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Cetacean observations during seismic surveys in 1998

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1. Summary

1. Recording of cetaceans during 1998 operations in UK waters and some adjacent areas, in compliance with the *Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys (April 1998)*, yielded a total of 518 sightings comprising 4,175 individuals. There were only four sightings of seals. The total time spent watching for marine mammals during seismic surveys in 1998 was 15,834 hrs 21 mins.

2. The most frequently seen species was the pilot whale. Fin whales, sperm whales, white-sided dolphins, common dolphins and minke whales were also seen in moderate numbers, with lower numbers of other species. Sightings of cetaceans peaked in July, with most occurring in waters to the north and west of the UK, which reflected the location and timing of surveys.

3. Allowing for factors such as geographical distribution, seasonal variations in sightings, weather conditions and the power output of the airguns, the sighting rate of all baleen whales combined was found to be higher when the airguns were firing during seismic surveys. It was thought that this could possibly reflect an increased tendency to remain near the water surface during periods of shooting, and thus be more visible. Sighting rates of fin whales, fin/sei whales, sperm whales, pilot whales, all dolphins combined and white-sided dolphins did not differ significantly with seismic activity.

4. After taking account of weather conditions at the time of sighting, fin whales and all baleen whales combined were found to be significantly further from the airguns when they were firing than when they were not.

5. More subtle effects of seismic activity were observed in many of the species examined. Feeding was observed more often when the airguns were not firing than when they were firing. More cetaceans were seen heading away from the survey vessel when the airguns were firing, while more were heading towards or in the same direction as the vessel when the airguns were not firing. Positive interactions with the survey vessel occurred less frequently during periods of shooting. Baleen whales were more likely to dive when the airguns were not firing.

6. Behaviour indicating a 'startle' response was observed on two occasions when cetaceans were present as the soft-start commenced, once involving pilot whales and once involving a sperm whale.

7. Responses of cetaceans to seismic activity were generally less than has been demonstrated in previous years. Low sample sizes may have led to non-significant results. Alternatively, cetaceans may have tolerated seismic activity because it was of some benefit to them to remain in the area. Increased numbers of cetaceans observed feeding in 1998 suggested that the presence of prey in areas subject to seismic activity may have led to an increased tolerance of seismic activity when compared to previous years.

8. Sample sizes were too small to permit conclusions to be drawn regarding the effects of site surveys on cetaceans.

9. The proportion of seismic surveys during 1998 (in blocks licensed in the 16th and 17th rounds) for which JNCC received both notification and a report was 56%.

10. The duration of searches for marine mammals prior to shooting met or exceeded the required minimum of 30 minutes on 88% of occasions when the airguns were used during daylight hours in blocks licensed in the 16th and 17th rounds of offshore licensing. On 35 out of 926 occasions there was no search for marine mammals prior to shooting commencing during daylight hours in these blocks. There were a further 81 instances where the search in these blocks was shorter than the required 30 minutes. Reduced duration of searches was more common in blocks licensed prior to the 16th round of offshore licensing.

11. Excluding site surveys, where a soft-start was not always possible, most soft-starts were between 20 and 40 minutes duration. However, 14% of soft-starts in 16th/17th round blocks were either absent or shorter than the required minimum duration of 20 minutes. Absent or short soft-starts occurred much less frequently when dedicated marine mammal observers were on board the survey vessel.

12. Dedicated marine mammal observers were found to be more efficient at detecting marine mammals than other personnel - the mean sighting rate of dedicated marine mammal observers was more than seven times higher than that of other personnel.

13. Marine mammals were seen within 500 m of the airguns prior to shooting commencing on ten occasions in 16th/17th round blocks, requiring a delay in shooting in order to comply with the *Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys*. Correct procedures were followed on two of these ten occasions. On the two occasions when correct procedures were followed, dedicated marine mammal observers were present.

14. Recommendations for future revisions to the guidelines are made. Such revisions might include a maximum duration of the soft-start, action to be taken if marine mammals are detected during the soft-start, prohibition of unnecessary shooting, extra protection for vulnerable species, and consideration of the effects of time-sharing.

2. Introduction

In February 1995, in response to the Agreement on the Conservation of Small Cetaceans in the Baltic and North Seas (ASCOBANS), the then Department of the Environment published the *Guidelines for minimising acoustic disturbance to small cetaceans*. These guidelines aimed to reduce disturbance to cetaceans from seismic surveys, where airguns are used to generate sound, mostly of low frequency. Baleen whales, which also produce low frequency sounds, are considered to be vulnerable to disturbance from seismic surveys (e.g. Moscrop & Simmonds 1994 and references therein). Toothed whales and dolphins use higher frequency sounds for communication and echolocation, but as seismic operations may incidentally emit high frequency sounds (Goold & Fish 1998) these species may also be vulnerable to disturbance (Goold 1996; Stone 1996, 1997a, b, 1998a, b).

Since their original publication, the guidelines have been revised twice by the Joint Nature Conservation Committee (JNCC). In the latest revision (April 1998) the guidelines were expanded to include all marine mammals, and were thus renamed the *Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys* (Appendix 1). Under the guidelines, operators are required to consult JNCC when planning a seismic survey (including site surveys) in UK waters and, if necessary, discuss precautions that can be taken to reduce disturbance. The timing of surveys should be planned to reduce the likelihood of encounters with marine mammals. Operators are advised to provide appropriately qualified and experienced personnel to act as marine mammal observers on surveys taking place in areas of importance for marine mammals. Throughout a seismic survey, the guidelines require that prior to commencing shooting observers should make a careful check for the presence of marine mammals within 500 m. If any marine mammals are detected then shooting must be delayed until at least 20 minutes have elapsed since the animals were last seen. Whether marine mammals are detected or not, a soft-start procedure should be employed whenever possible, gradually building up the airgun power over at least 20 minutes from a low energy starting level. In addition, the lowest practicable energy levels should be used throughout the survey. Operators are also required to send a report to JNCC after the survey, including details of the implementation of the guidelines, the time spent watching for marine mammals and any sightings that occurred. Standard forms designed by JNCC are available for this purpose (Appendix 2). The results of the analysis of data recorded during 1998 are presented here.

3. Methods

Watches for marine mammals were carried out on seismic survey vessels throughout daylight hours on surveys conducted during 1998. Details of seismic (= airgun) activity, the watch for marine mammals and any sightings were recorded on standard recording forms. Data from 58 surveys were forwarded to JNCC, covering 90 quadrants (Figure 1).

Observers were asked to provide descriptions of marine mammals to support their identification. Where descriptions were missing or inadequate, or did not correspond with the identification given, then identifications were amended on the basis of the information available. This usually involved downgrading of identifications from one species to a group of similar species which the animal could have been, based on the description given. For example, if an observer identified an animal 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 videos of cetaceans were forwarded to JNCC and used to confirm identification. Videos were viewed prior to examining the recording forms, to allow an independent assessment of identification without knowledge of what the observer believed the species to be. Where this assessment of identification differed considerably from the observer's identification, 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 (78% 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 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 geographical areas (Figure 1). Weather conditions were recorded daily (or occasionally more frequently) by observers, with sea state classed as 'glassy', 'slight', 'choppy' or 'rough', swell as 'low', 'medium' or 'large', 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).

Species maps were drawn after summing the number of individuals of a species in each ¼ ICES square (15' latitude x 30' longitude). All maps were plotted using DMAP for Windows, and show the 1,000 m isobath.

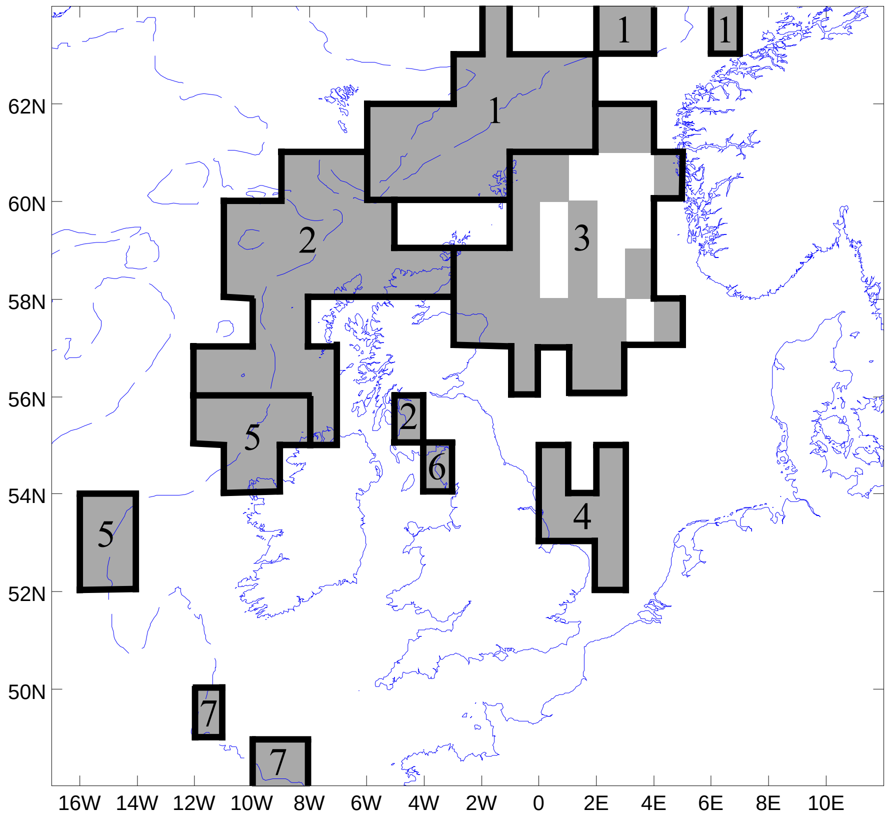


Figure 1 Quadrants surveyed for marine mammals from seismic survey vessels in 1998, and areas used in analysis: 1) West of Shetland; 2) Rockall; 3) Northern North Sea; 4) Southern North Sea; 5) West of Ireland; 6) Irish Sea; 7) South-West Approaches.

4. An overview of marine mammal sightings and survey effort

There were a total of 518 sightings of cetaceans (4,175 individuals) and four sightings of seals (four individuals) during 1998 (Table 1). The most frequently seen species was the pilot whale. Fin whales, sperm whales, white-sided dolphins, common dolphins and minke whales were also seen in moderate numbers, with lower numbers of other species. 63% of sightings were identified to species level, and a further 20% were identified as being one of a pair or group of similar species. Dolphins and pilot whales were occasionally seen as solitary individuals, but were more often seen in groups that could at times be quite large (mean pod size = 10.40 for pilot whales, 28.53 for white-sided dolphins, 10.64 for common dolphins). The larger whales tended to occur either singly or in small groups (mean pod size = 1.89 for fin whales, 1.43 for sperm whales). There was a large peak in sightings of cetaceans during the month of July (Figure 2), when more time was spent watching for marine mammals.

The length of time spent watching for marine mammals was summed using the surveys where 'Location and Effort' recording forms were completed correctly (45 of the 58 surveys). Excluding site surveys, a total of 14,730 hrs 41 mins were spent watching for marine mammals, of which the airguns were firing for 5,239 hrs 36 mins (36% of the time on watch). 18 of the 58 surveys from which reports were received were site surveys. During site surveys 1,103 hrs 40 mins were recorded as watching for marine mammals, of which the airguns were firing for 239 hrs 21 mins (22% of the time on watch). The time spent watching for marine mammals during site surveys equated to less than 7% of the total time spent watching during all surveys (15,834 hrs 21 mins). When the airguns were not firing the survey vessels were engaged in a variety of activities e.g. turning between survey lines, deploying, retrieving or carrying out maintenance on the airguns and streamers, waiting for weather conditions to improve, time-sharing with other seismic survey vessels, and steaming between survey areas and ports. In the case of site surveys, some of the periods when the airguns were not firing were occupied by analogue surveys for which airguns were not used.

The overall time spent watching for marine mammals peaked in July, although the proportion of time spent shooting peaked in May, October and November (Figure 3). Most survey effort was concentrated in areas to the West of Shetland, around Rockall and in the Northern North Sea (Figure 4), although in each of these areas survey effort peaked in different months (Figure 5). The proportion of time spent shooting was greatest in Rockall, to the West of Ireland and in the South-West Approaches.

