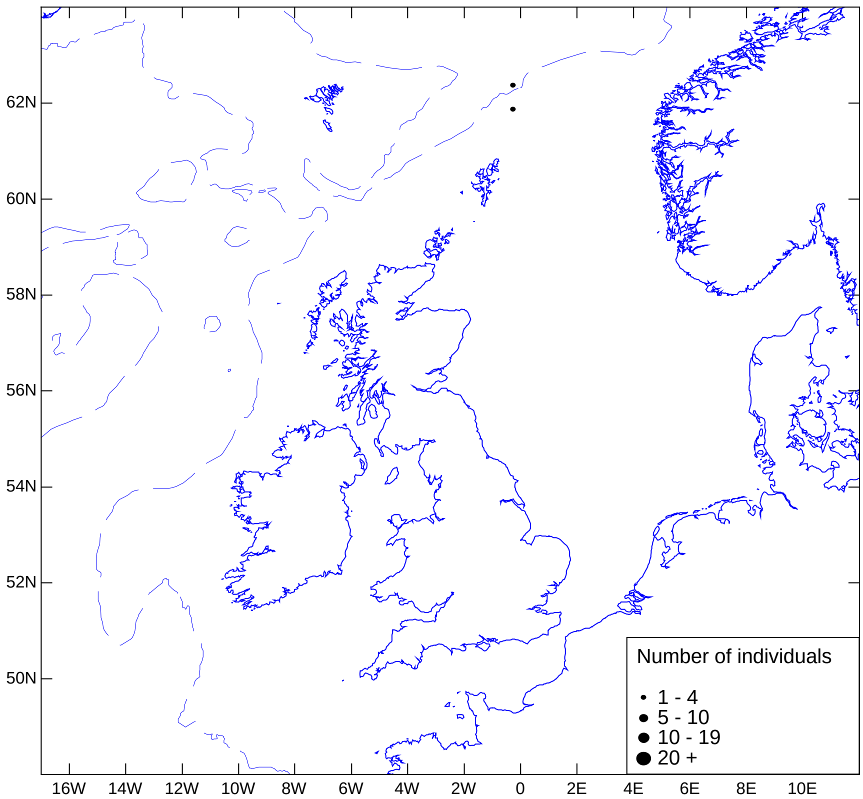

Figure 13 Distribution of northern bottlenose whales seen during seismic surveys in 1997.

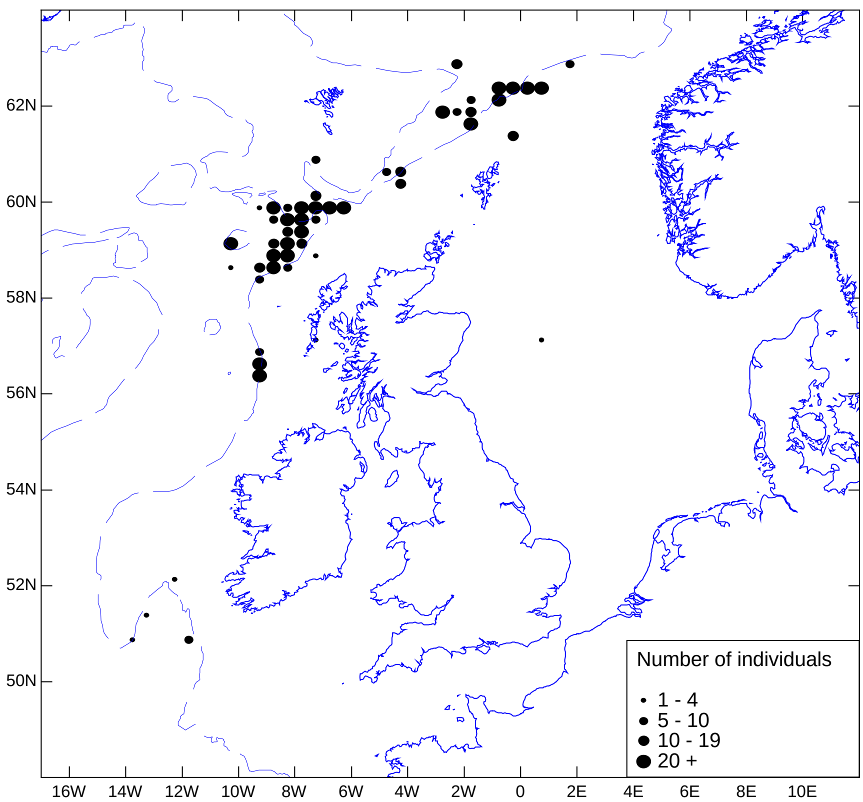

Figure 14 Distribution of pilot whales seen during seismic surveys in 1997.

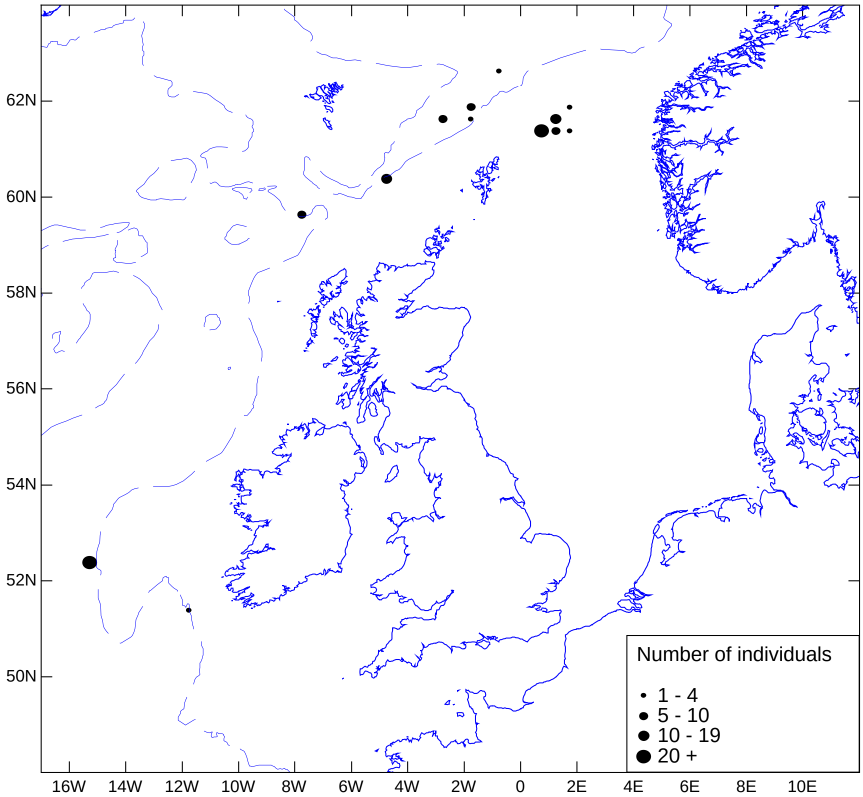

Figure 15 Distribution of killer whales seen during seismic surveys in 1997.

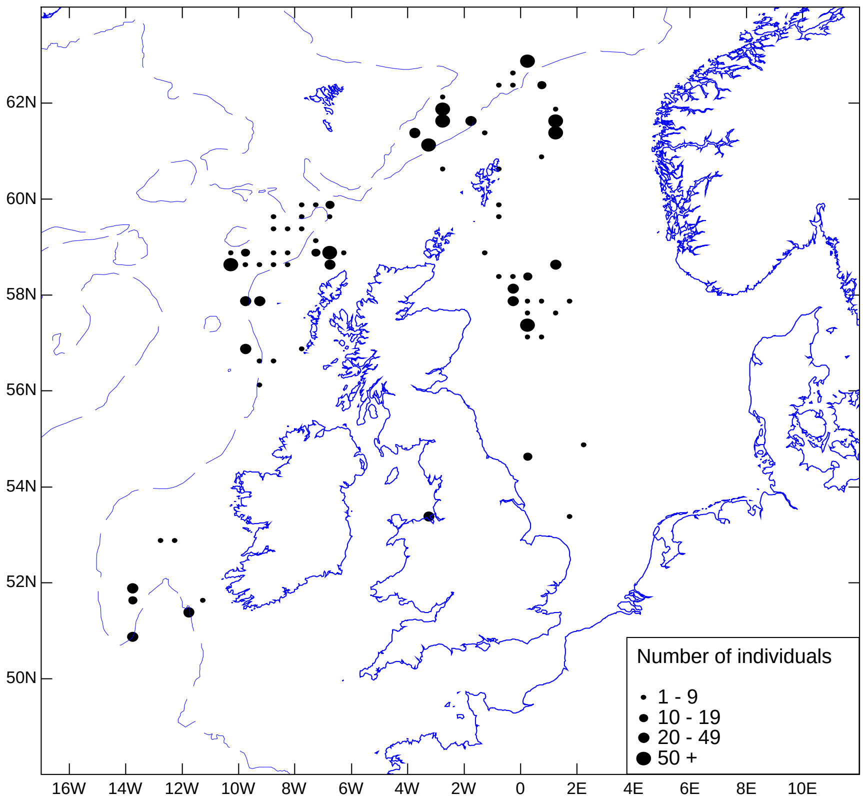

Figure 16 Distribution of unidentified dolphins seen during seismic surveys in 1997.

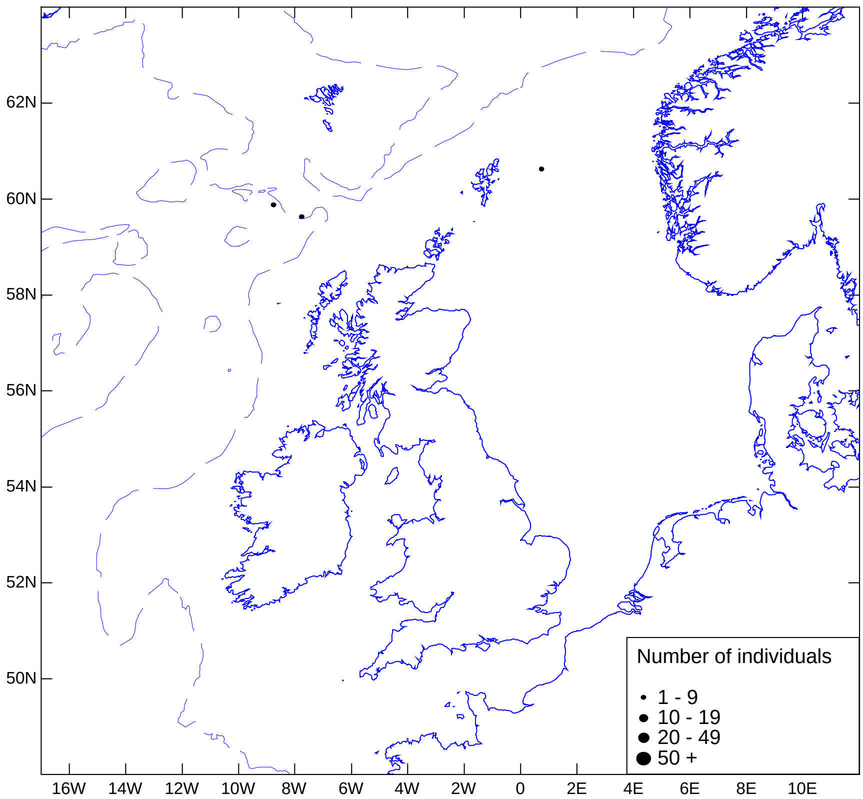

Figure 17 Distribution of Risso's dolphins seen during seismic surveys in 1997.

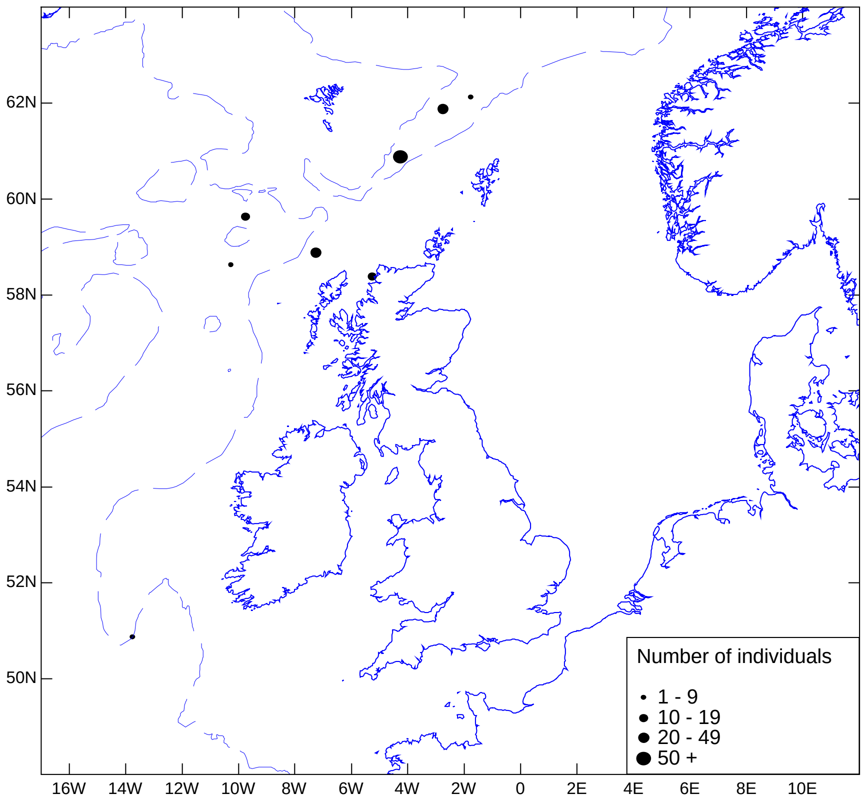

Figure 18 Distribution of bottlenose dolphins seen during seismic surveys in 1997.