Table 1 Summary of marine mammal sightings from seismic survey vessels in 1998

Species	***Number of sightings***	***Number of individuals***
Seal sp.	2	2
Grey seal	2	2
Cetacean sp.	20	276
Whale sp.	13	49
Large whale sp.	25	59
Humpback whale	6	8
Blue whale	4 [a,b]	4
Fin whale	46 [a,c]	87
Sei whale	4	7
Sperm whale	35	50
Fin/ blue whale	5	5
Fin/ sei whale	36 [b]	57
Fin/ sei/ blue whale	3	3
Fin/ sei/ humpback whale	15	22
Fin/ sei/ blue/ humpback whale	6	7
Humpback/ sperm whale	6	9
Minke whale	21 [d]	29
Sowerby's beaked whale	1	1
Pilot whale	111 [d,e,f,g,h]	1,154
Killer whale	16	60
Dolphin sp.	70 [e,i]	896
Risso's dolphin	3	6
Bottlenose dolphin	15 [f,i]	179
White-beaked dolphin	4	13
White-sided dolphin	30 [c,g,j]	856
Lagenorhynchus sp.*[1]	4 [h]	42
Common dolphin	22 [j]	234
Common/ white-sided dolphin	2	5
Striped dolphin	1	13
Common/ striped dolphin	3	17
Patterned dolphin sp.*[2]	2	6
Harbour porpoise	6	21
Total	**522**	**4,179**

*[1] *Lagenorhynchus* sp. = white-beaked/ white-sided dolphin
*[2] patterned dolphin = white-beaked/ white-sided/ common/ striped dolphin
a includes 1 sighting of blue whales associated with fin whales
b includes 1 sighting of blue whales associated with fin/ sei whales
c includes 2 sightings of fin whales associated with white-sided dolphins
d includes 1 sighting of minke whales associated with pilot whales
e includes 2 sightings of pilot whales associated with dolphin sp.
f includes 1 sighting of pilot whales associated with bottlenose dolphins
g includes 5 sightings of pilot whales associated with white-sided dolphins
h includes 1 sighting of pilot whales associated with *Lagenorhynchus* sp.
i includes 2 sightings of bottlenose dolphins associated with dolphin sp.
j includes 1 sighting of white-sided dolphins associated with common dolphins

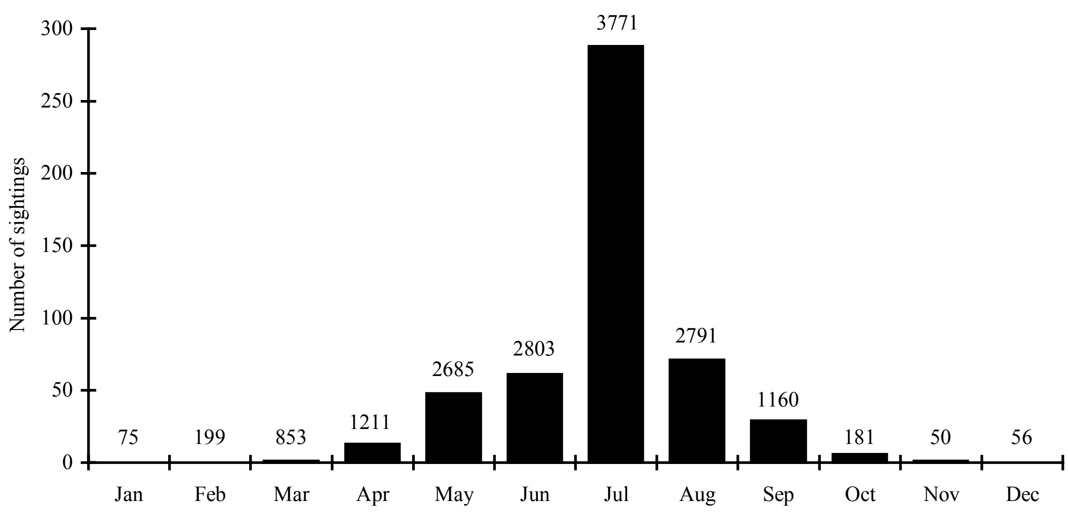


Figure 2 Number of cetacean sightings per month, with number of hours spent watching for marine mammals

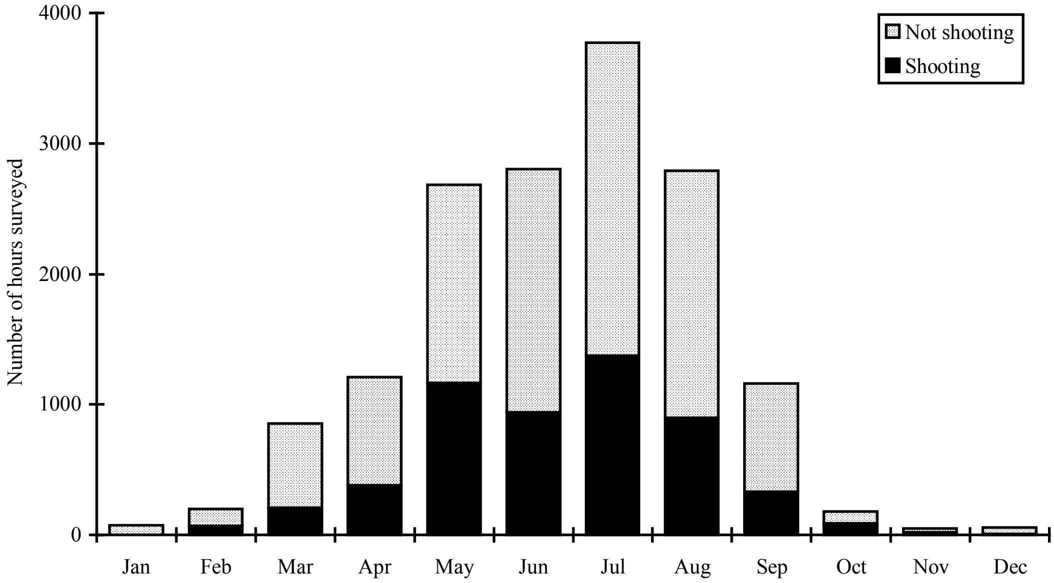


Figure 3 Length of time spent watching for marine mammals throughout 1998, and seismic activity during watches (all areas combined; only includes surveys where effort was correctly recorded).

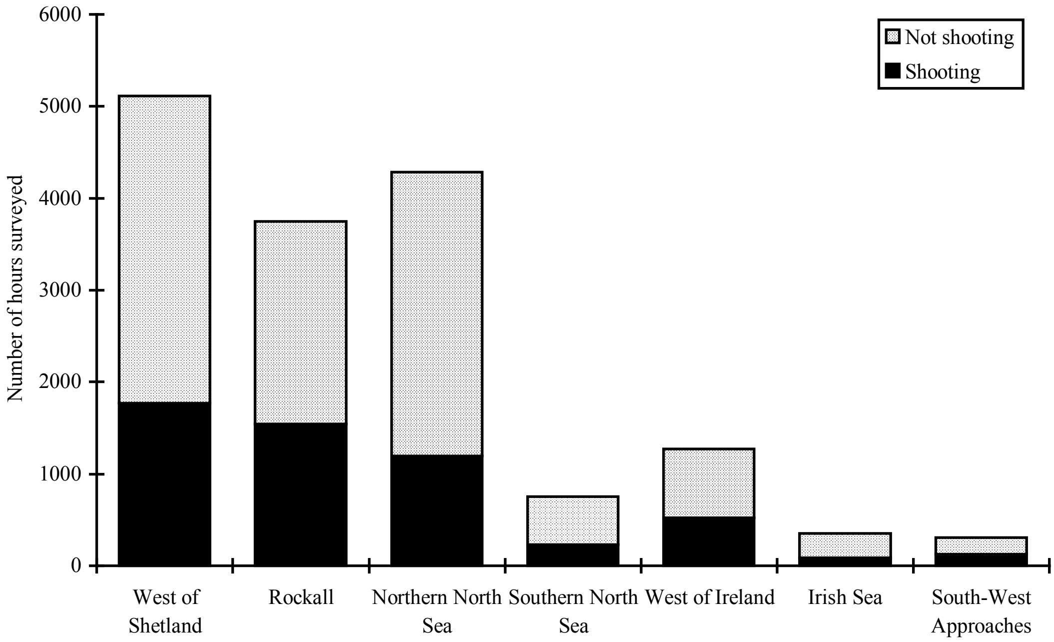


Figure 4 Length of time spent watching for marine mammals in each area, and seismic activity during watches (all months combined; only includes surveys where effort was correctly recorded).

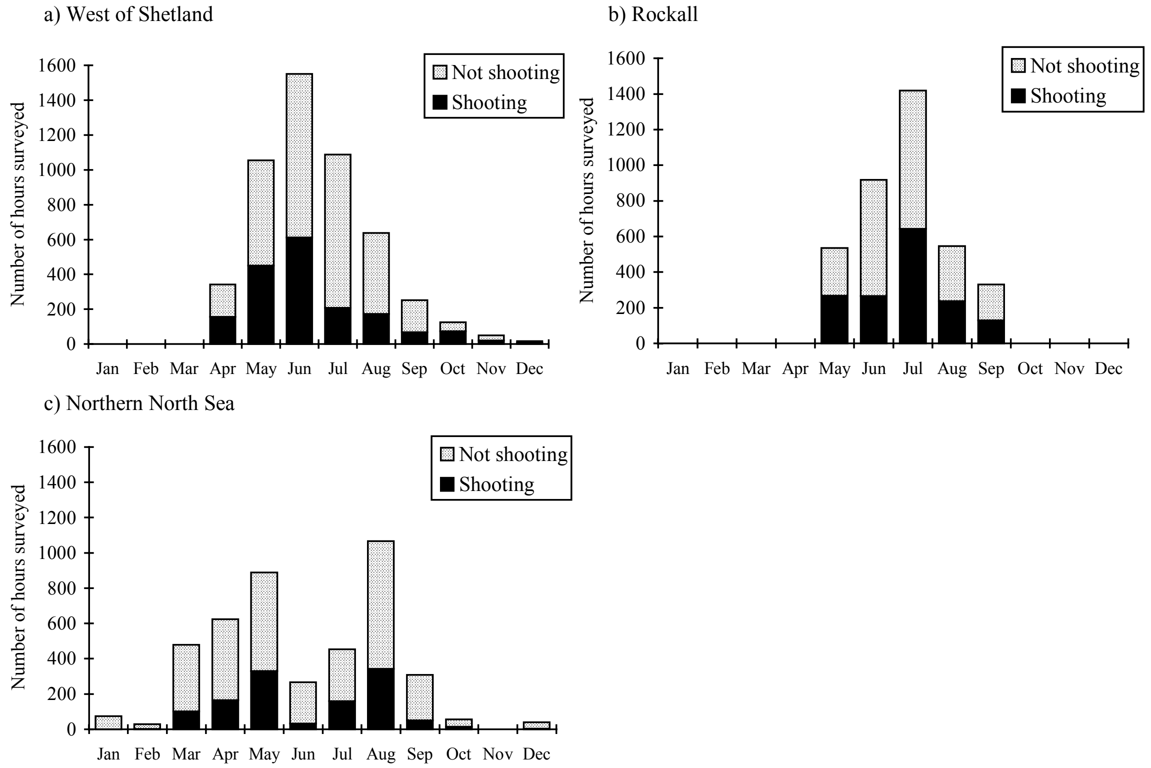


Figure 5 Comparison of survey effort throughout the year for the most intensively surveyed areas (only includes surveys where effort was correctly recorded).

5. Distribution of cetaceans

Most sightings of cetaceans occurred in waters to the north and west of the UK (Figure 6). There were many sightings in deep (> 1,000 m) waters to the west and north of Scotland and, to a lesser extent, to the west of Ireland. There were scattered sightings in continental shelf waters to the north and west of Scotland, and in the northern North Sea. There were only a few sightings in the South-West Approaches, and none in the southern North Sea.

Species maps (Figures 7 - 24) showed that the large whales and pilot whales were seen most often in deep waters beyond the edge of the continental shelf, while dolphins and killer whales were sometimes seen in shelf waters. Some species (humpback whale, blue whale and Sowerby's beaked whale) were seen exclusively in deep north-western waters, mostly around Rockall (Figures 8, 9 & 14). Risso's dolphin and harbour porpoise were also seen only to the north-west of the UK, but these species occurred in shallower waters over the continental shelf or the shelf slope (Figures 18 & 24). Fin whales, killer whales and white-sided dolphins also occurred almost exclusively in north-western waters, with only one or two sightings elsewhere in each case (Figures 10, 16 & 21). Similarly, bottlenose dolphins were seen on all but one occasion in north-western waters, the exception in this case being in the northern North Sea (Figure 19).

Other species, although seen most often in north-western waters, were also seen in moderate numbers further south. Sperm whales and minke whales were seen most often around Rockall, with some sightings to the west of Shetland, but were also sometimes seen to the west of Ireland (Figures 12 & 13). One sighting of a minke whale occurred in the northern North Sea. Similarly pilot whale distribution, although concentrated between Shetland and the Faroes and around Rockall, extended south to the west of Ireland and the South-West Approaches (Figure 15).

The centre of distribution for some species was more southerly; sightings of both sei whales and common dolphins occurred with more or less equal frequency around Rockall and to the west of Ireland (Figures 11 & 22). Common dolphins were occasionally seen further north and in the northern North Sea. Striped dolphins were seen only to the west of Ireland (Figure 23).

White-beaked dolphin distribution differed from that of the other species (Figure 20), with none seen to the west of the UK. This species was seen only occasionally, usually in the northern North Sea, and once near Shetland.

The distribution maps should not be interpreted as being representative of a species' range in UK waters. Although watches for marine mammals encompassed a wide area (Figure 1), survey effort throughout the area was unequal. As 'Location and Effort' forms were not always completed, it was impossible to calculate the total effort in each quadrant. From those surveys where effort was correctly recorded it was apparent that, during the summer months when cetaceans were more likely to be seen, more time was spent in the areas Rockall and West of Shetland than elsewhere (Figures 4 & 5). 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.

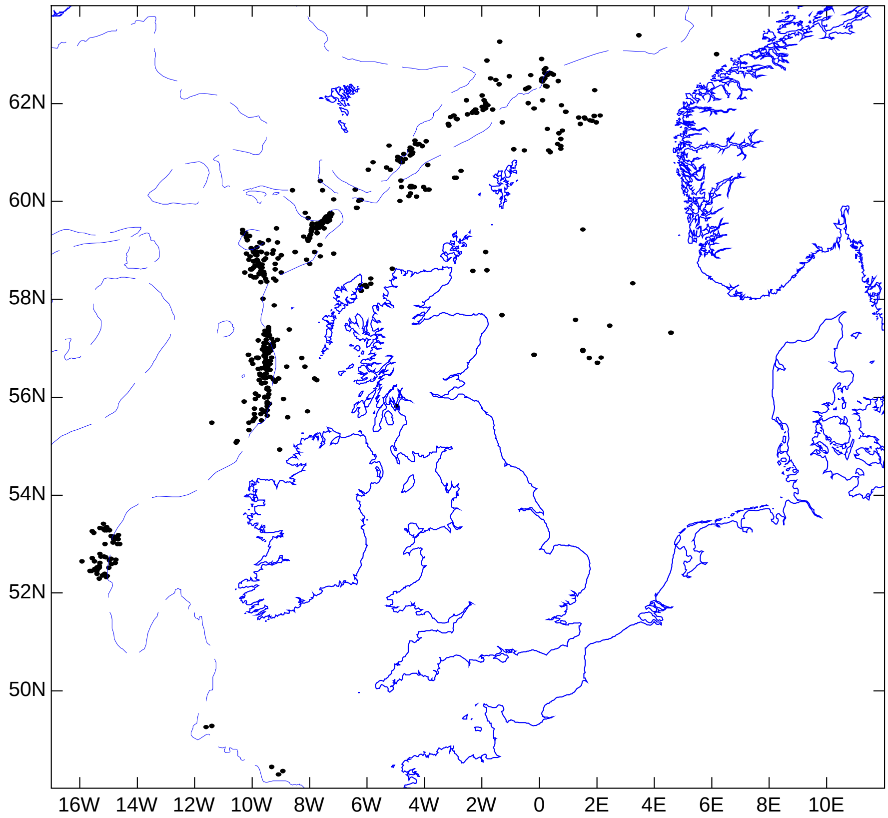


Figure 6 Cetacean sightings (all species) from seismic survey vessels during 1998