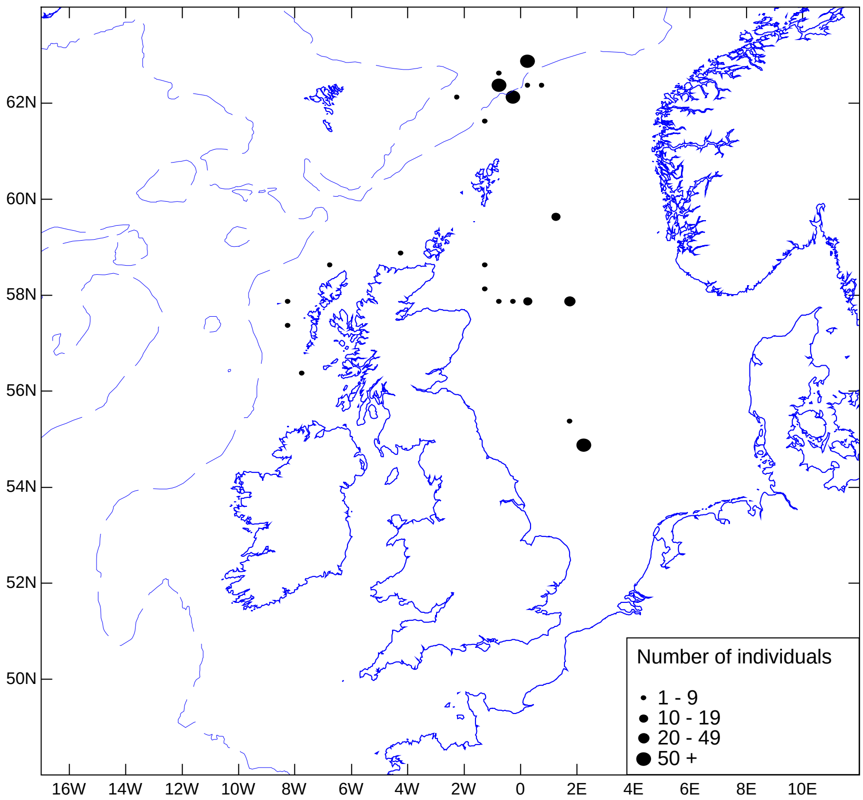

Figure 19 Distribution of white-beaked dolphins seen during seismic surveys in 1997.

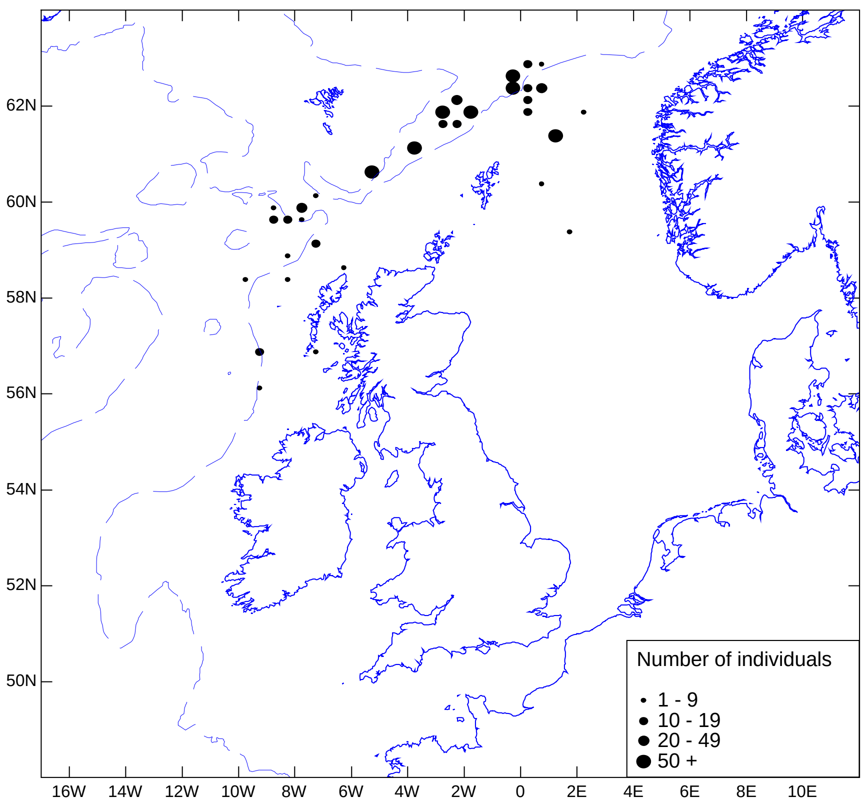

Figure 20 Distribution of white-sided dolphins seen during seismic surveys in 1997.

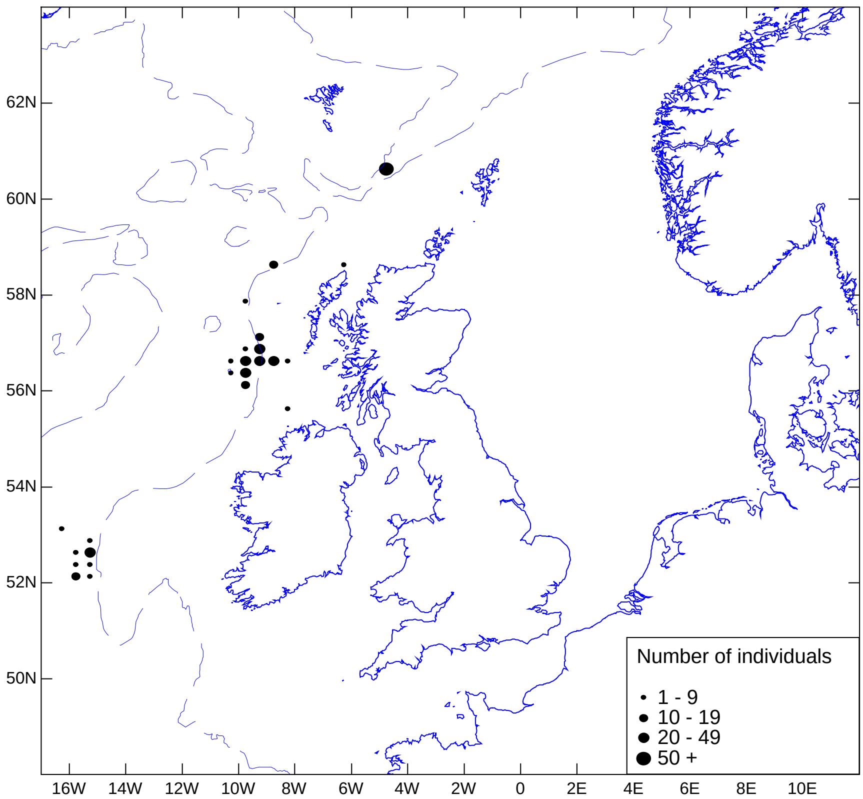

Figure 21 Distribution of common dolphins seen during seismic surveys in 1997.

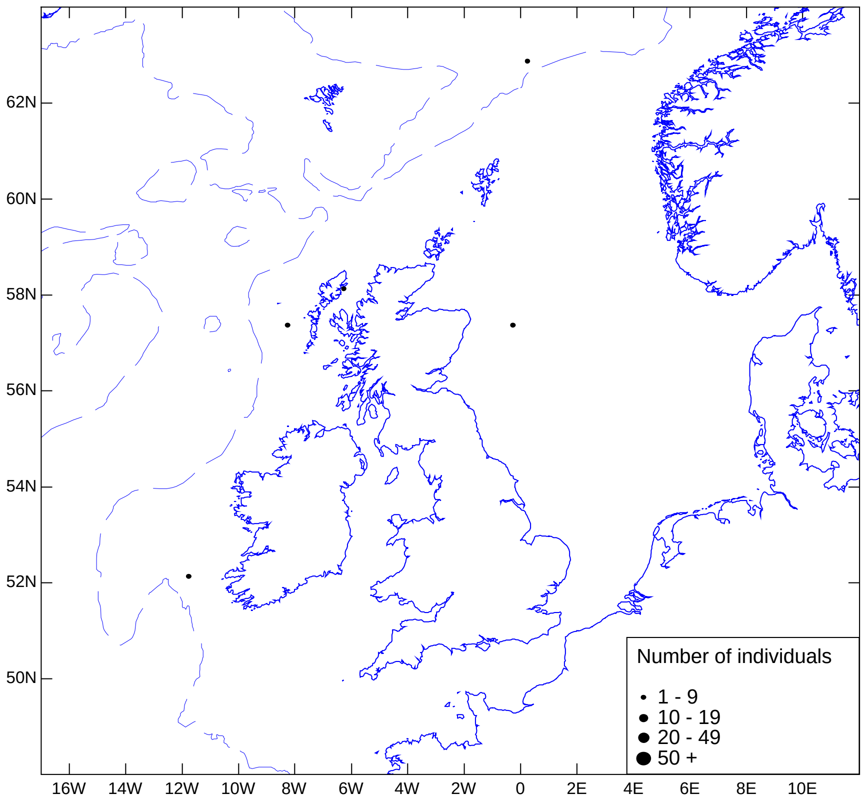

Figure 22 Distribution of harbour porpoises seen during seismic surveys in 1997.

6. Seasonal abundance and migration of cetaceans

Cetacean sightings peaked during summer months (Figure 24), when the amount of time spent watching also reached a peak (Figure 3). Although the low number of sightings at other times may in part reflect weather conditions less suitable for detecting cetaceans, there were marked seasonal patterns for some species. There were few sightings of large whales, such as fin and sperm whale, outside summer months. Pilot whales were seen in more months, but with peaks of occurrence in July and August and low numbers outside the summer. Dolphin sightings also peaked in the summer, with white-beaked dolphins peaking earlier than white-sided dolphins. Common dolphins were only seen in late summer and early autumn, possibly reflecting an offshore movement of this species then.

Most species showed no obvious trends in their direction of travel, except that in June most fin whales were moving either north-east or north-west (Figure 23). In later months this trend was not apparent. The northerly component in fin whale movements in early summer was reflected in their distribution throughout the season (Figure 25). All fin whales were seen to the north and west of Scotland, but there were some movements within this area. In June, most fin whales were seen to the north-west of the Hebrides, even though more time was spent watching for cetaceans to the west of Shetland. In July, some remained in waters to the north-west of the Hebrides but most were seen further north to the west of Shetland. In August, more time was spent watching for cetaceans to the north-west of the Hebrides than in June or July, but very few fin whales were seen there. By this time, almost all fin whales were seen to the west and north of Shetland, and they remained in these waters until October, when they were last seen.

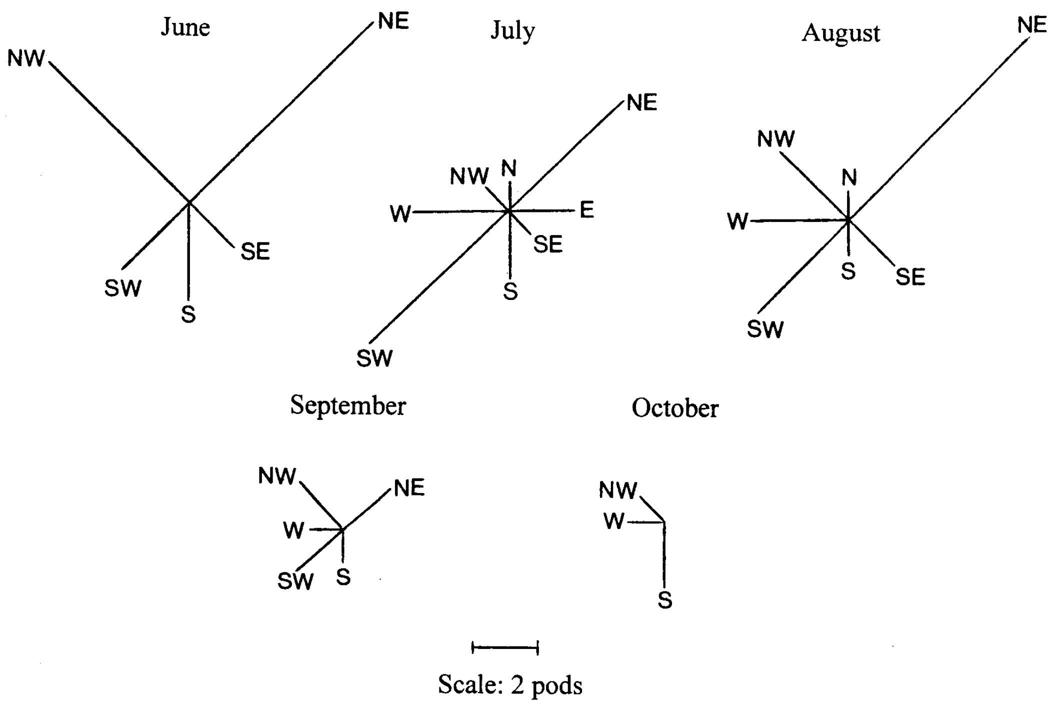

Figure 23 Direction of travel of fin whales.