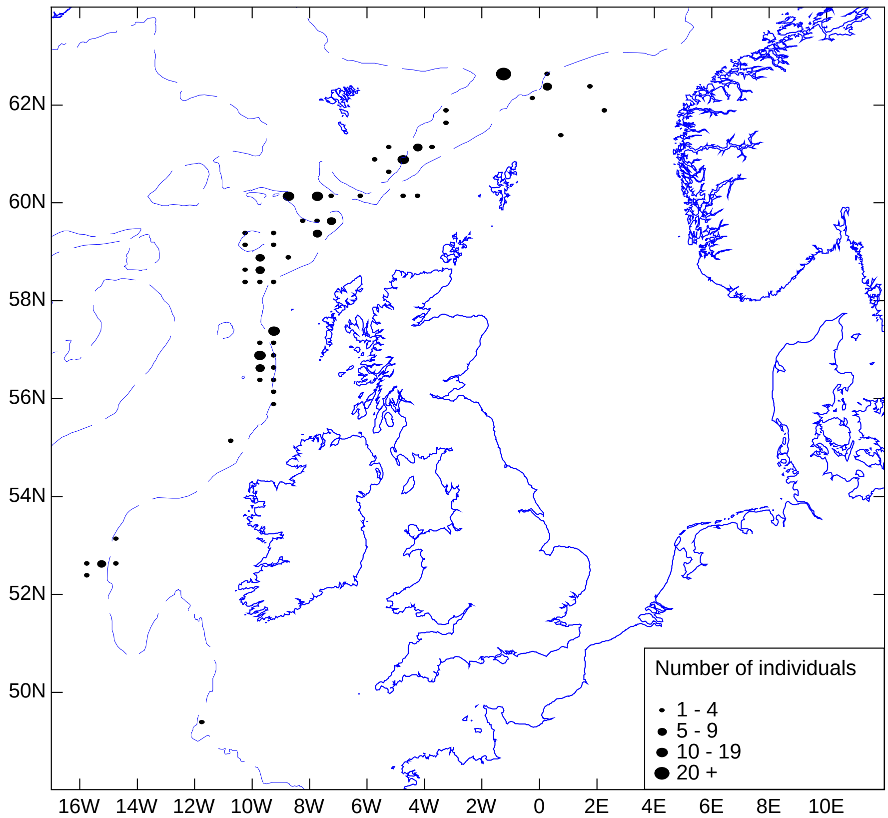


Figure 7 Distribution of unidentified whales seen during seismic surveys in 1998

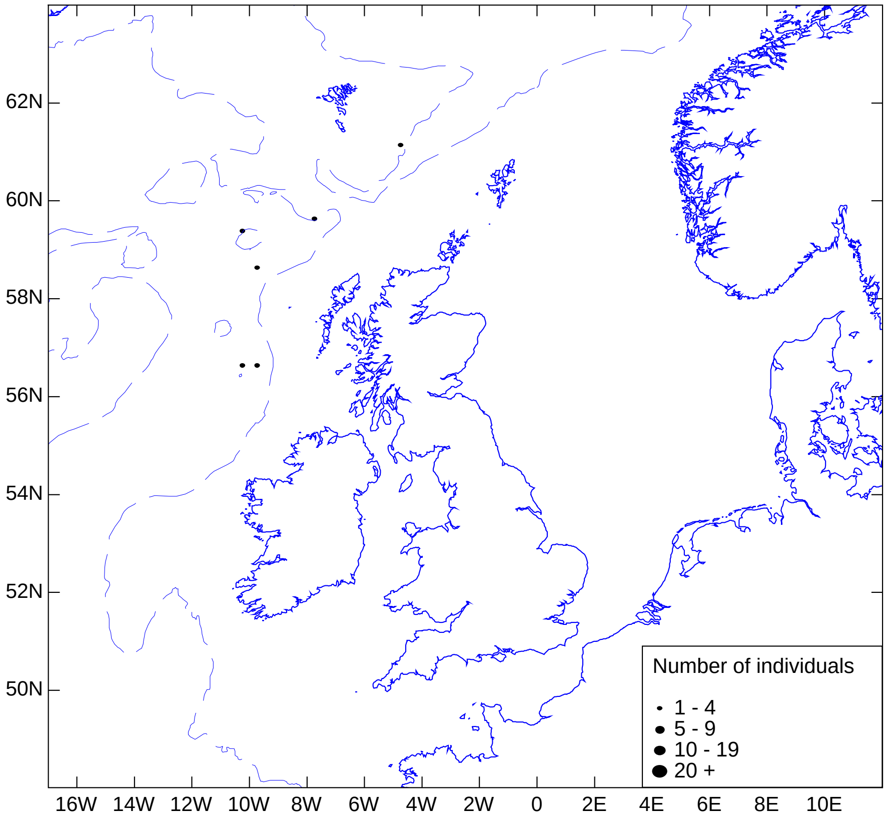


Figure 8 Distribution of humpback whales seen during seismic surveys in 1998

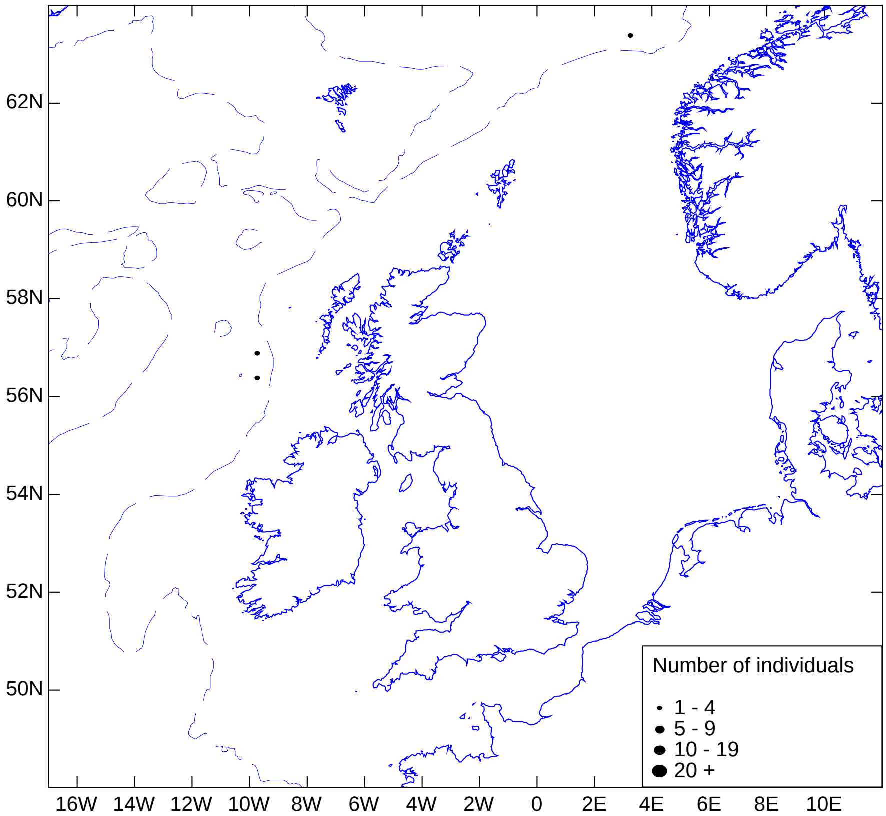


Figure 9 Distribution of blue whales seen during seismic surveys in 1998

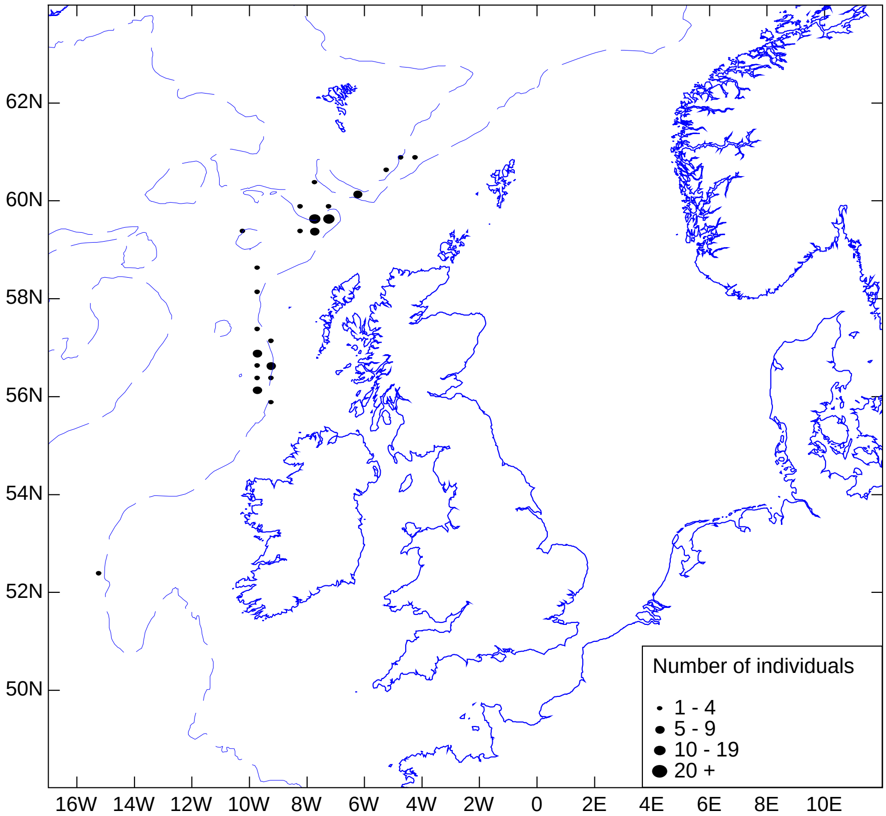


Figure 10 Distribution of fin whales seen during seismic surveys in 1998

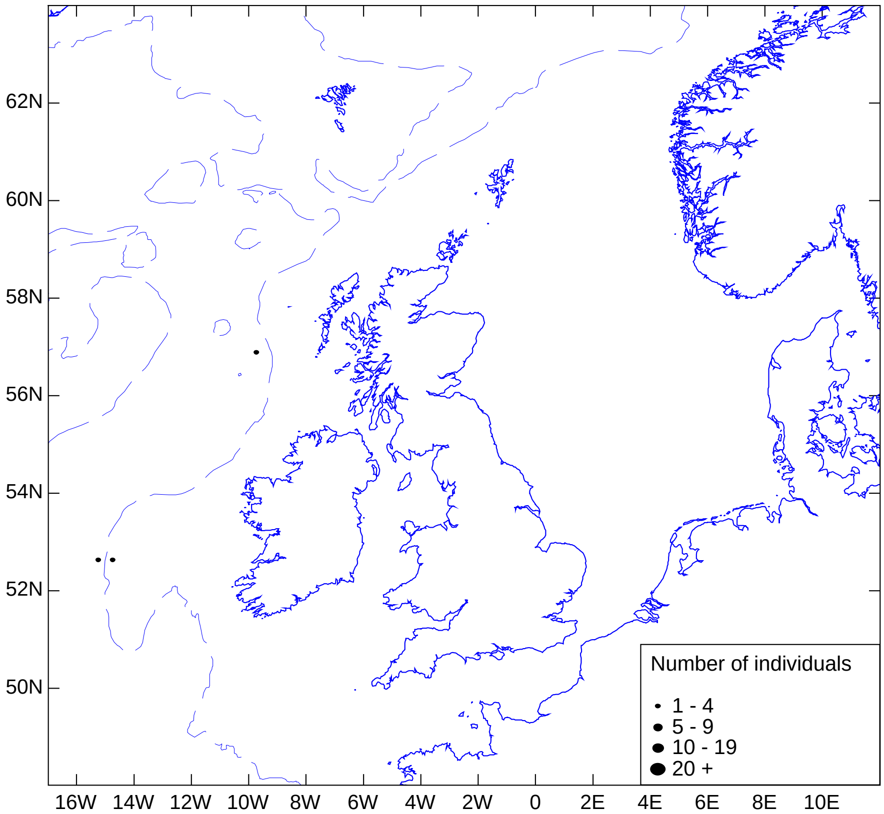


Figure 11 Distribution of sei whales seen during seismic surveys in 1998

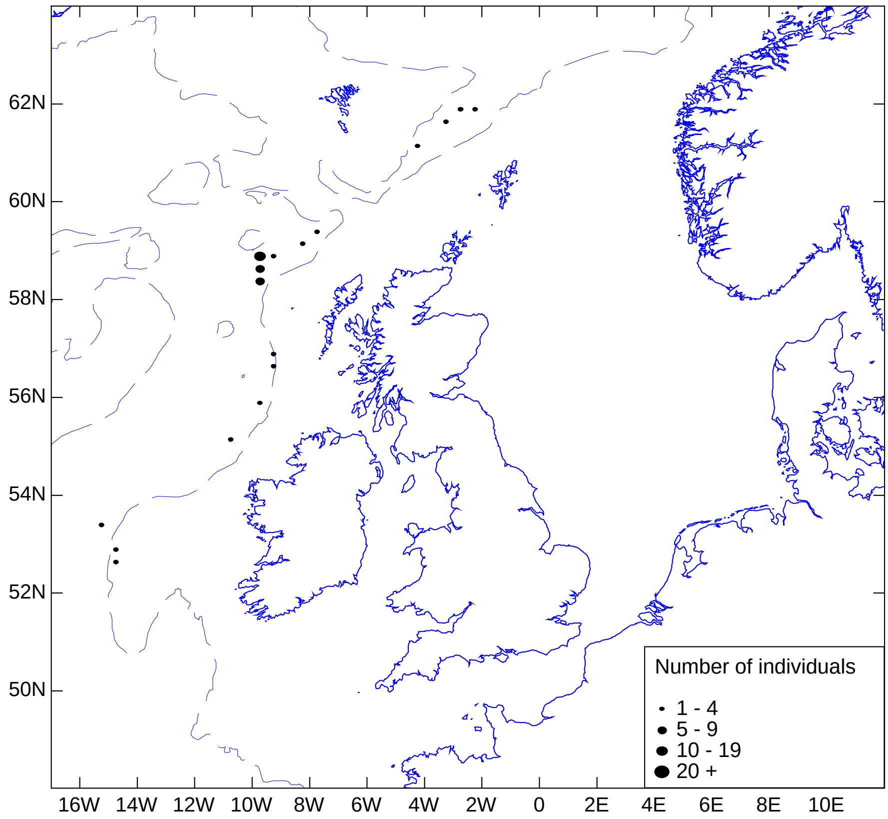


Figure 12 Distribution of sperm whales seen during seismic surveys in 1998

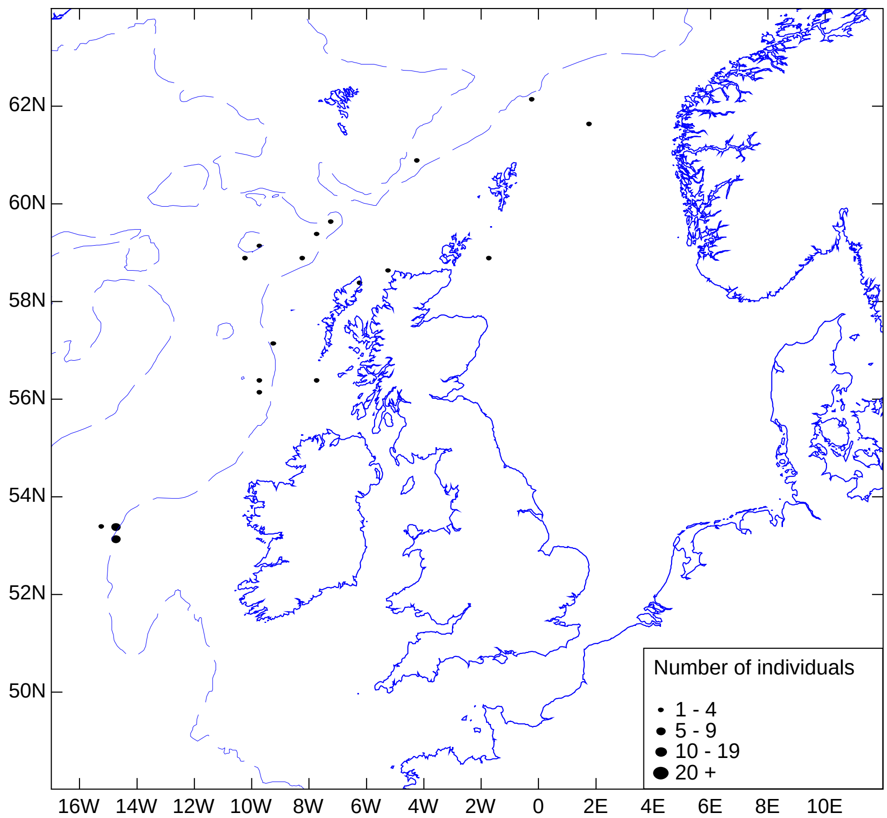


Figure 13 Distribution of minke whales seen during seismic surveys in 1998

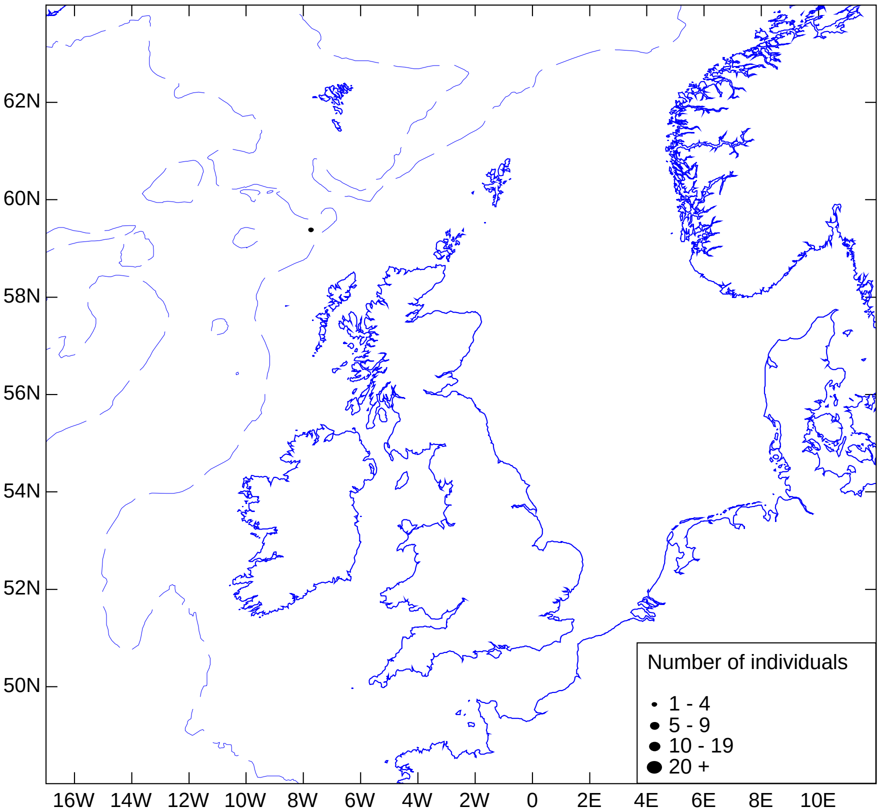


Figure 14 Distribution of Sowerby's beaked whales seen during seismic surveys in 1998