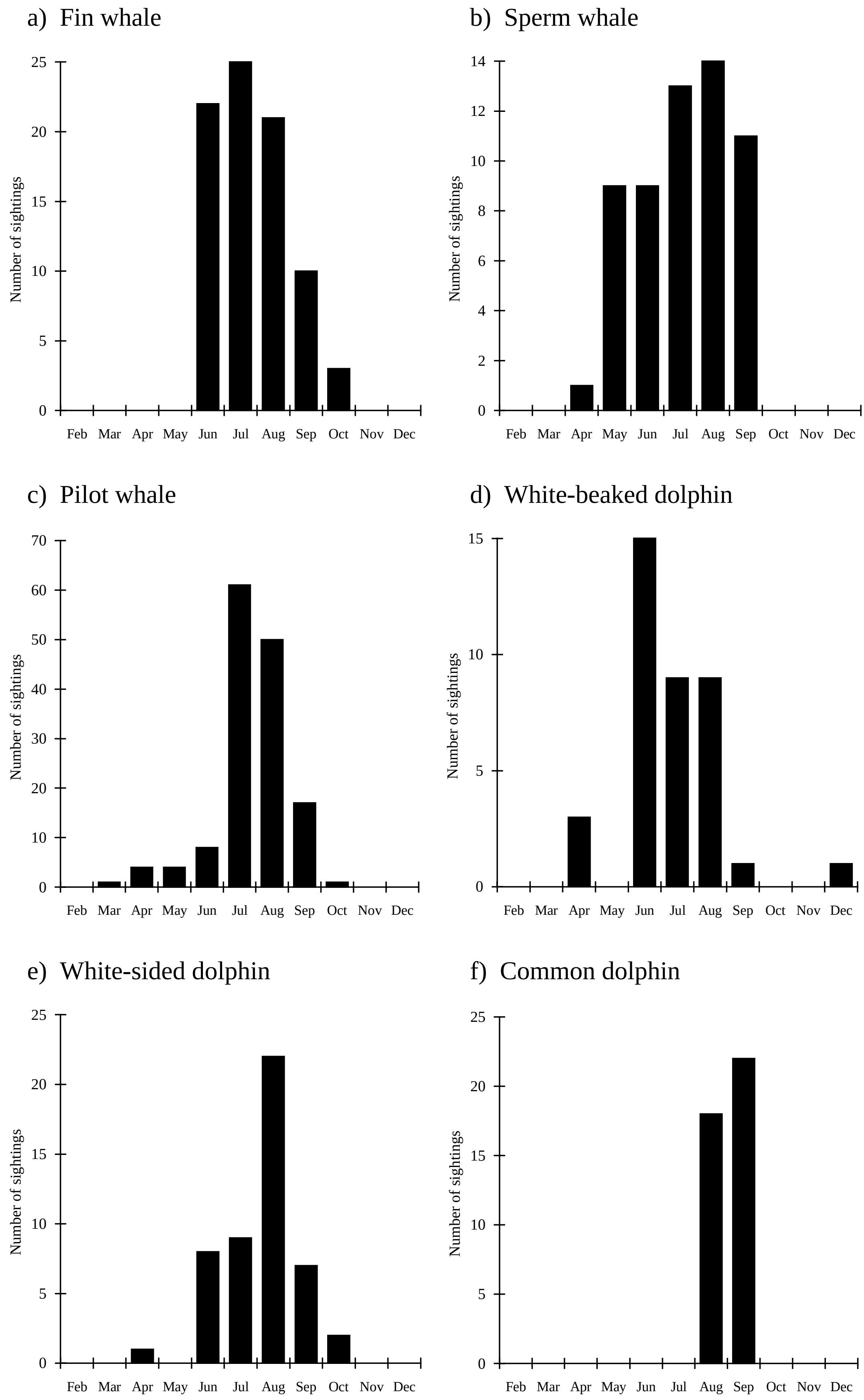

Figure 24 Number of sightings of cetaceans per month.

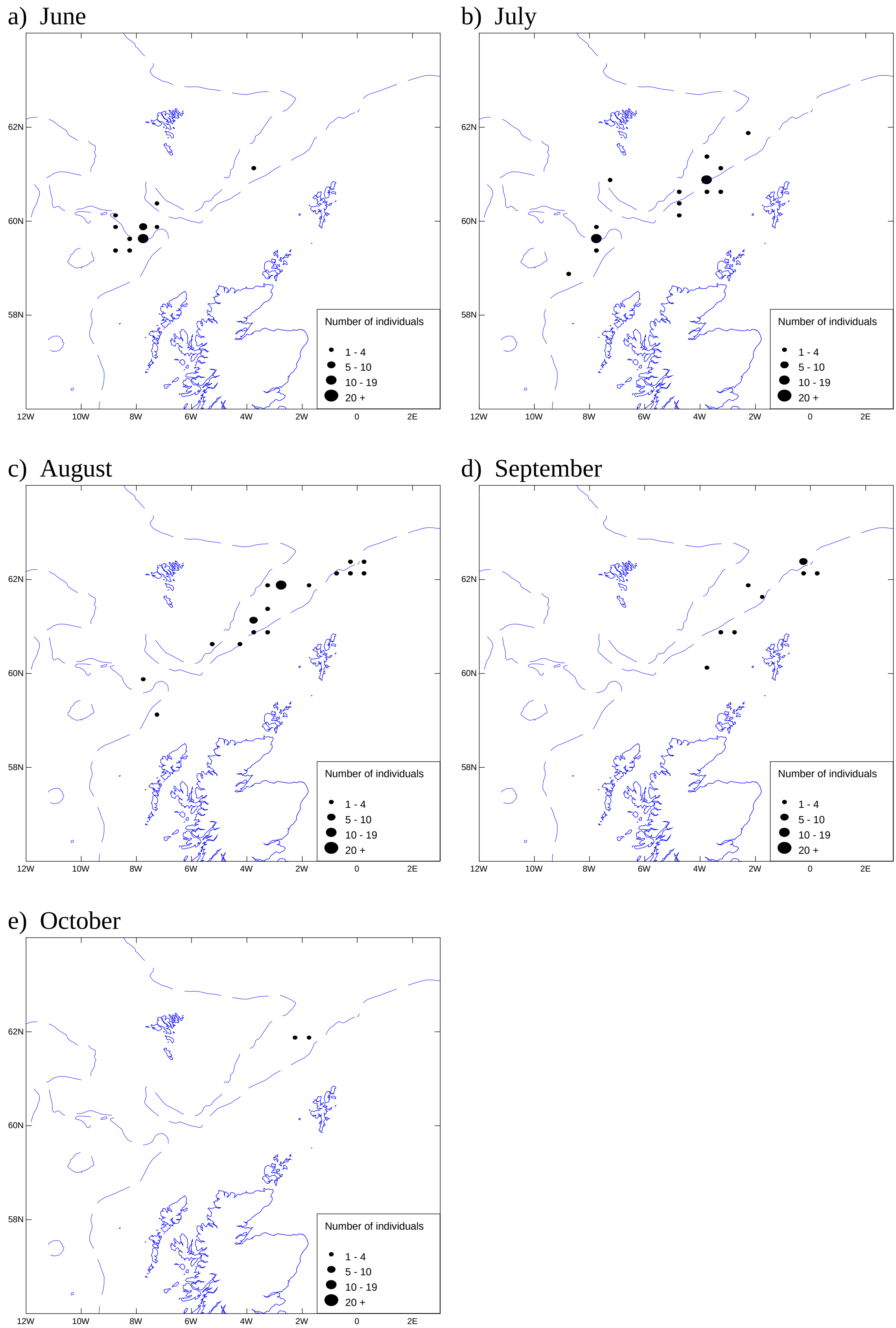

Figure 25 Fin whale sightings throughout the summer.

7. Effects of seismic activity on cetaceans

7.1 Sighting rate of cetaceans

Sighting rates per unit effort (i.e. per 1,000 hours observations) were compared for periods when the airguns were firing and when they were not firing. Therefore, to correctly assess cetacean sighting rates only those sightings from surveys where effort was correctly recorded were used. There was no clear pattern amongst baleen whales (Figure 26), with some species being seen more frequently during periods of shooting, and others being seen more frequently when the airguns were not firing. The sighting rate of fin whales was significantly higher when the airguns were firing ($\chi^2 = 5.455$, d.f. = 1, $p < 0.05$; expected values calculated based on the time spent searching at each activity), but for all other baleen whales the variation in sighting rate with seismic activity was non-significant.

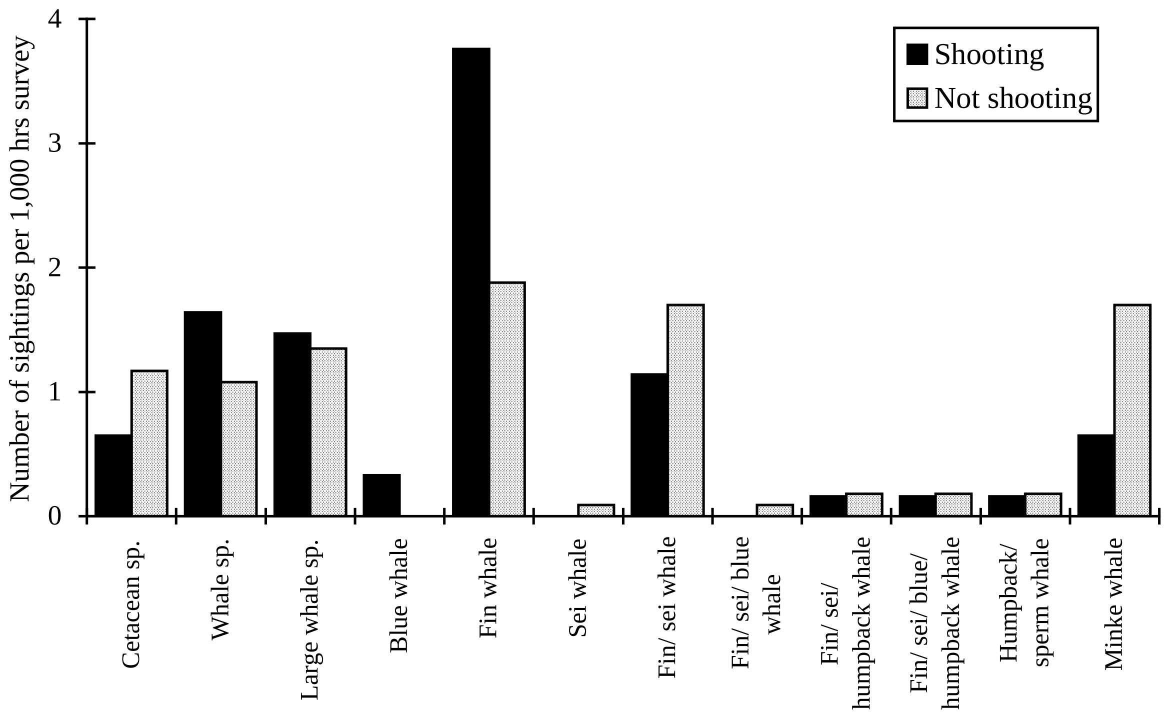

Figure 26 Sightings of baleen whales in relation to seismic activity.

A clearer pattern emerged amongst the dolphin species. Most dolphins were seen more often when the airguns were not firing (Figure 27), although this was only statistically significant for common dolphins ($\chi^2 = 4.801$, d.f. = 1, $p < 0.05$). This pattern did not extend to the other odontocetes. The sighting rate of sperm whales was similar regardless of seismic activity. In contrast to the dolphins, pilot whales were seen significantly more often during periods of shooting ($\chi^2 = 8.015$, d.f. = 1, $p < 0.01$).

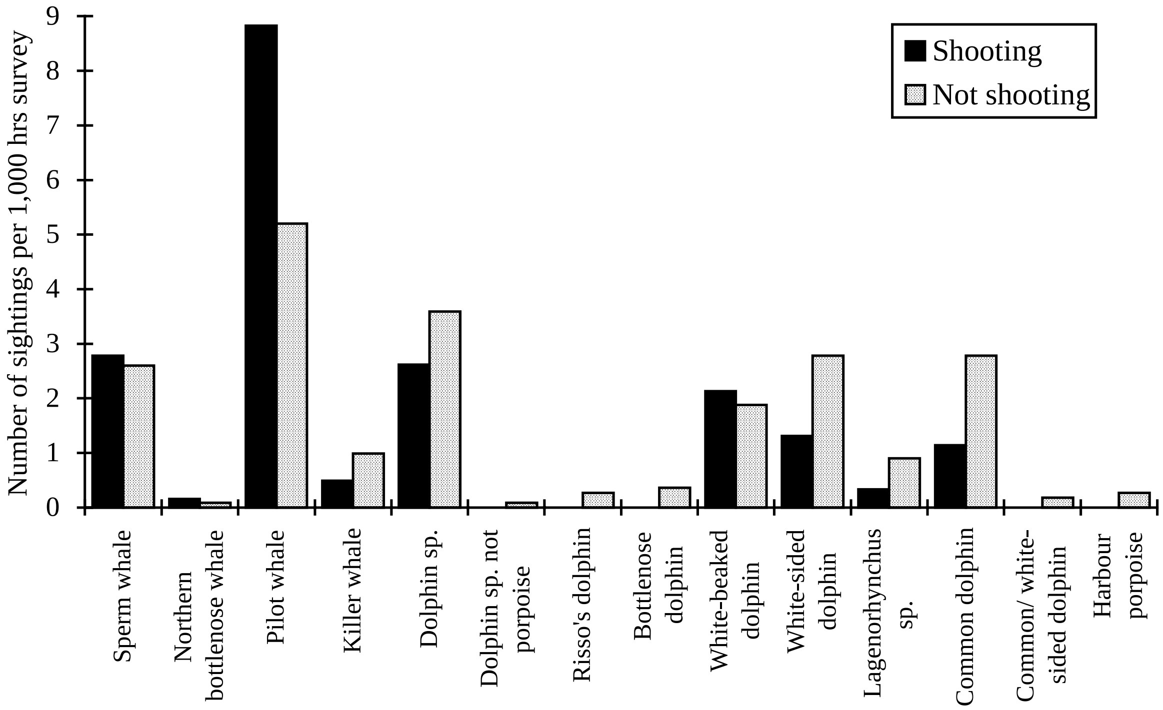

Figure 27 Sightings of odontocetes in relation to seismic activity.

There were a number of factors that could have influenced these results. Data from both seismic and site surveys were used for this analysis. Site surveys use lower power airguns that may be less likely to disturb cetaceans. One previous study has indicated that pilot whales may be attracted to low power airguns of the kind used in site surveys (Stone 1997b). It may therefore be inappropriate to combine data from both site and seismic surveys when considering sighting rates of cetaceans.

Another factor that could have influenced the results is the effect of weather on the ability to detect cetaceans. This was particularly important as the proportion of time spent shooting varied with differing weather conditions. As sea state decreased, the proportion of time spent shooting increased (Figure 28) and cetaceans became easier to detect (Figure 29). This could lead to higher sighting rates during periods of shooting. Cetaceans were also easier to detect in conditions of good visibility (Figure 30). The proportion of time spent shooting was greater in good and moderate visibility than in poor visibility (Figure 31). This could also have increased the number of cetaceans seen when shooting.

Some species were seen more frequently in certain areas and at certain times of year. As the proportion of time spent shooting varied with location and season (Figures 3 & 4), this could also have introduced bias. For example, the inclusion of surveys in areas or seasons where cetacean abundance is naturally low but where much time was spent shooting could lead to the erroneous conclusion that sighting rates were reduced due to seismic activity, when in fact natural factors could explain the reduction in sightings.

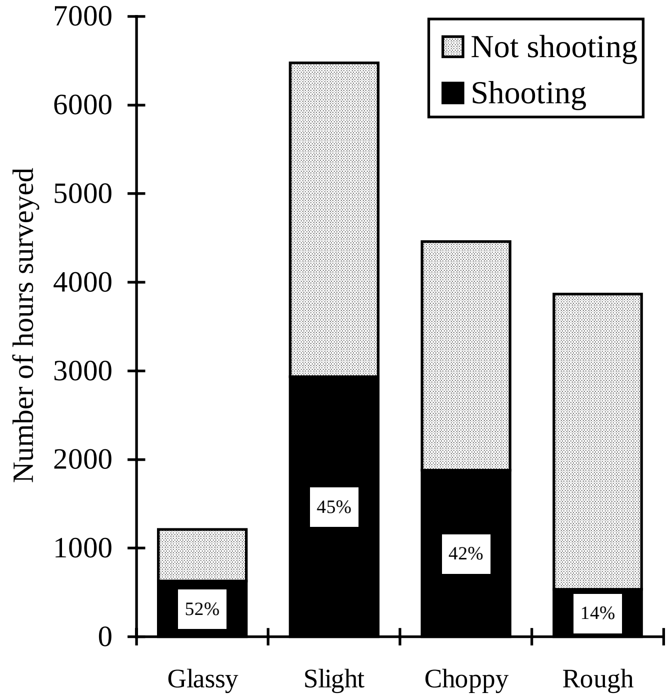

Figure 28 Length of time spent watching for cetaceans at each sea state in relation to seismic activity, with percentage of time spent shooting (only includes surveys where effort was correctly recorded).

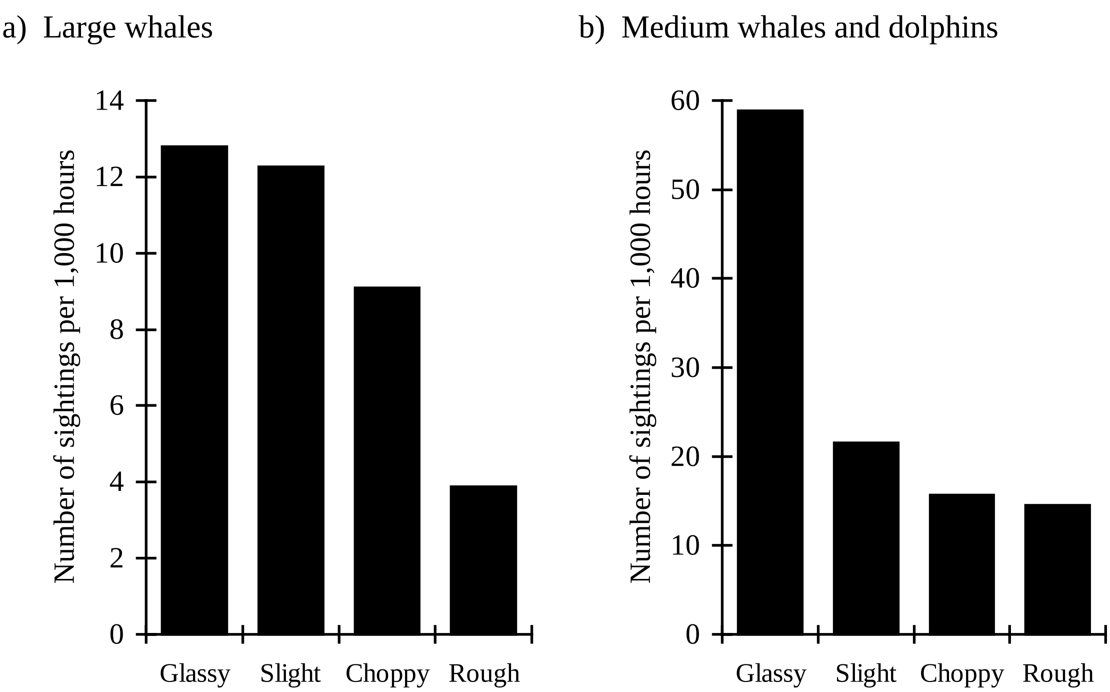

Figure 29 Frequency of cetacean sightings in relation to sea state (large whales = fin/ sei/ blue/ humpback/ sperm whales i.e. whales over 10 m long with a conspicuous blow; medium whales = minke/ northern bottlenose/ pilot whale/ killer whale).

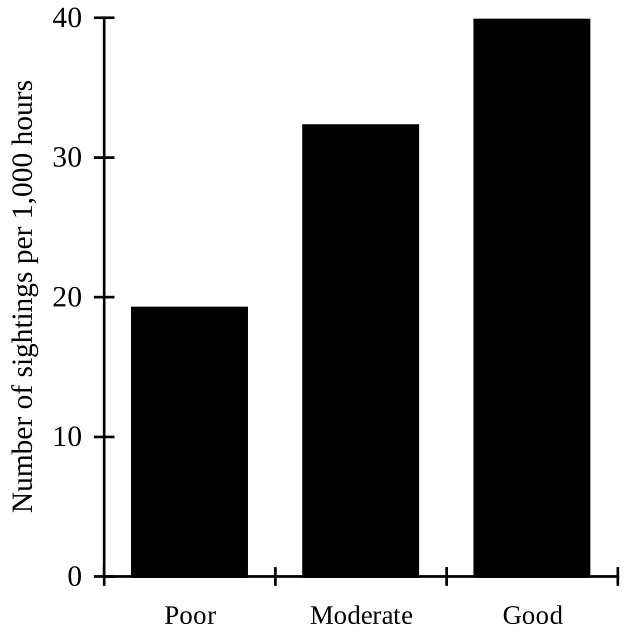

Figure 30 Frequency of cetacean sightings in relation to visibility.

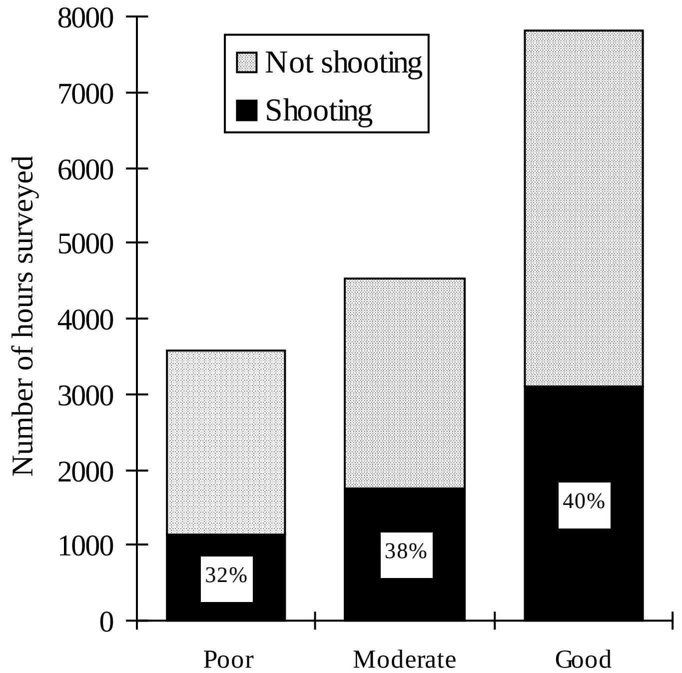

Figure 31 Length of time spent watching for cetaceans in different conditions of visibility in relation to seismic activity, with percentage of time spent shooting (only includes surveys where effort was recorded correctly).

Where sample sizes allowed, sighting rates were re-calculated allowing for these potential sources of bias. Site surveys were excluded, and for each species subsets of data were selected according to the areas and months of peak occurrence. To reduce the influence of weather, data from days with poor weather conditions were disregarded. Ideally analysis would be restricted to days with glassy seas, but as there were relatively few days with such conditions the consequent reduction in sample size would have prevented meaningful analysis. There was some interspecific variation in the rate at which cetaceans became less detectable with increasing sea state (Figure 29). Large whales were still relatively detectable in choppy seas, while for medium whales and dolphins detectability decreased sharply once seas became anything other than glassy. Therefore, for medium whales and dolphins, days with choppy or rough seas were disregarded, while for large whales only days with rough seas were disregarded. Days with poor visibility were also disregarded for all species.

After selecting only the most appropriate data for each species, sample sizes were only sufficient to compare sighting rates in relation to seismic activity for eight species or species groups. The criteria used to select data for each taxonomic category in order to reduce bias are summarised in Table 2. The large whales showed little difference in sighting rates between periods of shooting and not shooting (Figure 32). For pilot whales and dolphins there were more marked differences. Pilot whales were seen significantly more frequently when the airguns were firing (Table 3). Conversely, white-beaked dolphins, white-sided dolphins and all dolphin species combined were seen significantly less frequently when the airguns were firing.

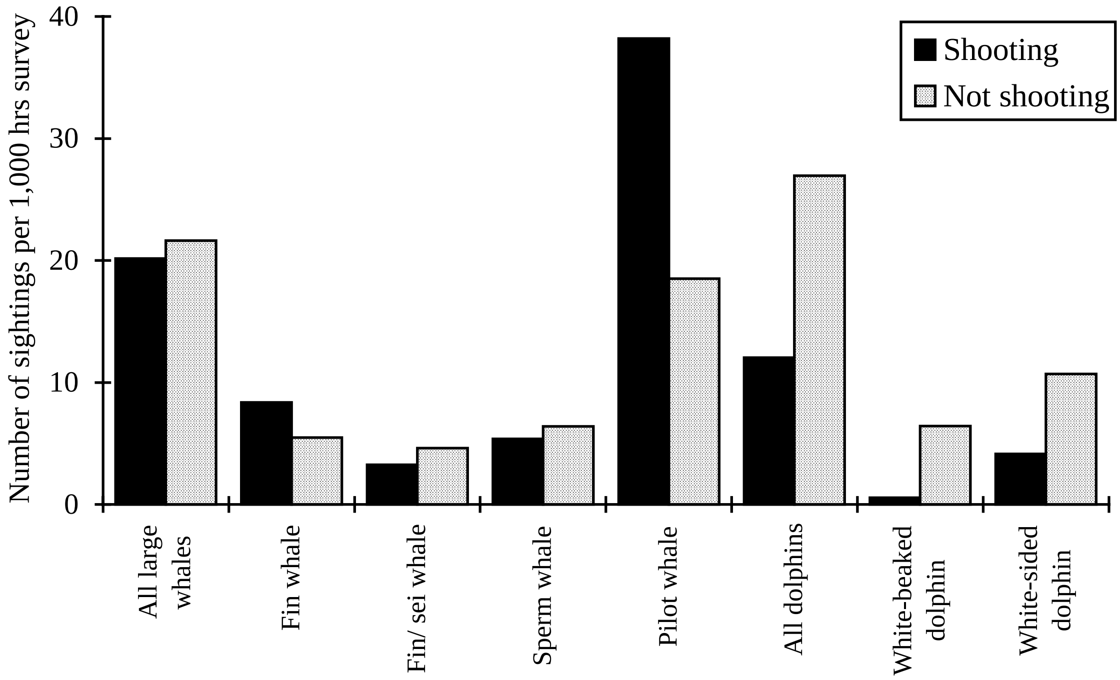

Figure 32 Sighting rates of cetaceans in relation to seismic activity, excluding site surveys and taking account of weather, location and season (see Table 2).

Table 2 Criteria for selection of data for assessing sighting rate of cetaceans.