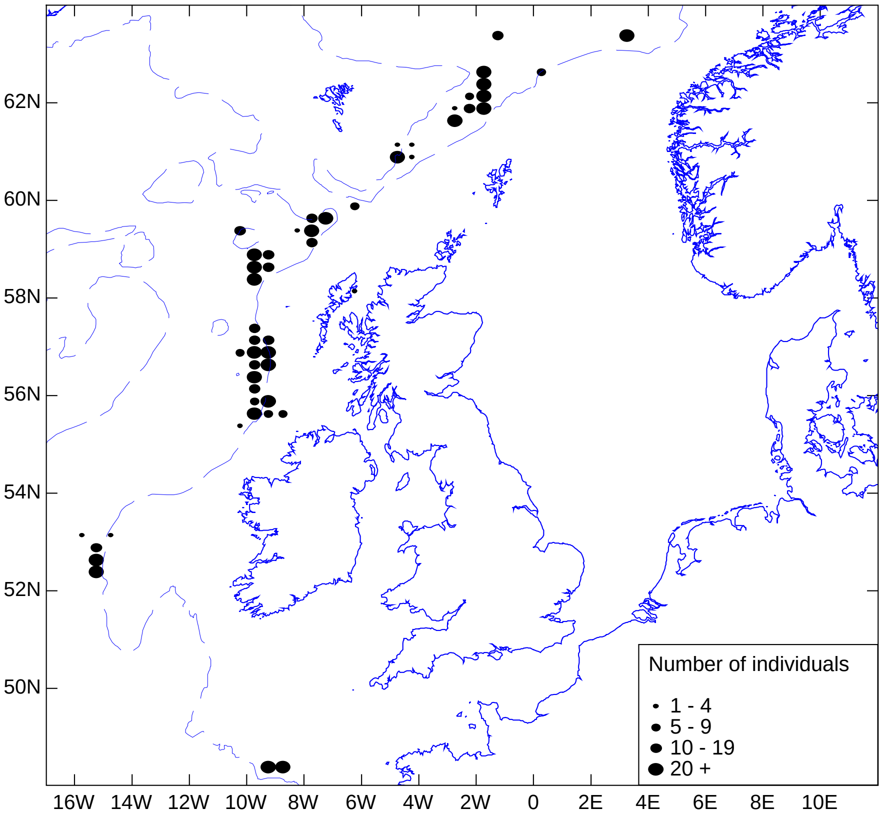


Figure 15 Distribution of pilot whales seen during seismic surveys in 1998

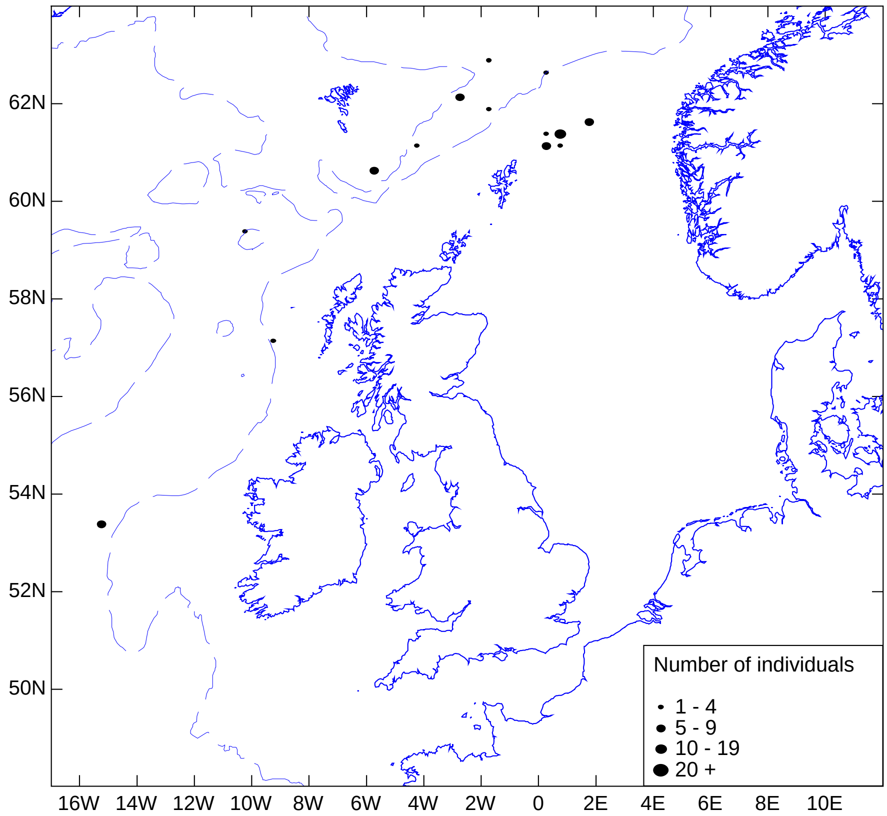


Figure 16 Distribution of killer whales seen during seismic surveys in 1998

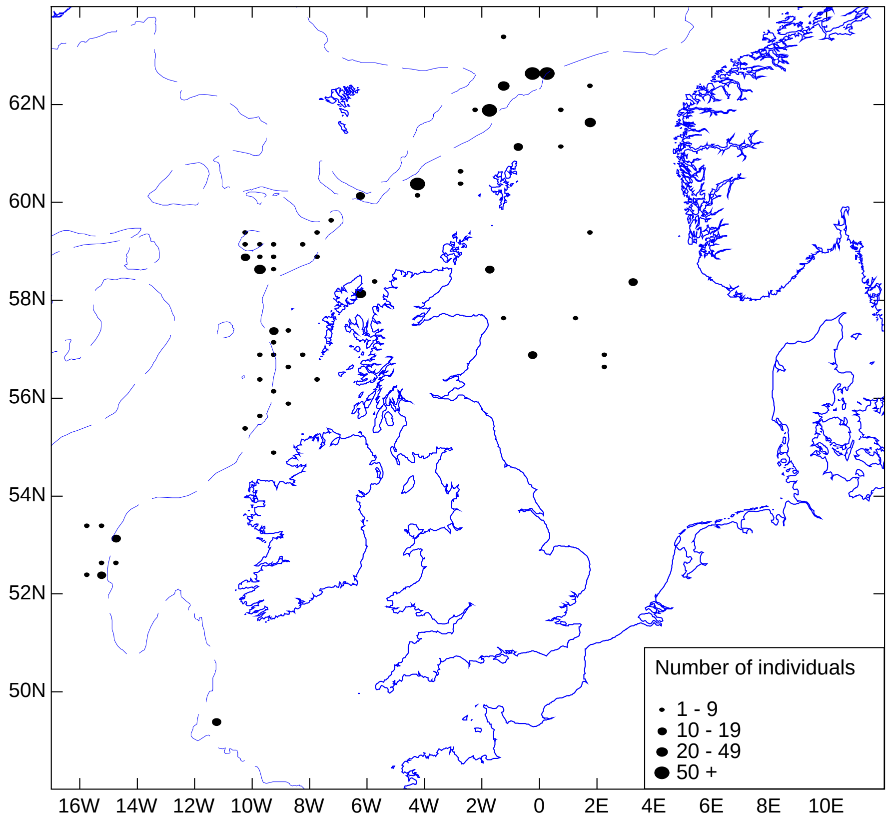


Figure 17 Distribution of unidentified dolphins seen during seismic surveys in 1998

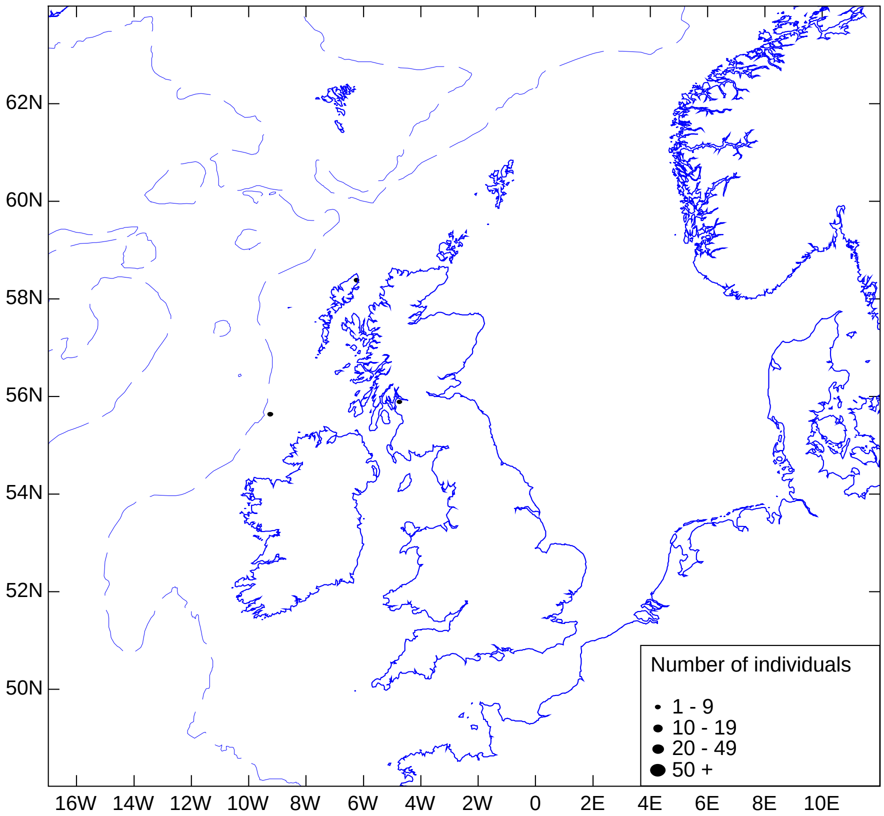


Figure 18 Distribution of Risso's dolphins seen during seismic surveys in 1998

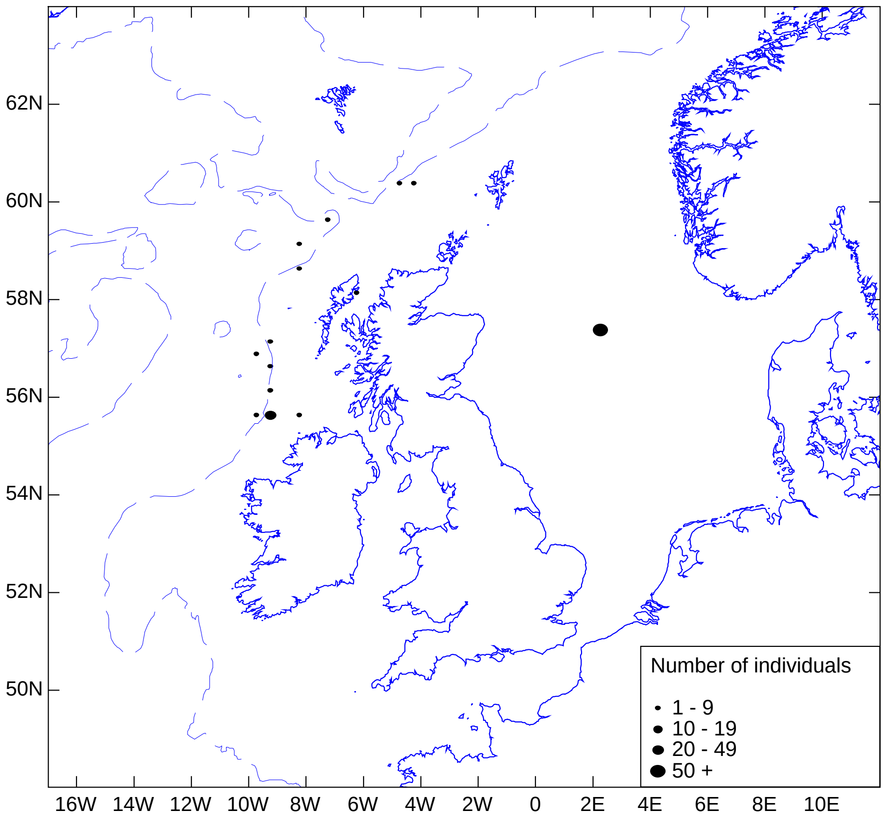


Figure 19 Distribution of bottlenose dolphins seen during seismic surveys in 1998

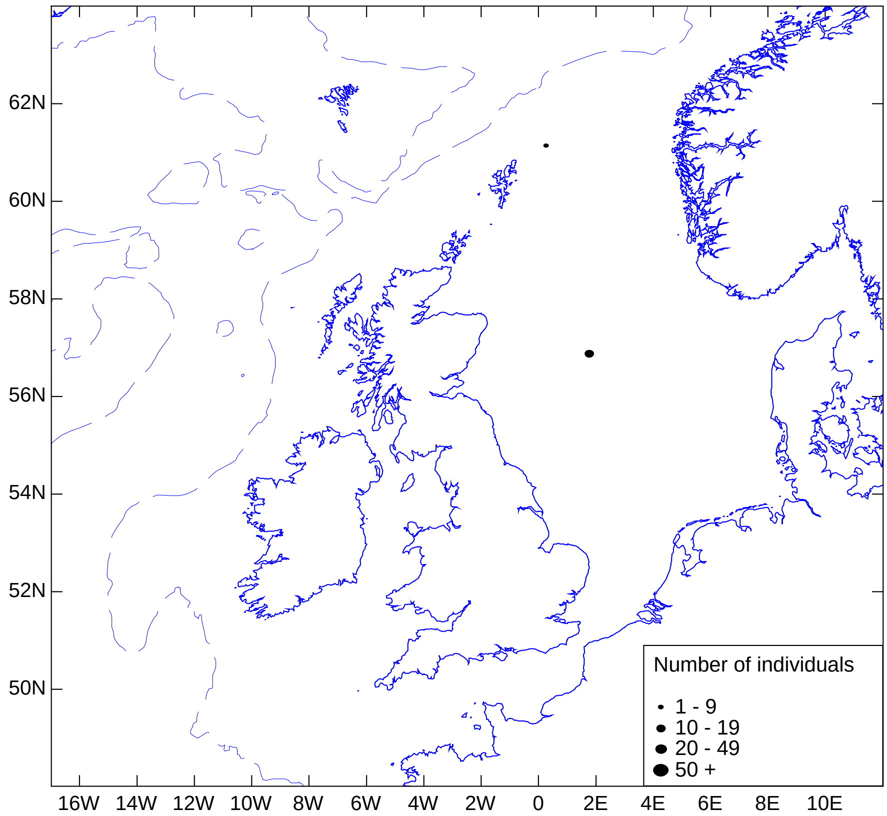


Figure 20 Distribution of white-beaked dolphins seen during seismic surveys in 1998

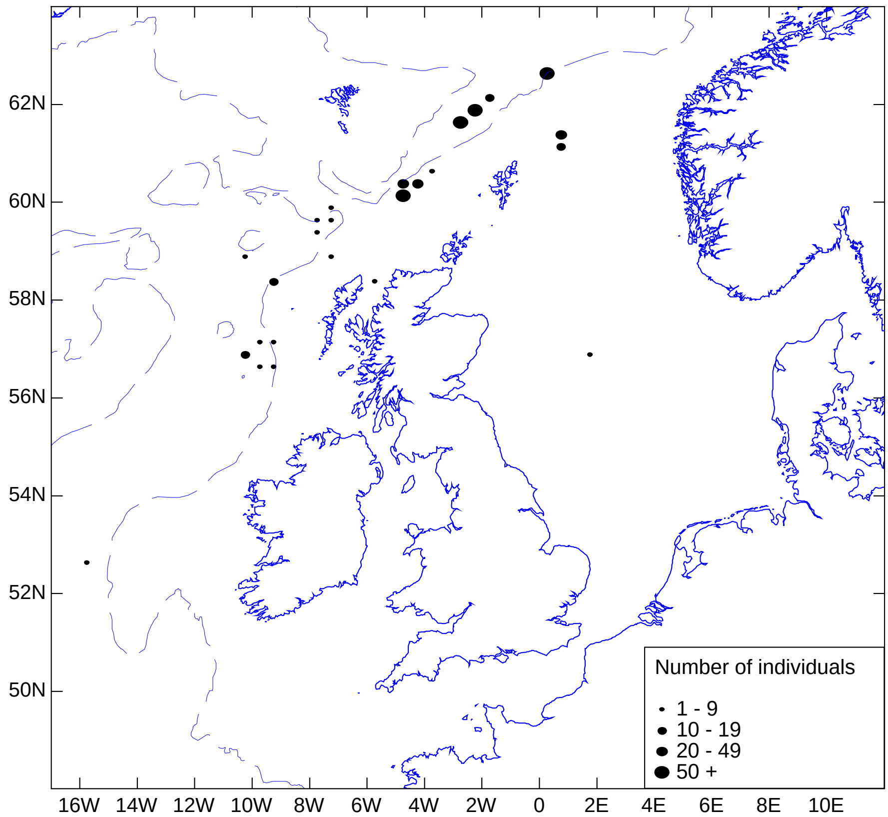


Figure 21 Distribution of white-sided dolphins seen during seismic surveys in 1998