Species	Type of survey	Season	Areas	Sea state	Visibility
All large whales combined	Not site	May - Sep	West of Shetland Rockall	Glassy Slight Choppy	Good Moderate
Fin whale	Not site	Jun - Sep	West of Shetland Rockall	Glassy Slight Choppy	Good Moderate
Fin/ sei whale	Not site	Jun - Sep	West of Shetland Rockall	Glassy Slight Choppy	Good Moderate
Sperm whale	Not site	May - Sep	West of Shetland Rockall	Glassy Slight Choppy	Good Moderate
Pilot whale	Not site	Jul - Sep	West of Shetland Rockall	Glassy Slight	Good Moderate
All dolphins combined	Not site	Jun - Sep	West of Shetland Rockall Northern North Sea Southern North Sea West of Ireland	Glassy Slight	Good Moderate
White-beaked dolphin	Not site	Jun - Aug	West of Shetland Rockall Northern North Sea Southern North Sea	Glassy Slight	Good Moderate
White-sided dolphin	Not site	Jun - Sep	West of Shetland Rockall	Glassy Slight	Good Moderate

Table 3 Statistical significance of difference in sighting rate of cetaceans in relation to seismic activity (n.s. = not significant).

Species	χ^2	**d.f.**	**P**
All large whales combined	0.120	1	n.s.
Fin whale	1.383	1	n.s.
Fin/ sei whale	0.535	1	n.s.
Sperm whale	0.210	1	n.s.
Pilot whale	7.994	1	< 0.01
All dolphins combined	13.339	1	< 0.001
White-beaked dolphin	9.207	1	< 0.01
White-sided dolphin	4.243	1	< 0.05

7.2 Distance of cetaceans from airguns

The mean distance of cetacean pods (a group of any size) from the airguns was compared for all species where distance was recorded during periods of both shooting and not shooting. To preclude any possible masking effect that could occur if cetaceans react differently to airguns of different power levels, mean distance was calculated excluding data from site surveys. Weather conditions could also have influenced this analysis, as shooting took place mostly in better weather when it would have been easier to see cetaceans at greater distances. To take account of weather conditions, sightings occurring on days of poor visibility or higher sea states were excluded. Higher sea states were again defined as choppy or rough seas for medium whales and dolphins, and as rough seas for large whales. Only those species where the sample size exceeded ten pods were used.

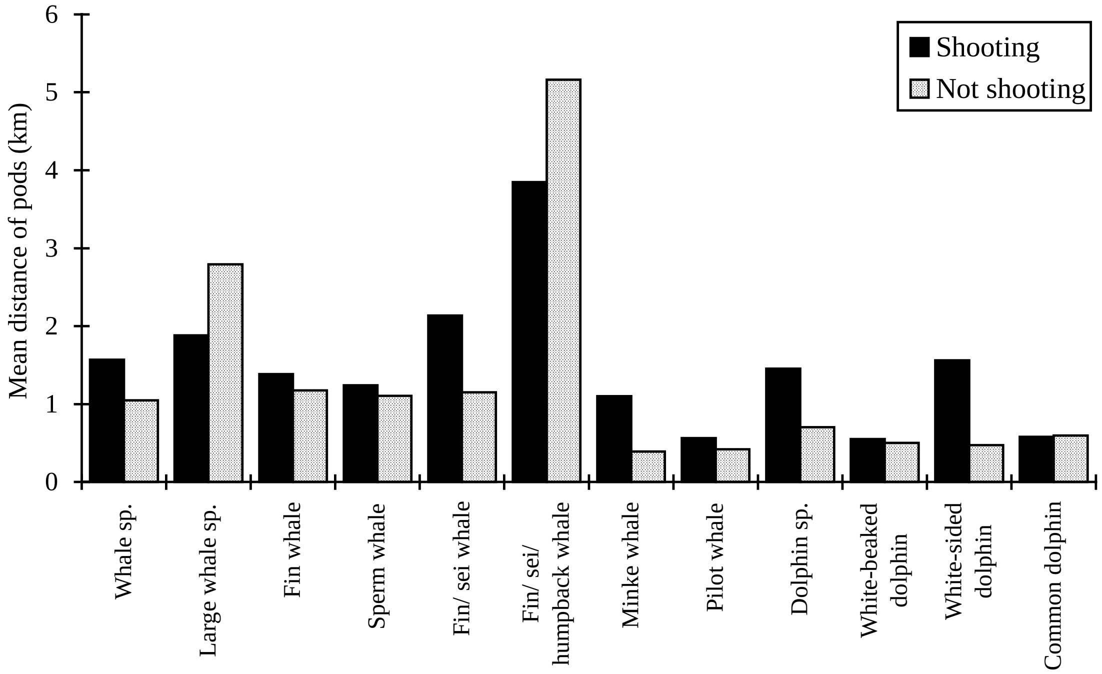

Figure 33 Mean distance of cetacean pods from the airguns in relation to seismic activity.

Most species were found to be further from the airguns when they were firing (Figure 33). However, permutation tests showed that the differences were only statistically significant for fin/ sei whales, minke whales, unidentified dolphins and white-sided dolphins ($p = 0.007$, $p = 0.030$, $p = 0.015$ and $p = 0.003$ respectively). In all four cases, pods of these species were further from the airguns during periods of shooting.

White-sided dolphins came closer to the airguns during periods of shooting if they were in association with pilot whales than they did if they were on their own (Table 4). When unaccompanied, white-sided dolphins remained at some distance from the airguns when they were firing. When the airguns were not firing, the mean distance of white-sided dolphin pods from the airguns was similar whether they were in association with pilot whales or not.

Table 4 Mean distance of white-sided dolphin pods from the airguns, in association with pilot whales or unaccompanied, in relation to seismic activity.

Seismic activity	**Mean distance of white-sided dolphin pods**	
	With pilot whales	**Without pilot whales**
Shooting	650 m	1867 m
Not shooting	518 m	464 m

7.3 Behaviour of cetaceans

Observers recorded any types of behaviour that were apparent. On 28% of occasions behaviour was recorded as being nothing other than "normal swimming". There were 26 other types of behaviour recorded, but some were noted on only a few occasions e.g. spy-hopping and lob-tailing. The more frequently recorded types of behaviour are summarised in Table 5. The number of pods exhibiting each type of behaviour during periods of shooting or not shooting is expressed as a percentage of the total number of pods encountered at the respective seismic activity. Where types of behaviour were exhibited more frequently by particular species, the results for individual species are shown; otherwise species were combined. Data from site surveys were again excluded to eliminate any potential variation in the reaction of cetaceans to airguns of different levels of power.

Cetacean behaviour is difficult to assess based on surface observations, and little is known about the significance of behaviours that are apparent at the surface. Certain types of natural behaviour (e.g. feeding and logging/ resting) were still apparent while the airguns were firing, although they were seen marginally less often at these times than when the airguns were not firing.

Seismic activity had some effect on the swimming characteristics of cetaceans. Pilot whales and fin whales normally swim relatively slowly; both species showed a greater tendency to swim at an increased speed when the airguns were firing than when they were not firing. Pilot and fin whales swimming rapidly during periods of shooting were sometimes heading away from the ship, but never towards the ship. Fin whales were more often recorded as surfacing infrequently when the airguns were not firing, perhaps concurrent with a more leisurely swimming speed at these times. Cetaceans altered their course more frequently during periods of shooting than during periods of not shooting - in most cases these were alterations of course away from the ship, although there were some instances where cetaceans altered course towards the ship when the airguns were firing. Sperm whales dived more often during periods of shooting, although the same was not true for fin whales. Dolphins were seen breaching or jumping in a similar proportion of encounters regardless of seismic activity.

Positive interactions of cetaceans with the vessel or its equipment (i.e. bow-riding, approaching the vessel, swimming alongside the paravanes or following the vessel) occurred both when the airguns were firing and when they were not firing. However, cetaceans showed a greater tendency to engage in positive interactions with the vessel during periods when the airguns were not firing. While the airguns were firing at full power during seismic surveys there were few instances of bow-riding, swimming alongside the paravanes or following the ship - in these circumstances positive interactions were restricted mostly to approaching the vessel. Negative interactions (i.e. definite avoidance) occurred in only a small number of cases, but marginally more often during periods of shooting.

Table 5 Behaviour of cetaceans in relation to seismic activity.

Behaviour	**Species**	**% of encounters while shooting when behaviour was exhibited**	**% of encounters while not shooting when behaviour was exhibited**
Feeding	All species combined	2.71	4.89
+ve interactions	Fin whale	2.22	5.56
	Pilot whale	10.96	16.18
	White-beaked dolphin	16.67	19.05
	Common dolphin	14.29	30.30
	All species combined	4.65	10.27
-ve interactions	All species combined	1.55	0.73
Alteration of course	Fin whale	15.56	11.11
	Pilot whale	17.81	14.71
	White-sided dolphin	15.38	8.82
	All species combined	10.08	6.60
Breaching or jumping	All dolphins combined	36.07	34.32
Fast swimming	Fin whale Pilot whale	11.11 12.33	5.56 5.88
Surfacing frequently	All species combined	1.55	1.22
Surfacing infrequently	Fin whale	11.11	16.67
	Pilot whale	2.74	2.94
Diving	Fin whale	6.67	8.33
	Sperm whale	27.27	19.23
Logging	Sperm whale	9.09	11.54
	Pilot whale	1.37	2.94

Table 6 Direction of travel of cetacean pods relative to the ship in relation to seismic activity.

Species	**Seismic activity**	**Towards ship**	**Crossing path of ship**	**Away from ship**	**Parallel to ship in same direction**	**Parallel to ship in opposite direction**	**Milling**
Cetacean sp.	Shooting			3		2	
	Not shooting	3	1	3	2	5	3
Whale sp.	Shooting		2	2	1	1	
	Not shooting	1	5				
All large whales combined	Shooting	3	9	29	13	30	3
	Not shooting	8	17	20	9	32	6
Large whale sp.	Shooting		1	4		1	
	Not shooting	1	9	3	1	2	1
Fin whale	Shooting	2	7	13	5	11	2
	Not shooting	3	3	7	2	14	2
Sperm whale	Shooting	2	1	5	2	8	
	Not shooting	2	3	3	2	4	3
Fin/ sei whale	Shooting			2	3	8	
	Not shooting	2	5	2	2	9	
Fin/ sei/ humpback whale	Shooting			2	2	3	1
	Not shooting			3	1	2	
Minke whale	Shooting		1		1	2	
	Not shooting	2	5	1	6	6	1
Pilot whale	Shooting	9	17	8	3	21	2
	Not shooting	13	8	2	9	28	2
Killer whale	Shooting		2	1			
	Not shooting	1	4	1	1	2	
All dolphins	Shooting	11	10	5	9	8	4
	Not shooting	15	21	16	14	34	14
Dolphin sp.	Shooting	3	9	2	3		2
	Not shooting	3	15	7	5	15	5
Bottlenose dolphin	Shooting		1		2		
	Not shooting	2	2		1	1	1
White-beaked dolphin	Shooting	6		2	2	1	
	Not shooting	4	1	5	3	2	1
White-sided dolphin	Shooting	1	2	1	2	3	1
	Not shooting	3	4	2	1	11	3
Lagenorhynchus sp.	Shooting					1	1
	Not shooting		4				4
Common dolphin	Shooting	2	1			4	
	Not shooting	2	5	2	16	6	2
Total for all species	Shooting	25	44	48	27	67	9
	Not shooting	44	74	47	55	114	28

The direction of travel of cetacean pods in relation to the ship was recorded in a diagram by observers. The directions were subsequently divided into the six categories represented in

Table 6, which presents the results for all species or groups of species where direction of travel was recorded for ten or more pods. When the airguns were firing 22% of cetacean pods headed away from the ship, whereas when the airguns were not firing only 13% of pods headed away from the ship. Approximately half as many pods came towards the ship as went away from it when the airguns were firing. When the airguns were not firing, roughly equal numbers of pods came towards the ship as went away. The only species for which the results were statistically significant was the pilot whale ($\chi^2 = 10.127$, d.f. = 3, $p < 0.05$). Partitioning showed that significantly more pods of pilot whales headed away from the ship or crossed its path when the airguns were firing.

7.4 The influence of depth on the level of disturbance of cetaceans

Many of the seismic surveys during 1997 were carried out in areas of deep water, often with depths exceeding 1,000 m. The depth of water can influence the propagation of sound underwater, and therefore could influence the response of cetaceans to seismic activity. On the "Location and Effort" forms observers were asked to give their location for each day. For surveys where these forms were correctly completed, each day could therefore be assigned 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). The proportion of time spent shooting in each depth category could then be calculated. The level of seismic activity was very similar over the continental shelf and the shelf slope (Table 7). Slightly more of the time spent in deeper waters was spent shooting, but the difference was not large.

Table 7 Proportion of time spent shooting at different depths.

Depth	**Proportion of time spent shooting**
0-200 m	37.38%
200-1,000 m	35.89%
> 1,000 m	40.93%

The depth of water was normally recorded whenever cetaceans were seen. The minimum, maximum and median depths for each species are presented in Table 8. Although there were occasional sightings of large whales in shallower waters, most were found in deeper waters. Pilot whales and white-sided dolphins were also predominantly seen in deep waters. Some species were found mostly over the outer continental shelf and the shelf slope e.g. killer whale. Harbour porpoise and white-beaked dolphin were the only species found primarily in shallower shelf waters.

Table 8 Median and range of depth of cetaceans encountered during seismic surveys.