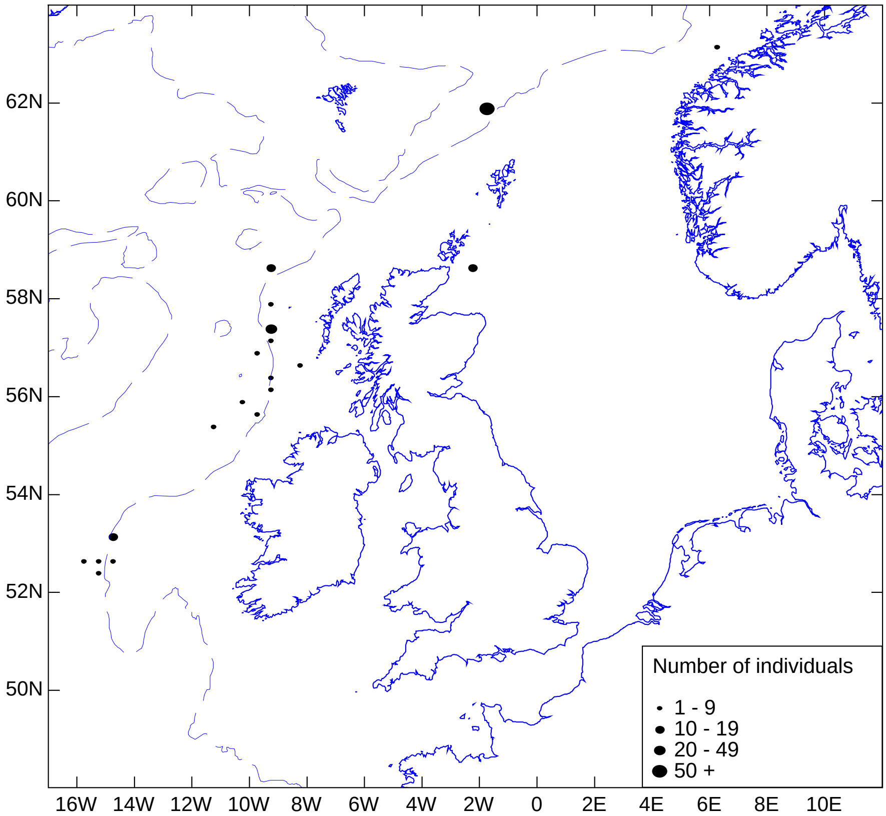


Figure 22 Distribution of common dolphins seen during seismic surveys in 1998

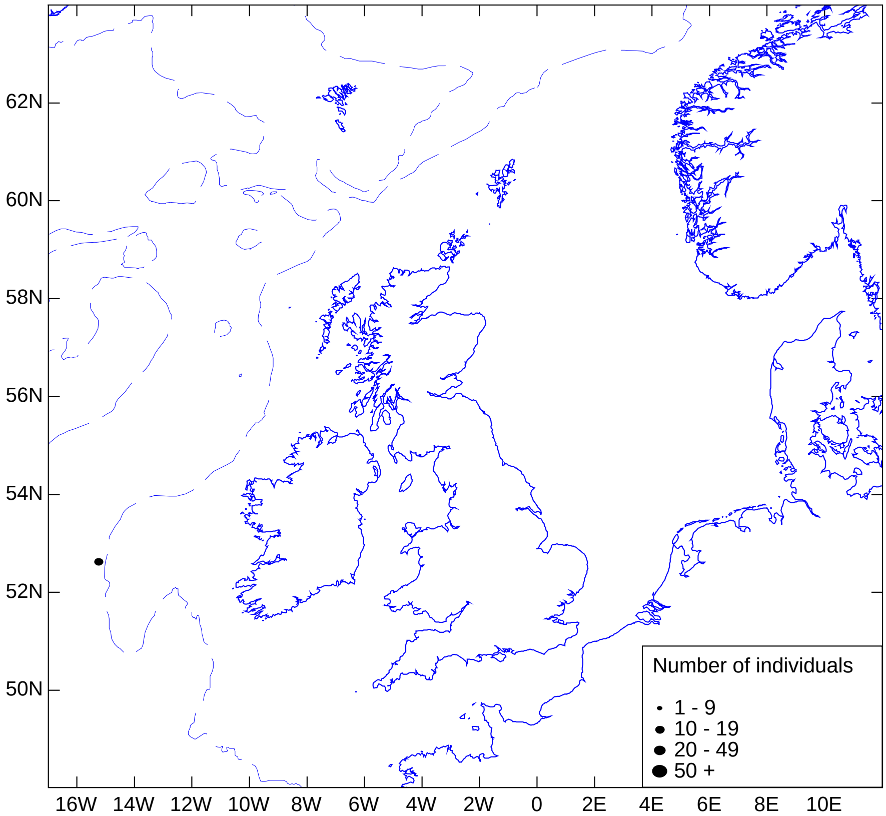


Figure 23 Distribution of striped dolphins seen during seismic surveys in 1998

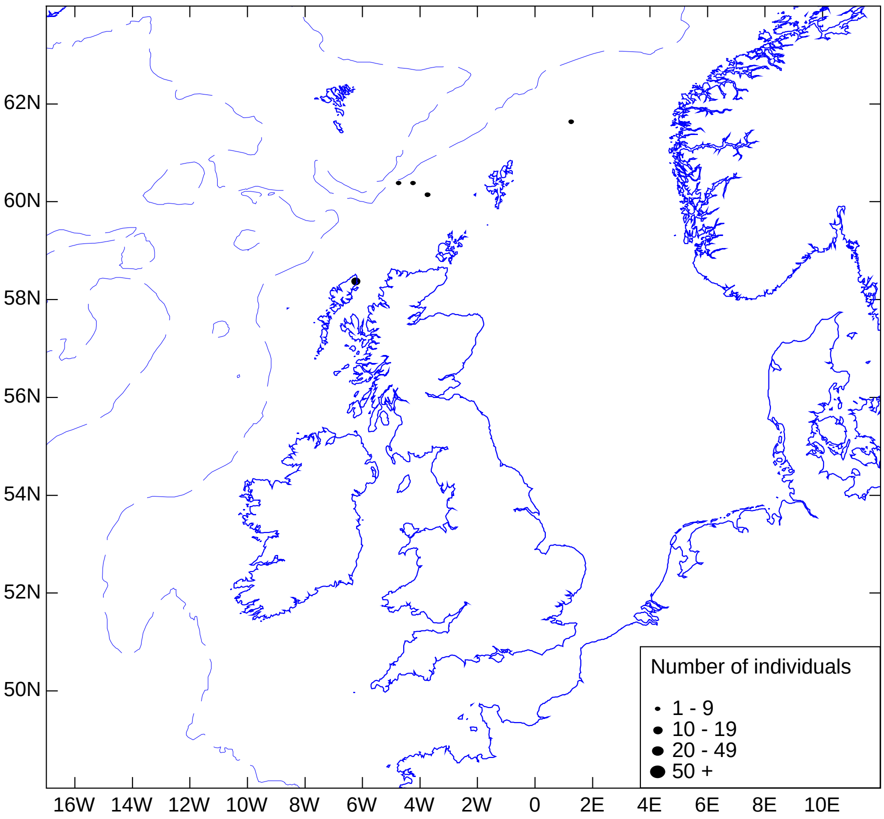


Figure 24 Distribution of harbour porpoises seen during seismic surveys in 1998

6. Seasonal abundance and migration of cetaceans

Sightings of most cetacean species peaked in July (Figure 25), when the time spent watching for marine mammals also reached a peak (Figure 3). However, for most species, with the possible exception of sperm whale and killer whale, the increase in the number of sightings in July was disproportionate to the increase in survey effort from previous months. For example, there were more than ten times as many fin whale sightings in July than in June, although total effort in areas of fin whale occurrence (West of Shetland and Rockall) increased only slightly from June to July (effort in West of Shetland and Rockall in June = 2467 hrs 04 mins; effort in these areas in July = 2506 hrs 03 mins). Similarly, white-sided dolphins, also found in areas West of Shetland and Rockall, showed a fourfold increase in sightings from June to July.

There were no sightings of large whales, such as fin and sperm whales, outside summer months, although surveys in areas where these species occur (West of Shetland, Rockall) commenced in April and continued until December. Killer whales were also only seen during the summer. Other species, such as pilot whales, minke whales, bottlenose dolphins and white-sided dolphins, were seen over more months of the year, although peak numbers of sightings still occurred during the summer.

Most species showed no obvious trends in their distribution or direction of travel that might have indicated a migratory pattern. However, sperm whale distribution showed a general southwards movement in the latter half of the summer (Figure 26). All sightings of sperm whales in May occurred north of 58°N, and all had a northerly component in their direction of travel i.e. were heading north, north-east or north-west. In June the proportion of sperm whales travelling in these directions had reduced to 57%. Survey effort in June was greater to the West of Shetland than in Rockall, but more sperm whales were seen in Rockall, with one sighting south of 58°N. By July, there were several sightings of sperm whales to the West of Ireland, and the proportion of pods heading in northerly directions had further reduced to 21%. In contrast, the proportion of pods with a southerly component in their direction of travel (i.e. heading south, south-west or south-east) increased from 29% in June to 64% in July. By August, although survey effort West of Shetland slightly exceeded that in Rockall, all sightings of sperm whales occurred south of 58°N, with 50% of pods travelling generally southwards and none heading northwards.

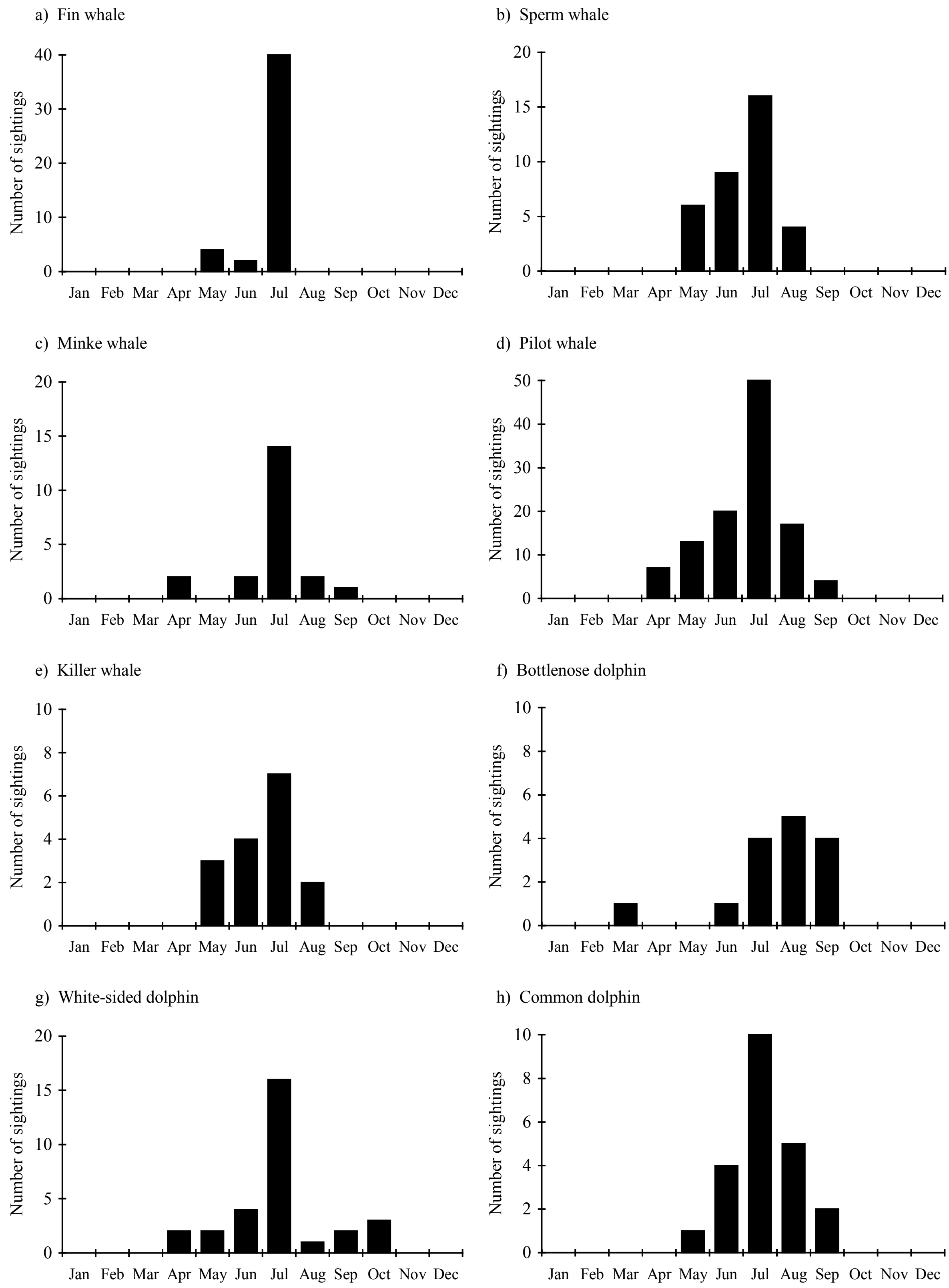


Figure 25 Number of sightings of cetaceans per month

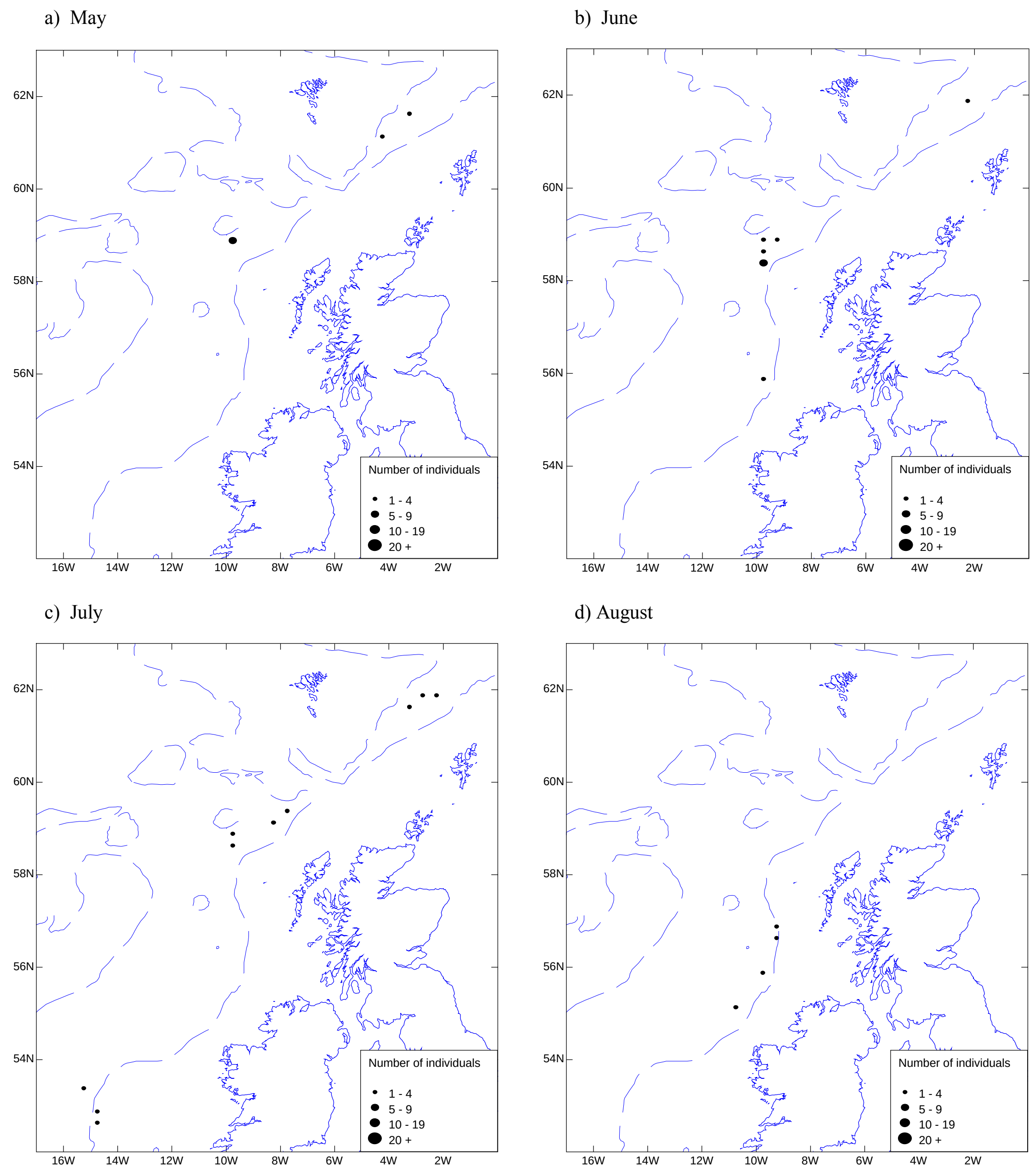


Figure 26 Sperm whale sightings throughout the summer

7. Effects of seismic activity on cetaceans

Site surveys use airguns of relatively low power, that may be likely to cause less disturbance to cetaceans. It was considered inappropriate to combine data from site surveys with data from seismic surveys using greater power levels. The initial analysis examining the effects of seismic activity on cetaceans (sections 7.1 - 7.5) therefore excluded data from site surveys. Observations during site surveys were analysed separately (section 7.6).

7.1 Sighting rate of cetaceans

As sighting rates were calculated per unit effort (i.e. per 1,000 hours of observations), only sightings from surveys where effort was correctly recorded were used in this analysis. Sighting rates of baleen whales were mostly higher when the airguns were firing than when they were not firing (Figure 27). Sample sizes were often too small to test the significance of the results. Of those species where sample sizes were sufficient to allow statistical testing, fin whales and fin/ sei whales were seen significantly more often when the airguns were firing, while sighting rates of minke whales were not significantly different (Table 2). Amongst the odontocetes trends were not clear (Figure 28). Sighting rates of pilot whales and sperm whales were higher when the airguns were firing, although not significantly so. The different dolphin species showed varying results, but where sample sizes were sufficient to permit testing only one significant result was found: sighting rates of unidentified dolphins were significantly higher when the airguns were not firing (Table 2).

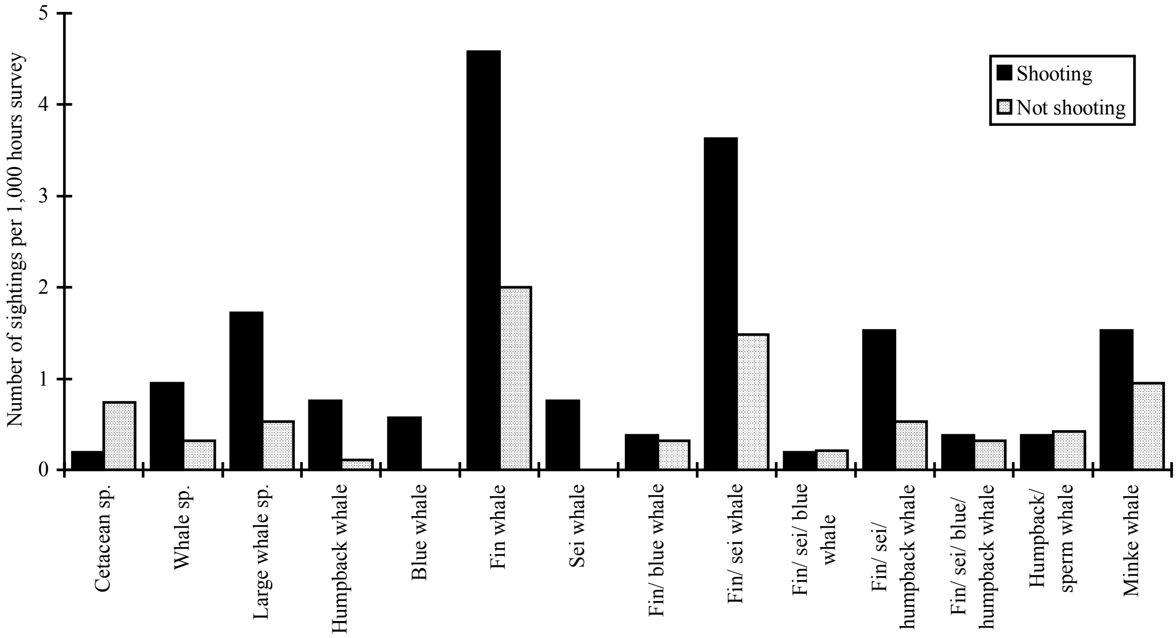


Figure 27 Sightings of baleen whales in relation to seismic activity (excluding site surveys, and not taking account of location, season or weather conditions).

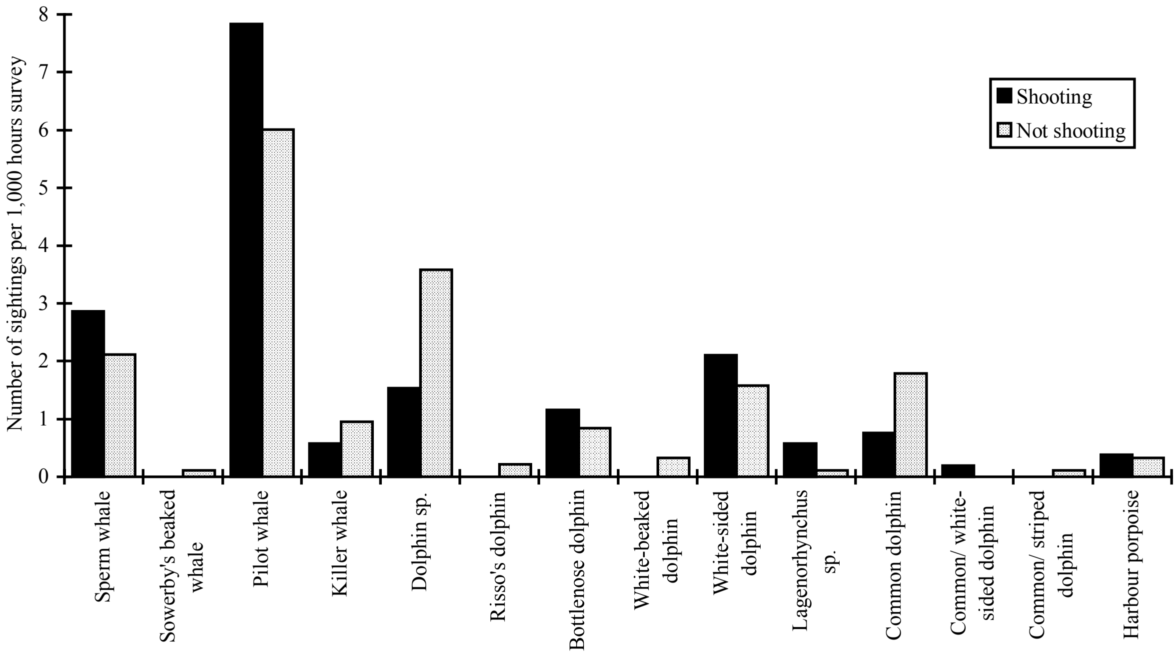


Figure 28 Sightings of odontocetes in relation to seismic activity (excluding site surveys, and not taking account of location, season or weather conditions).

Table 2 Statistical significance of difference in sighting rate of cetaceans in relation to seismic activity, not taking account of location, season or weather (n.s. = not significant).

Species	χ^2	*d.f.*	*P*
Fin whale	7.699	1	< 0.01
Fin/ sei whale	6.969	1	< 0.01
Minke whale	0.976	1	n.s.
Sperm whale	0.811	1	n.s.
Pilot whale	1.679	1	n.s.
Dolphin sp.	5.004	1	< 0.05
White-sided dolphin	0.514	1	n.s.
Common dolphin	2.502	1	n.s.

This initial analysis did not take account of other factors that could have influenced the results, such as the location and timing of surveys, and weather conditions. Some species are 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 & 5), this could 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.

Weather conditions affect an observer's ability to detect cetaceans. This was particularly important as the proportion of time spent shooting also varied with weather conditions. As sea state and swell decreased, the proportion of time spent shooting increased (Figures 29 & 31). There was a corresponding increase in the ability to detect cetaceans in these conditions (Figures 30 & 32), which could have led to higher sighting rates during periods of shooting. Conversely, the proportion of time spent shooting was greatest in conditions of poor visibility (Figure 33), yet more cetaceans were seen when visibility was good (Figure 34). This could have led to higher sighting rates during periods when the airguns were not firing.