Species	**Median depth of pods (m)**	**Minimum depth (m)**	**Maximum depth (m)**	**Number of pods**
Cetacean sp.	265	90	2,700	24
Whale sp.	874	65	2,711	20
All large whales combined	1,077	97	2,235	239
Large whale sp.	1,335	97	2,235	36
Humpback whale	890	853	1,008	3
Blue whale	942.5	748	1,175	4
Fin whale	1,035	325	1,670	77
Sei whale	1,550	1,550	1,550	1
Sperm whale	1,125	99	1,884	53
Fin/ sei whale	1,086	151	1,656	43
Fin/ sei/ blue whale	717	717	717	1
Fin/ sei/ humpback whale	1,077	450	1,655	15
Fin/ sei/ blue/ humpback whale	1,200	659	1,600	3
Humpback/ sperm whale	928	807	1,134	3
Medium whale sp.	89	89	89	1
Minke whale	1,000	70	1,690	35
Northern bottlenose whale	650	300	1,000	2
Pilot whale	1,011	90	1,800	134
Killer whale	735	156	2,000	16
All dolphins combined	706	36	3,479	201
Dolphin sp.	330	36	2,200	69
Dolphin sp. not porpoise	653	653	653	1
Risso's dolphin	911	200	1,500	3
Bottlenose dolphin	1,635	156	1,884	8
White-beaked dolphin	99	69	1,568	38
White-sided dolphin	950	99	1,800	49
Lagenorhynchus sp.	1,400	95	1,685	13
Common dolphin	1,357	900	3,479	13
Common/ white-sided dolphin	142	118	166	2
Patterned dolphin	89	89	89	1
Harbour porpoise	165	70	600	4

In deeper waters the proportion of large whale sightings occurring during periods of shooting was greater than in shallower waters (Table 9). The same was true for dolphins (Table 10). Median tests showed that these differences were statistically significant ($\chi^2 = 3.933$ for large whales, $\chi^2 = 5.404$ for dolphins, d.f. = 1, $p < 0.05$ for both groups). It seems unlikely that this could be due to varying amounts of seismic activity in waters of different depths as the proportion of time spent shooting was similar regardless of depth (Table 7). It may indicate a greater tolerance of seismic activity in waters of greater depth. However, none of the species encountered were sufficiently abundant in both shallow shelf waters and in deep waters to enable a more comprehensive comparison of the effects of seismic activity at different depths.

Table 9 Number of pods of large whales (all large whales combined) in relation to depth and seismic activity.

Seismic activity	Number of pods in waters < median depth (1,077 m)	Number of pods in waters > median depth (1,077 m)
Shooting	39	60
Not shooting	63	54
Total	102	114

Table 10 Number of pods of dolphins (all dolphins combined) in relation to depth and seismic activity.

Seismic activity	Number of pods in waters < median depth (706 m)	Number of pods in waters > median depth (706 m)
Shooting	18	35
Not shooting	71	60
Total	89	95

7.5 The effects of site surveys on cetaceans

As site surveys use airguns of relatively low power, data from these surveys were analysed separately. There were nine site surveys during 1997 for which data was forwarded to JNCC. The airguns were firing for only 20% of the time spent watching for cetaceans on site surveys. There were 58 sightings of cetaceans during site surveys, only ten of which occurred during periods of shooting.

As the sample sizes for site surveys were relatively small, it was not practical to take account of weather conditions when analysing the data, as this would have reduced sample sizes even further. Sighting rates of cetaceans were calculated using data from all site surveys where effort was correctly recorded. Once again, dolphins were seen more frequently when the airguns were not firing (Figure 34), with no dolphins being seen during periods of shooting. The total absence of dolphins during periods of shooting on site surveys may in part reflect the relatively small amount of effort at these times (293 hrs 26 mins). Some other species appeared to be more tolerant of the airguns, with pilot whales and unidentified large whales being seen more often when the airguns were firing. Sample sizes were too small to permit testing of the statistical significance of these results.

The mean distance of cetacean pods from the airguns was also calculated without taking account of weather conditions. Sperm whales remained much further from the airguns during periods of shooting, while pilot whales came closer when the airguns were firing (Figure 35). Permutation tests showed that these differences were not significant, although the lack of statistical significance may be due to the small sample sizes.

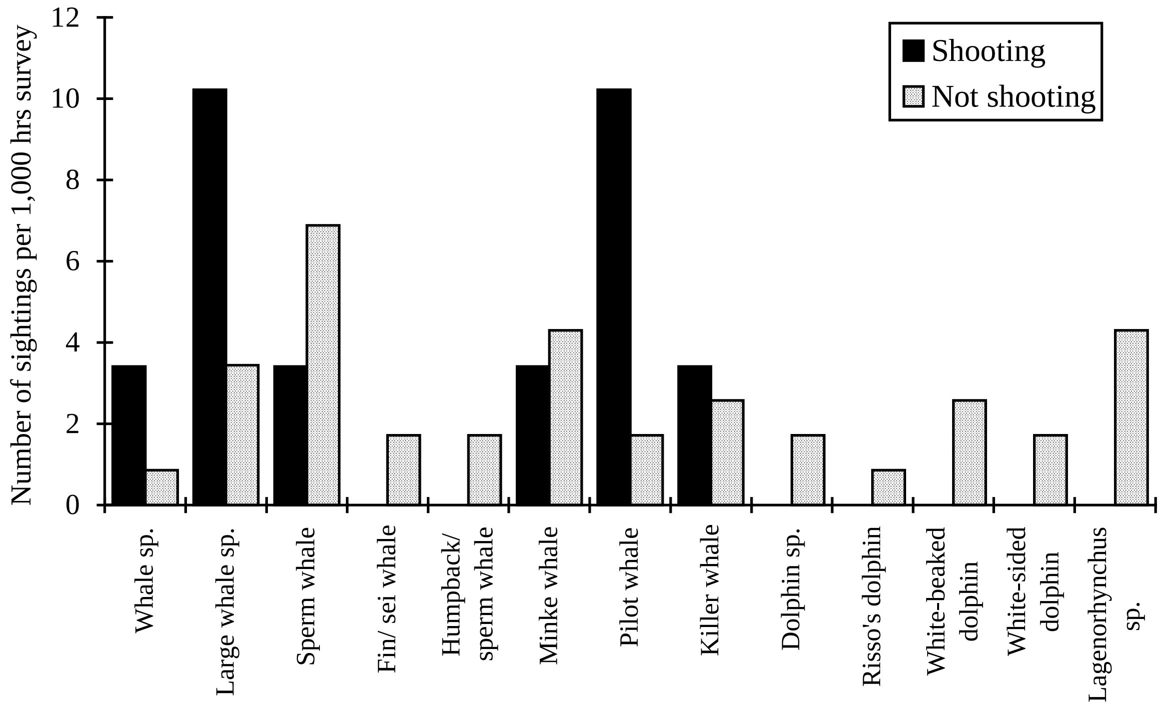

Figure 34 Sighting rates of cetaceans in relation to seismic activity during site surveys.

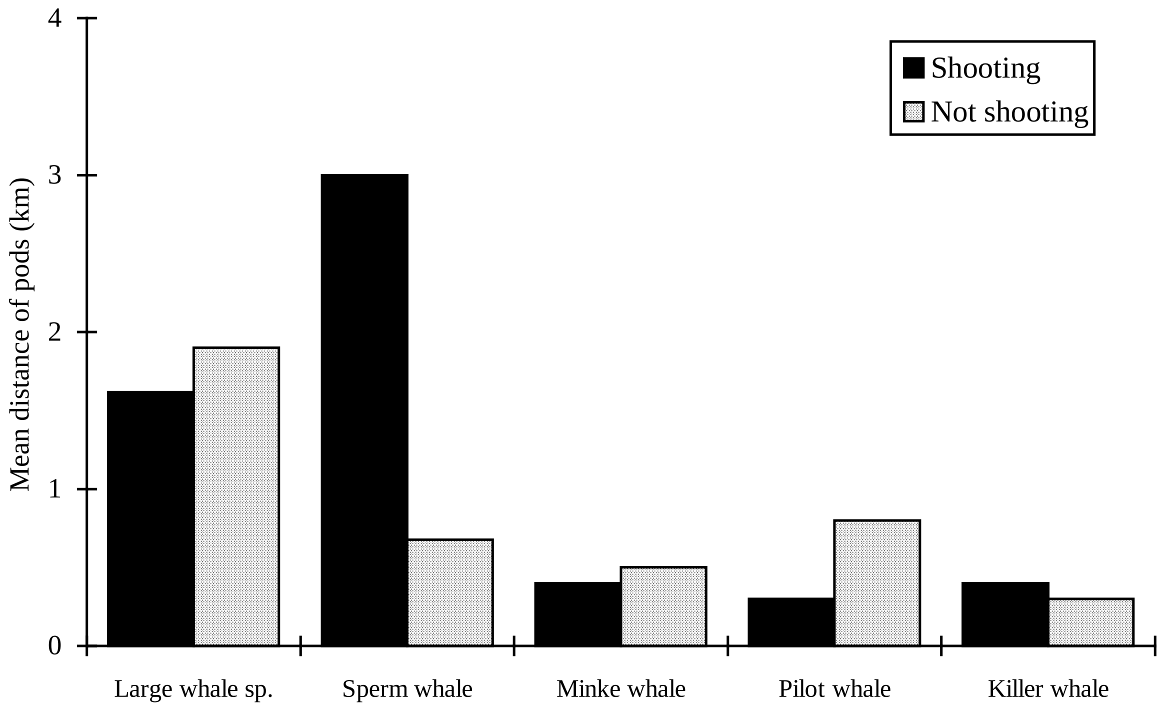

Figure 35 Mean distance of cetacean pods from the airguns in relation to seismic activity during site surveys.

Positive interactions of cetaceans with the vessel or its equipment (approaching the vessel or bow-riding) during site surveys were recorded for 23% of encounters with cetaceans when the airguns were not firing. There were no positive interactions with the vessel or its equipment recorded during periods of shooting. There were no obvious trends in the direction of travel of cetaceans relative to the ship during site surveys. While the airguns were not firing, 26% of cetaceans encountered were heading towards the ship and only 6% were heading away from the ship. During periods of shooting, no cetaceans were seen heading towards the ship, but nor were any seen heading away from the ship. Analysis of cetacean behaviour during site surveys was limited by the low number of sightings during periods of shooting. Caution should be applied when considering the absence of certain types of behaviour when the airguns were firing, as this probably reflects the lack of sightings during periods of shooting rather than any behavioural response.

8. Discussion

8.1 Distribution of cetaceans

The distribution of cetaceans seen during seismic surveys largely concurs with previous knowledge. Fin and sperm whales were seen in deep waters to the north-west of the UK, corresponding with whaling records which show that these species were caught most often in waters just beyond the edge of the continental shelf (Thompson 1928; Evans 1990). Evans (1980) considered that male sperm whales move northwards through deep waters to the west of the UK during the summer months, and some individuals may progress eastwards to the north of the UK into the northern North Sea, possibly following squid, which form the main prey of this species.

It is not clear whether, or to what extent, fin whales migrate. Fin whales appeared to be moving northwards in June. Whether this reflects part of a larger-scale migratory movement or a localised movement, perhaps following prey species, is not known. Evans (1980) suggests that at least some fin whales undergo a latitudinal migration, but recent studies using underwater acoustic systems suggest that some fin whales are present in waters to the north-west of the UK throughout the year (Clark *et al.* 1998).

Other species were also seen in areas where they were expected to occur. Pilot whales and white-sided dolphins were seen mainly in deep waters to the north-west of the UK. Pilot whales are common in north-western waters (e.g. JNCC 1995; Skov *et al.* 1995). The occurrence of pilot whales in the North Sea, although less common, is not unknown in winter months (Evans 1992). The distribution of white-sided dolphins was similar to that found previously (e.g. Stone 1997a), with some also found in waters over the continental shelf around the Hebrides and Shetland where they are also known to occur (Evans 1992). Killer whales were seen mostly in northern waters - Evans (1992) notes that although this species has a widespread distribution its abundance is greatest in colder waters.

In the North Sea the main species seen were minke whales and white-beaked dolphins, which again was as expected. Minke whale distribution concurred with that found by Evans (1980) and Northridge *et al.* (1995), with sightings to the north-west and north of Scotland as well as in the northern North Sea. White-beaked dolphins were also seen to the north of Scotland as well as in the North Sea, with further sightings in shelf waters close to the Hebrides.

Northridge *et al.* (1995) have noted that white-beaked dolphins occupy shelf waters and have a distribution centred on Scotland.

It was not surprising that the common dolphin was the most frequently occurring species to the west of Ireland. The distribution of common dolphins in north-west European waters is predominantly south-westerly (JNCC 1995), although they are also known to occupy more northern waters (Skov *et al.* 1995). The concentration of common dolphins to the south-west of the Hebrides was therefore not unusual.

Some species were seen less often than might have been expected. There were few sightings of Risso's dolphins; more might have been expected in areas where they are known to occur, such as the inshore waters around the Hebrides (Evans 1992; JNCC 1995). However, relatively little time was spent in inshore waters near the Hebrides, with vessels in these waters being mainly in transit to offshore waters. Similarly, there were not many sightings of harbour porpoises, although this is one of the most widespread cetacean species found in UK waters (JNCC 1995; Northridge *et al.* 1995). Certainly it might have been expected that more would be seen in the North Sea. This species is often difficult to detect due to its small size and shy nature.

Bottlenose dolphins are normally considered to be an inhabitant of inshore waters, although offshore populations do exist (e.g. Skov *et al.* 1995). During seismic surveys this species was seen mainly in deep waters to the north-west of the UK. The lack of sightings of this species in inshore waters, particularly around the Moray Firth where there is a resident population, probably reflects the fact that relatively little time was spent in inshore waters by seismic survey vessels.

8.2 The effects of seismic activity on cetaceans

Since the *Guidelines for minimising acoustic disturbance to small cetaceans* have been in operation, the data gathered during seismic surveys has been used in an attempt to assess the effects of seismic activity on cetaceans. The results from the present study on the whole agree with those of previous studies (Stone 1996, 1997a,b).

Dolphins were more strongly affected by seismic activity than other species. Sighting rates of both white-beaked dolphins and white-sided dolphins were lower during periods of shooting. Similar results have been found previously for both species (white-beaked dolphins: Stone 1997a; white-sided dolphins: Stone 1996, 1997b). Only one previous study has found that sighting rates of white-sided dolphins did not differ significantly between periods of shooting and not shooting (Stone 1997a), but in that study the influence of weather on the ease of detection of cetaceans could not be taken into account. In addition to a reduction in sighting rates, dolphins also showed other responses to seismic activity. White-sided dolphins remained further from the airguns when they were firing, which also agrees with previous results (Stone 1996, 1997a,b). During periods of shooting more pods of white-sided dolphins altered course away from the ship, while common dolphins and white-beaked dolphins engaged less often in positive interactions with the vessel. Even during low power site surveys dolphins were seen less frequently during periods of shooting, although sample sizes were too low to assess the statistical significance of this.

As was found previously (Stone 1997b), white-sided dolphins were apparently more tolerant of seismic activity when they were in association with pilot whales, remaining closer to the airguns during periods of shooting when pilot whales were present. There are two possible explanations for this. One is that white-sided dolphins, often regarded as a sociable species (e.g. Cawardine 1995), associates with other species as a means of protection. The other is that the sociable instincts of white-sided dolphins are sufficiently strong as to override the deterrent effects of seismic activity.

The largest odontocete occurring in UK waters, the sperm whale, has previously not been seen in sufficient numbers to assess the effects of seismic activity on sighting rates. In the present study, no significant differences were found in sighting rates of sperm whales between periods of shooting and not shooting. Similarly, there were no significant differences in the distance at which sperm whales were seen from the airguns whether the airguns were firing or not, which was also the case in previous studies (Stone 1997a,b). However, sperm whales were observed to dive more frequently when the airguns were firing.

The only positively identified species of large baleen whale occurring in sufficient numbers to assess the effects of seismic activity was the fin whale. Sightings of fin whales in the Rockall area declined after June, but there was a corresponding increase in fin whales to the West of Shetland from July. It seems unlikely that fin whales were avoiding seismic activity in Rockall as there was more seismic activity to the West of Shetland than in Rockall, yet sightings there did not decline as the season progressed. Sighting rates of fin whales did not differ significantly between periods of shooting and not shooting, nor did their distance from the airguns. One previous study found that fin whales were seen more often during periods of shooting, but were further from the airguns at those times (Stone 1997a). In that study, weather conditions were not taken into account when assessing sighting rates or when calculating mean distance from the airguns. The tendency to shoot in better weather conditions can result in cetaceans being seen in greater numbers and at greater distances during periods of shooting. Weather conditions have been taken into account in some previous studies (Stone 1996, 1997b) as well as in the present study; the results from these previous studies match the present results. Thus it seems that fin whales are not affected by seismic activity in terms of the numbers encountered or their distance from the airguns. However, there were indications of some more subtle effects of seismic activity. Fin whales tended to swim at an increased speed and altered course more often when the airguns were firing, and were less likely to engage in positive interactions with the vessel.

The smaller minke whale (a baleen whale) was not seen in sufficient numbers to assess the effects of seismic activity on sighting rates, but this species was seen at significantly greater distances from the airguns when they were firing. Previous studies found that the distance of minke whales from the airguns did not differ significantly between periods of shooting and not shooting (Stone 1997a,b), although sample sizes in these cases were smaller than in the present study.

The one species where the results from studies so far give a confusing picture is the pilot whale. Indications are that pilot whales may be attracted to the low power airguns used for site surveys, being seen more frequently and at closer distances to the airguns during periods of shooting on these surveys. This confirms previous findings (Stone 1997b). However, there is no consistency between the studies with regard to sighting rates of pilot whales during seismic surveys. Sighting rates have been found to be similar regardless of seismic activity (Stone 1997a), higher when the airguns were not firing (Stone 1997b), and, in the present study, higher during periods of shooting. This merits further consideration of the possible causes of the variation in these results. The present study has a larger sample size for pilot whales than previous studies, which should make the results more reliable. The higher sighting rate of pilot whales observed during periods of shooting could reflect an increased abundance not evident in earlier studies with smaller sample sizes, signifying that pilot whales are tolerant of seismic activity. Alternatively, there are some factors that may have influenced the present analysis, leading to results that conflict with previous studies. It is possible that some low power surveys were analysed together with seismic surveys in the present study, as little information was received regarding the technical characteristics of each survey. If pilot whales were attracted to low power sources, this could have contributed to the increased sighting rate observed during periods of shooting. Similarly, pilot whales could have been attracted to the low power firing during the soft-start. It is also possible that the increased sighting rate during periods of shooting reflects a change in behaviour making pilot whales more conspicuous at these times. The increased swimming speed of pilot whales sometimes observed during periods of shooting may have increased the ability of observers to detect pilot whales. This may be a particular problem where many observers are used, as in the present study, including some less experienced ones.

It is not inconceivable that pilot whales, known for their curiosity, may be attracted to airguns during seismic surveys, and that this might lead to increased sighting rates during periods of shooting. However, other observed responses were not consistent with this. During periods of shooting, relatively more pods of pilot whales swam away from the vessel and fewer engaged in positive interactions with the vessel. As in previous studies (Stone 1997a,b), there were no significant differences in the distance at which pilot whales were seen between periods of shooting and not shooting, which neither supports nor refutes the idea that pilot whales may be attracted to the airguns. One possible explanation of the observed effects is that pilot whales may initially be curious and appear in the vicinity of the vessel when the airguns are firing, but that they do not linger and instead leave again.

A pattern is emerging which suggests that, contrary to earlier expectations, dolphins are more affected by seismic activity than the large baleen whales. Many of the baleen whales communicate at frequencies which overlap with those used by airguns, which typically generate sound with frequencies of 1-200 Hz. For example, fin whales use low frequency sounds at 10-750 Hz and blue whales have sounds with frequencies in the range 12-390 Hz (Evans & Nice 1996, from various sources), although both species also use higher frequency sounds. Most dolphins, on the other hand, use sounds that are almost all of higher frequency. White-sided dolphins whistle at dominant frequencies of 6-15 kHz, and white-beaked dolphins have squeals at 8-12 kHz (Evans & Nice 1996, from various sources). Other odontocetes also use higher frequencies than baleen whales - sperm whales produce clicks with dominant frequencies of 2.4 kHz and 10-16 kHz, and pilot whales whistle at dominant frequencies of 1.6-6.7 kHz (Evans & Nice 1996, from various sources). These species also seem to be less affected than the dolphins. Although dolphins use frequencies much higher than those typically generated by airguns, it is probable that airguns incidentally emit higher frequency sounds (Goold 1995). In addition to white-sided and white-beaked dolphins, common dolphins have been found at reduced abundance during periods of seismic activity (Goold 1996). Richardson *et al.* (1995) considered that the sensitivity of odontocetes to low frequency noise below 1 kHz may be poor, although their ability to hear high frequency noise is very good.

Although baleen whales such as fin whales seem to be relatively unaffected by seismic activity, there may be more subtle effects which were not within the scope of the present study. There have been some cases of cetaceans responding to seismic activity by altering their respiration and dive cycles even when avoidance was not apparent (Richardson *et al.* 1985). These types of response have sometimes been evident even at considerable distances (6-99 km) from the source (Richardson, Würsig & Greene 1986). Fin whales have been found to have shorter blow intervals during periods of shooting, although not significantly so (Stone 1997b). However, more data and increased sample sizes may lead to previously undetected effects being discovered.

Although studies so far have indicated that there is some disturbance to cetaceans, especially dolphins, from seismic activity, it is still unclear to what extent this poses a threat to cetaceans. Some cetaceans were seen relatively close to the airguns during periods of shooting, and there were some instances of positive interactions with the vessel or its equipment during periods of shooting. It appears that at least some individuals are tolerant of seismic activity. Cetaceans were seen more frequently from seismic survey vessels in 1997 than in previous years, although this almost certainly reflects an increase in the number of reports received from surveys and an increase in awareness amongst the crews of survey vessels, rather than an actual increase in cetacean numbers. Similarly, cetacean sightings in the areas surveyed continued throughout the summer, even though seismic activity had commenced early in the season. It seems that seismic activity may result in short-term displacement and/ or behavioural reactions in some species, but whether it constitutes a major threat is, as yet, unknown.

Although the continued presence of cetaceans may indeed be evidence that disturbance is not excessive, there are several reasons why caution should be exercised when making such interpretations. Cetaceans continued to be seen throughout the duration of most surveys, but it is not known whether the same individuals returned or whether later sightings were new individuals passing through. Furthermore, even though cetaceans may not abandon areas where there is seismic activity, Richardson *et al.* (1995) point out that they may have no choice but to remain in these areas. This may apply particularly where neighbouring areas are subject to seismic activity. Figure 1, which shows the quadrants from which reports were received during 1997, indicates that seismic activity was widespread in UK waters in 1997. A lack of suitable refuge areas may be exacerbated if noise from seismic sources propagates over long distances. Finally, studies so far have concentrated on short-term effects, and longer-term effects on individuals and populations may remain undetected for many years.

Other factors may have influenced sighting rates and distribution of cetaceans, the most obvious of these being the distribution and abundance of prey species. However, this in turn may be affected by seismic activity. Fish have sometimes been recorded as being affected by seismic activity (Turnpenny & Nedwell 1994), but there is no knowledge of whether prey species were affected by seismic activity in UK waters in 1997.

There is still a need for the *Guidelines for minimising acoustic disturbance to small cetaceans* (now the *Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys*) to be followed by both site and seismic surveys, and for the requirements of the guidelines to be observed in full for all species. Although surveys with low power sources, such as site surveys, could conceivably cause less disturbance than surveys with higher power sources, the data from site surveys is so far limited and therefore it is too early to draw conclusions about their effects on cetaceans. The information gathered so far indicates that while some species, such as pilot whales, may be tolerant of acoustic emissions from site surveys, other species, such as dolphins, may be affected by site surveys in much the same way as they are by larger scale seismic surveys. Until the effects of site surveys are better documented, the guidelines should be applied to them. There is clearly a need for seismic surveys to continue to observe the guidelines, especially where dolphins are concerned; the possibility of as yet undetected subtle and/or long-term effects also necessitates application of the guidelines to all cetacean species (as has been the general practice to date). Furthermore, there are a number of species which are known to occur regularly in UK waters (e.g. blue whale, sei whale, northern bottlenose whale, Risso's dolphin, bottlenose dolphin, harbour porpoise) for which there are not yet sufficient data available to assess the effects of seismic activity, therefore it is important that the guidelines apply equally to all species.

8.3 Quality of observations

In 1995, 43% of sightings were identified to species level, while in 1996 this proportion increased to 57% (excluding sightings made by experienced cetacean observers) (Stone 1997a). During 1997, only 39% of sightings were identified to species level with the identification being categorised as "definite" (again excluding the few surveys where experienced cetacean observers were used). At first sight this appears to imply that the ability of observers to identify cetaceans has decreased since previous years. However, the figure for 1997 is not strictly comparable with earlier years. In 1997 the data was treated much more rigorously than in previous years, with an adequate description being regarded as an essential pre-requisite to a definite identification. As a consequence many more identifications were not accepted and were down-graded. Many of these identifications may have been correct, but there was insufficient information to confirm this. As many observers have now undergone training all records should be accompanied by adequate descriptions. The decrease in the proportion of sightings identified to species level in 1997 probably reflects the more rigorous standards now applied, rather than a decrease in the ability of observers to identify cetaceans. The 1997 figure should be taken as a more accurate assessment of the identification skills of observers than the figures from previous years, which were assessed often giving observers the benefit of the doubt.

The more rigorous standards applied have been made possible because those descriptions received were generally more detailed than they have been in previous years. However, although descriptions showed a level of improvement, in some cases they were still insufficient to confirm the observer's identification. Excluding records from experienced cetacean observers, 26% of all sightings had a description which was not sufficient to distinguish the animal from other similar species even though these sightings were identified by the observer to species level. All of these records were down-graded. A further 14% of sightings had no accompanying description, and these were also down-graded in cases where the animal had been identified by the observer. There were no sightings by experienced cetacean observers that had to be down-graded.

There have been a number of training courses for observers during 1997, and there is some evidence that identification skills have actually improved. Only in a small number of cases (5%) were sightings identified to species level but the identification was definitely wrong, i.e. did not agree with the description given. There has been a decrease in the proportion of sightings that were not identified beyond "cetacean", "whale", "large whale" or "dolphin". In 1996 these categories accounted for 42% of sightings (excluding those by experienced cetacean observers), whereas in 1997 this figure dropped to 27%. However, this is still much higher than the proportion of unidentified sightings by experienced cetacean observers, which typically may be less than 10%.

In terms of the operation of the *Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys* correct identification is not necessary. It is essential though, that observers are skilled at detecting marine mammals. Direct comparisons with other sets of data are difficult, due to the different nature of the surveys. Most distribution surveys use ships travelling at faster speeds than seismic survey vessels and cover a wider area, and furthermore results are expressed in terms of number of sightings per km rather than number of sightings per 1,000 hours. However, extrapolation from Northridge *et al.* (1995) indicates that the rate sightings of harbour porpoises and white-beaked dolphins were at least an order of magnitude less during seismic surveys. On the other hand, the rate of sightings of fin whales and sperm whales during seismic surveys to the north-west of the UK far exceeds that of standard distribution surveys (e.g. Bloor *et al.* 1995). These differences probably partly reflect the different platforms used for observations.

"Location and Effort" forms were competed correctly for 37 of the 58 surveys. Observers on a further five surveys completed earlier versions of these forms, which had details of effort but not of weather conditions. Two of the five surveys where older versions of the forms were used commenced at about the time that the new forms were issued, therefore the use of previous versions is understandable. "Location and Effort" forms were completed incorrectly for 18% of surveys. The most common mistake, accounting for 81% of errors, was that the number of hours recorded as shooting during the watch for cetaceans exceeded the number of hours spent watching for cetaceans, which is clearly impossible. It seems likely that in these cases observers were actually copying from the ship's log the number of hours spent shooting throughout a 24 hour period, which would include hours when there was no watch for cetaceans. This error prevented the calculation of sighting rate of cetaceans in relation to seismic activity for those surveys. A common error in previous years was to only complete the "Location and Effort" form on days when cetaceans were seen, but this only occurred on one survey in 1997. For 11% of surveys no "Location and Effort" forms were used (a reduction from 30% of surveys in 1996).

To summarise, although there have been improvements in the quality of observations, the level of improvement is not as great as would be preferred. Not surprisingly, there is a big difference between the standard of observations received from experienced cetacean observers and those from other observers, who are usually fishery liaison representatives or members of the ship's crew. It seems logical that in areas important for cetaceans operators and contractors should seek to recruit personnel who are best suited to act as cetacean observers. In view of the current revision of the guidelines, it is anticipated that experienced cetacean biologists will be more widely used in future. Where fishery liaison representatives are still used as cetacean observers it is important that future training should incorporate items to address the errors identified during 1997. There are still some observers who have not yet attended any training courses - these observers should receive training.

8.4 Compliance with guidelines

The conditions and restrictions attached to blocks licensed in the 16th and 17th rounds of offshore licensing require that seismic exploration shall be conducted in accordance with the

Guidelines for minimising acoustic disturbance to small cetaceans (now the *Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys*). As part of the guidelines, operators are required to contact JNCC when planning a seismic survey to determine the likelihood that cetaceans will be encountered, and to send a report to JNCC after the survey. There were a total of 43 surveys in blocks licensed in the 16th and 17th rounds for which JNCC received notifications and/or reports during 1997. Both notifications and reports were received for 22 of these surveys, while for 17 surveys notifications were received but no reports and for 4 surveys reports alone were received (Figure 36). The proportion of surveys that were both notified and reported has increased since 1996, when 38% were both notified and reported. Similarly the number of surveys about which JNCC is not notified has decreased (45% in 1996, 4% in 1997). However, with the increase in numbers of notifications it has become apparent that there were still a number of surveys being carried out in 16th and 17th round blocks in 1997 from which no reports were received. Enquiries revealed that during some of these surveys, no cetaceans were seen. "Location and Effort" forms should nevertheless have been completed for these surveys, but apparently this was not done. On one survey data was accidentally lost. This still leaves 26% of surveys that JNCC was notified of for which reports are still outstanding. Overall though, it should be noted that even though there is room for improvement in the notification and reporting of surveys, many more reports and notifications were received in 1997 than in previous years.

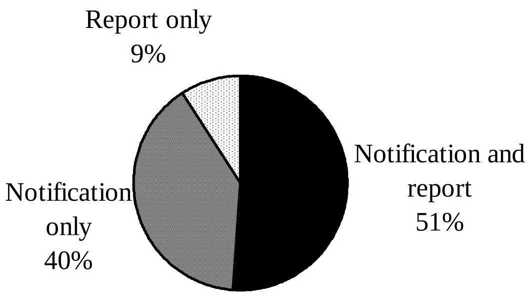

Figure 36 Proportion of seismic surveys being notified and/or reported to JNCC.

Although reports were received from 58 surveys, 32 of these occurred in blocks other than those licensed in the 16th and 17th rounds. This demonstrates the high level of co-operation of the industry in supplying data from surveys in blocks licensed prior to the 16th round, where the license conditions do not require compliance with the guidelines. It is pleasing to note industry and contractor commitment to carrying out surveys in accordance with the guidelines over all the UK continental shelf, and in several cases, further afield.

Completion of the recording forms is only one requirement of the *Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys*, and is useful mainly as a tool for research into the effects of seismic activity on cetaceans and also in helping to gain a wider picture of the importance of some areas to cetaceans. Completion of the forms, in itself, will not reduce disturbance to cetaceans. It is more important, in terms of minimising disturbance to cetaceans, that an observer checks whether cetaceans are present prior to any use of the airguns, and acts accordingly i.e. recommends a delay if cetaceans are within 500 m when the airguns are about to start firing. In areas of importance for cetaceans, the use of a qualified and experienced cetacean biologist to act as a dedicated observer may be a better means of fulfilling this responsibility than the use of fishery liaison representatives. Amongst other issues, fishery liaison representatives have other duties which place demands on their time and could result in cetaceans passing by undetected, particularly in areas where cetaceans are abundant. In such circumstances it is unrealistic to expect one person to fulfil two roles simultaneously. An incidental benefit of using qualified and experienced cetacean biologists would be observations of a better scientific quality, thus improving current knowledge of the effects of seismic activity on cetaceans.

Although the guidelines suggest that reports to JNCC should include details of any problems encountered in complying with the guidelines and technical details of the survey (e.g. airgun frequency and intensity), the majority of reports contain nothing other than the standard recording forms i.e. "Location and Effort" and "Record of Sighting" forms. Only two surveys in 1997 reported delays in commencing firing due to the presence of cetaceans. No delays have been reported in previous years. It can only be assumed that compliance with the guidelines is not causing an undue number of delays. It would be helpful if more reports of the ease or difficulty of applying the guidelines were received.

In one of the surveys from which delays were reported there were three delays in the first month due to the presence of white-beaked dolphins. After this first month, a practice of continuous shooting was adopted on this survey, whereby the airguns continued firing between survey lines but at approximately one third of the normal power output. After the continuous shooting practice was adopted, 89% of white-beaked dolphin sightings occurred while the airguns were firing at low power in between survey lines. Under the current guidelines, a delay is only necessary if cetaceans are close by when firing is about to commence, and not when firing is already underway. Therefore, by shooting continuously on this survey, no further delays were required under the guidelines in their current form. This type of practice seems to be contrary to the principles of the guidelines. Continuous shooting aims to deter cetaceans and relieves the operator of the need to take any action if cetaceans are present, whereas the guidelines operate on the principle that cetaceans and seismic surveys can co-exist if appropriate measures are taken, with periods of no noise. Repeated exposure to noise may in some cases lead to habituation of cetaceans, whereas in other cases it may result in increased sensitisation (Richardson *et al.* 1995). At present, there is no evidence of either habituation or increased sensitisation of cetaceans to seismic activity. Certainly, continuous firing at low power between the survey lines did not make white-beaked dolphins any more tolerant of firing at full power.

Present knowledge is insufficient to assess whether continuous shooting would be an acceptable practice in areas where cetaceans occur frequently. It could be argued that, if suitable alternative areas were available to cetaceans, it would seem better to keep them away from a seismic survey by continuous shooting. However, current knowledge is insufficient to predict whether adjacent areas would be suitable habitats at a given time. If cetaceans had no choice but to remain in a survey area, for example if the habitat there provided better feeding opportunities than elsewhere, then it would be better to allow them some respite from shooting between survey lines and use the normal soft-start procedures when commencing firing. As it is not possible to predict with confidence which areas present suitable habitats for cetaceans, the normal procedure of ceasing firing between survey lines and then using a soft-start when re-commencing is the best option. There is admittedly a risk that the frequent presence of cetaceans may necessitate many delays during the course of a survey, but this is the only instance since the guidelines came into operation in 1995 when JNCC have been informed of a problem in complying with them. The only other survey from which a report of a delay was received in 1997 had just one delay in over three months of operation. It therefore seems that the risk of frequent delays is minimal.

8.5 Recommendations for revisions of recording forms

There are a few minor changes to the recording forms that would improve the accuracy of the analysis of data. Although sea state is already recorded on the "Location and Effort" forms, there are some days when calm seas are accompanied by a large swell, inhibiting the detection of cetaceans. Some observers have added a note to the form if this is the case, but it would be better if swell were routinely recorded, so space has been added for this. One other improvement to the "Location and Effort" form is that the type of survey, e.g. site, 2D, 3D etc., should be included. There is only one recommended change to the "Record of Sighting" form. Sometimes cetaceans are seen when there is no specific watch for them. Including such sightings when calculating the number of sightings per unit effort leads to an inflated estimate of the sighting rate. To enable the analysis to be more accurate, the "Record of Sighting" form now includes a box which observers are asked to tick to indicate whether the sighting occurred whilst a continuous watch was being kept or whether it was incidental.

There is also a need for a standard recording form to monitor the operation of the guidelines. Reports on their ease of use or problems encountered in complying with them are rare. In order to gain more feedback on this, a standard form has been devised which should be completed each time the airguns are used. This form requests details about the checks made for the presence of marine mammals prior to starting firing, the duration of the soft-start, the duration of firing, and any problems encountered in detecting marine mammals.

In line with the current revision of the guidelines, the recording forms have been amended from "Cetacean Recording Forms" to "Marine Mammal Recording Forms" and accordingly they should be completed for all watches and sightings of any marine mammals, including seals as well as cetaceans. Revised recording forms are included in Appendix 3.

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11. Appendices

Appendix 1	Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys
Appendix 2	Cetacean recording forms used in 1997
Appendix 3	Proposed revised recording forms for 1998 and guide to using recording forms
Appendix 4	Scientific names of species mentioned in the text

Appendix 1

Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys

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

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.

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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.

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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.

Appendix 2

Cetacean recording forms used in 1997

CETACEAN RECORDING FORM - LOCATION AND EFFORT DATA

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

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

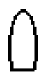
Date	Observer	Block number	Number of daylight hours during which a watch for cetaceans was kept	Length of time seismic guns were shooting during the watch	Wind force (Beaufort) and direction	Sea state Choose from: G = glassy S = slight C = choppy R = rough	Visibility Choose from: P = poor M = moderate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

Return to: JNCC, Dunnet House, 7 Thistle Place, Aberdeen, AB10 1UZ (Fax. 01224 621488).

CETACEAN 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="2">Ship</td><td colspan="2">Observer</td></tr>
<tr><td colspan="3">Position</td><td>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 cetaceans in relation to ship (draw arrow)
</td></tr>
<tr><td colspan="3">Behaviour</td><td>Direction of travel of cetaceans (compass points)</td></tr>
<tr><td>Activity of ship</td><td colspan="2">Airguns firing
Yes / No</td><td>Closest distance of cetaceans 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).

Appendix 3

Proposed revised recording forms for 1998 and guide to using recording forms

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 tasker_m@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 tasker_m@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 tasker_m@jncc.gov.uk).

GUIDE TO USING MARINE MAMMAL RECORDING FORMS

There are three forms to be completed: the first contains a summary of seismic operations ("Record of Operations"), the second contains basic information on where you looked for marine mammals and how long you looked for ("Location and Effort Data"), and the third contains information on each sighting of marine mammals ("Record of Sighting").

Record of Operations

This form requires you to fill in information on how the *Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys* were applied during the survey. You are asked to provide simple information such as the times you started and stopped looking for marine mammals, and the times the airguns started and stopped. You will need to know when the "soft start" began, and when the airguns reached full power - this is not necessarily the same as the start of line (the airguns may reach full power before the start of line). You will need to record whether marine mammals were seen prior to the airguns starting firing, and what action was taken if necessary under the guidelines.

Location and Effort Data

One line on the "Location and Effort" form should be filled out for each day, regardless of whether you actually see any marine mammals or not. This form includes basic information e.g. date, ship's name, survey type, observer's name, block number and weather. You will need to note the number of daylight hours over which a watch for marine mammals was kept and how long the airguns were firing during the watch for marine mammals (this should include any times when the guns were firing e.g. during the run-in to a line or when being tested, as well as the time spent shooting a line, but not time spent firing when there was no watch for marine mammals). This information is important to assess the effects of seismic activity on marine mammal abundance. 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 19 knots, so that we can convert it to Beaufort later. Swell should be recorded as low (0-2 m), medium (2-4 m) or large (> 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 out 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.

How did this sighting occur You should indicate whether you were keeping a continuous watch for marine mammals at the time of the sighting. Sometimes someone else may call your attention to a marine mammal that you would otherwise not have seen - we need to know this so that we can make an accurate assessment of abundance.

Position This is the position at the time of the sighting.

Depth This should be in metres - if it is in any other unit e.g. fathoms, please specify this.

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/striped/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 useful to include a description of the animal, even if you are certain which species it is. 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. 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); this could be drawn on the back of the form if more space is needed.

Photograph or video taken If you have the opportunity to photograph or video the animal this may be used later to help in identification.

Direction of travel of animals The direction of travel should be given in two ways - in relation to the boat, 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
- porpoising
- breaching (animal launches itself out of the water and falls back in)
- tail-slapping (animal slaps tail on the water surface)
- sky-pointing (animal almost vertical in the sea with its 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, 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 seen.

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 instead.

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

The forms should be returned to:

[*Oil company name*]
[*Oil company address*]

or if unsure to:

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

Tel. 01224 655704
Fax. 01224 621488

Appendix 4

Scientific names of species mentioned in the text

Humpback whale	*Megaptera novaeangliae*
Blue whale	*Balaenoptera musculus*
Fin whale	*Balaenoptera physalus*
Sei whale	*Balaenoptera borealis*
Sperm whale	*Physeter macrocephalus*
Minke whale	*Balaenoptera acutorostrata*
Northern bottlenose whale	*Hyperoodon ampullatus*
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*
Harbour porpoise	*Phocoena phocoena*