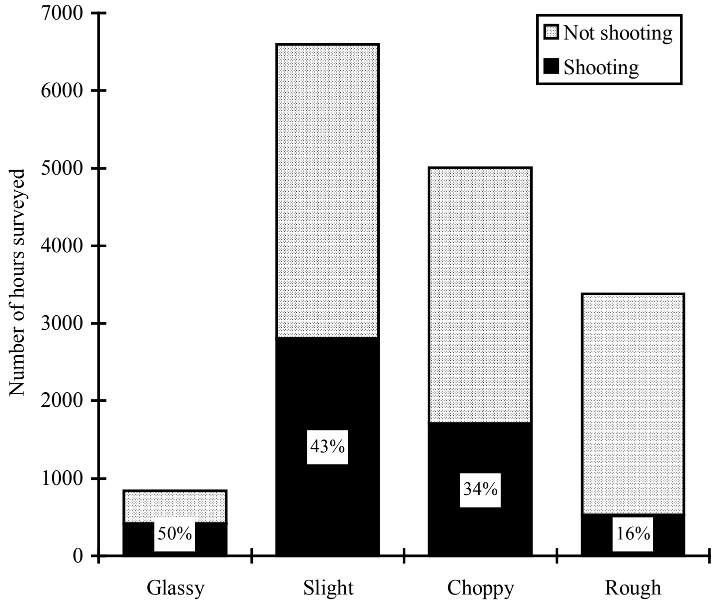


Figure 29 Length of time spent watching for marine mammals at each sea state in relation to seismic activity, with percentage of time spent shooting (only includes surveys where effort was correctly recorded).

Figure 30 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/ beaked/ pilot/ killer whales).

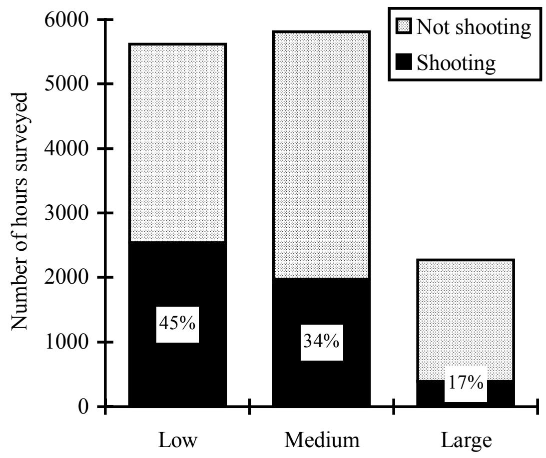


Figure 31 Length of time spent watching for marine mammals in different swell conditions in relation to seismic activity, with percentage of time spent shooting (only includes surveys where effort was correctly recorded).

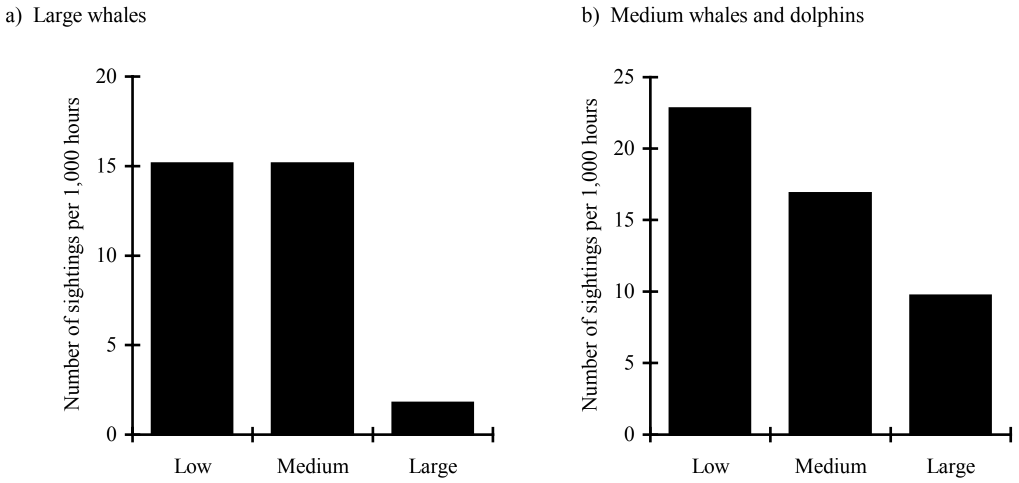


Figure 32 Frequency of cetacean sightings in relation to swell (large whales = fin/ sei/ blue/ humpback/ sperm whales i.e. whales over 10 m long with a conspicuous blow; medium whales = minke/ northern bottlenose/ beaked/ pilot/ killer whales).

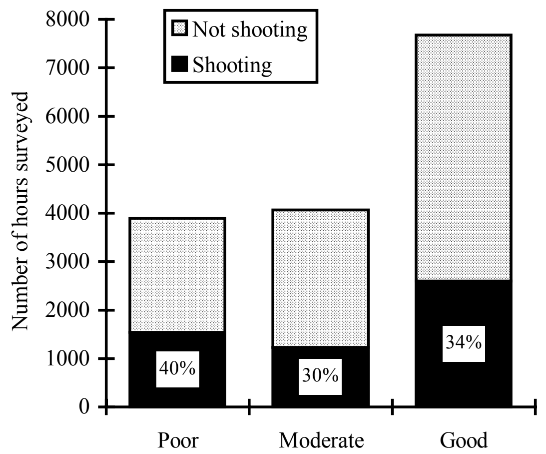
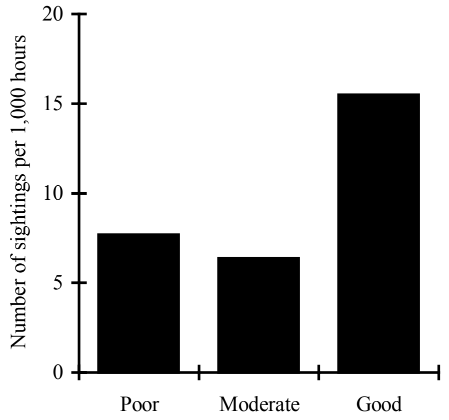


Figure 33 Length of time spent watching for marine mammals in different conditions of visibility in relation to seismic activity, with percentage of time spent shooting (only includes surveys where effort was correctly recorded).

a) Large whales



b) Medium whales and dolphins

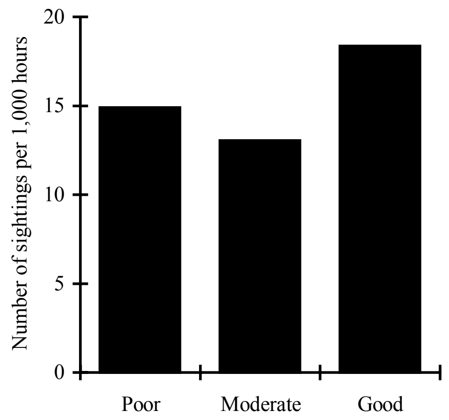


Figure 34 Frequency of cetacean sightings in relation to visibility (large whales = fin/ sei/ blue/ humpback/ sperm whales i.e. whales over 10 m long with a conspicuous blow; medium whales = minke/ northern bottlenose/ beaked/ pilot/ killer whales).

Where sample sizes permitted, sighting rates were re-calculated to take account of these potential sources of bias. Subsets of data were selected according to location and season, using various sources to establish known areas and months of peak abundance for each species (e.g. Bloor *et al.* 1996; Clark & Charif 1998; Evans 1980, 1990, 1992; JNCC 1995; Northridge *et al.* 1995; Pollock *et al.* 1997; Skov *et al.* 1995). To reduce the influence of weather, data from periods with poor weather conditions were disregarded. Periods of 'choppy' or 'rough' sea states or 'large' swell were disregarded as sighting rates of all species were reduced in these conditions (Figures 30 & 32). Ideally, for medium whales and dolphins periods of 'slight' sea states and 'medium' swell would also have been disregarded, but the consequent reduction in sample size would have prevented meaningful analysis. Interspecific variation was greater when considering the effect of visibility. Many more large whales were detected when visibility was 'good' than when it was 'moderate' or 'poor' (Figure 34), probably because their conspicuous blows meant that they were often detected at considerable distances. Therefore, for large whales periods of 'moderate' or 'poor' visibility were disregarded. Visibility had apparently little effect on the ability to detect medium whales and dolphins (Figure 34). Visibility was classed as 'poor' if it was less than 1 km; as most smaller cetaceans were detected within this range then visibility towards the upper limit of the 'poor' category would have had little effect on the sighting rate of these species. However, as this category could also have included thick fog, periods of 'poor' visibility were disregarded for medium whales and dolphins.

After selecting the most appropriate data, sample sizes were only sufficient to permit comparison of sighting rates for seven species or species groups. Table 3 summarises the criteria used to select data for each taxonomic category in order to reduce bias as much as possible. With the exception of sperm whales and pilot whales, sighting rates for most species or species groups were higher when the airguns were firing (Figure 35), but this was only statistically significant for all baleen whales combined (Table 4).

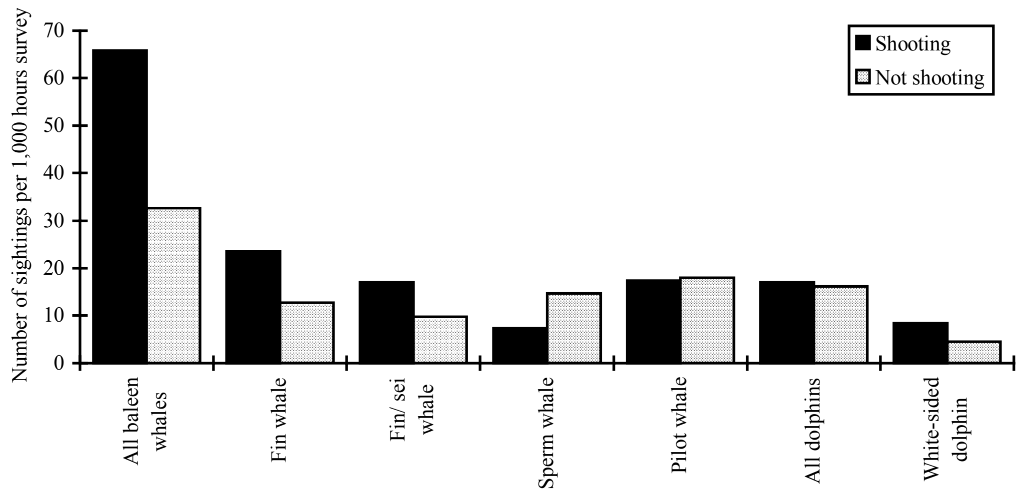


Figure 35 Sighting rates of cetaceans in relation to seismic activity (excluding site surveys), taking account of location, season and weather conditions.

Table 3 Criteria for selection of data for assessing sighting rate of cetaceans

Species	*Season*	*Areas*	*Sea state*	*Swell*	*Visibility*
All baleen whales	Jun - Aug	West of Shetland Rockall West of Ireland	Glassy Slight	Low Medium	Good
Fin whale	Jun - Aug	West of Shetland Rockall	Glassy Slight	Low Medium	Good
Fin/ sei whale	Jun - Aug	West of Shetland Rockall	Glassy Slight	Low Medium	Good
Sperm whale	May - Aug	West of Shetland Rockall West of Ireland	Glassy Slight	Low Medium	Good
Minke whale	Jun - Aug	West of Shetland Rockall Northern North Sea West of Ireland	Glassy Slight	Low Medium	Good Moderate
Pilot whale	May - Aug	West of Shetland Rockall West of Ireland	Glassy Slight	Low Medium	Good Moderate
All dolphins	Jun - Sep	West of Shetland Rockall Northern North Sea West of Ireland	Glassy Slight	Low Medium	Good Moderate
White-beaked dolphin	Jun - Aug	West of Shetland Rockall Northern North Sea	Glassy Slight	Low Medium	Good Moderate
White-sided dolphin	Jun - Sep	West of Shetland Rockall	Glassy Slight	Low Medium	Good Moderate

Table 4 Statistical significance of difference in sighting rate of cetaceans in relation to seismic activity, taking account of location, season and weather (d.f. = degrees of freedom; P = probability; n.s. = not significant).

Species	χ^2	*d.f.*	*P*
All baleen whales combined	10.909	1	< 0.001
Fin whale	3.000	1	n.s.
Fin/ sei whale	1.797	1	n.s.
Sperm whale	2.939	1	n.s.
Pilot whale	0.009	1	n.s.
All dolphins combined	0.040	1	n.s.
White-sided dolphin	1.357	1	n.s.

Although sighting rates of white-sided dolphins did not vary significantly with seismic activity, 55% of all white-sided dolphin pods encountered during periods of shooting were in association with other species, while only 11% of pods were accompanied by other species when the airguns were not firing. Sample sizes were insufficient to analyse unaccompanied white-sided dolphins separately from those that were accompanied.

Sighting rates of the more frequently occurring species were compared between 1997 and 1998 to see if there was any general increase or decrease in numbers of cetaceans seen. Subsets of data from each year were used according to the criteria in Table 3. Data from 1996 were not used as daily weather conditions were not recorded then. Fin whales, pilot whales and white-sided dolphins were seen slightly more often in 1997, although not significantly so (Figure 36). Minke whales and sperm whales were seen slightly more often in 1998, but again this increase was not significant. White-beaked dolphins were seen significantly more often in 1997 ($\chi^2 = 4.697$, d.f. = 1, $p < 0.05$).

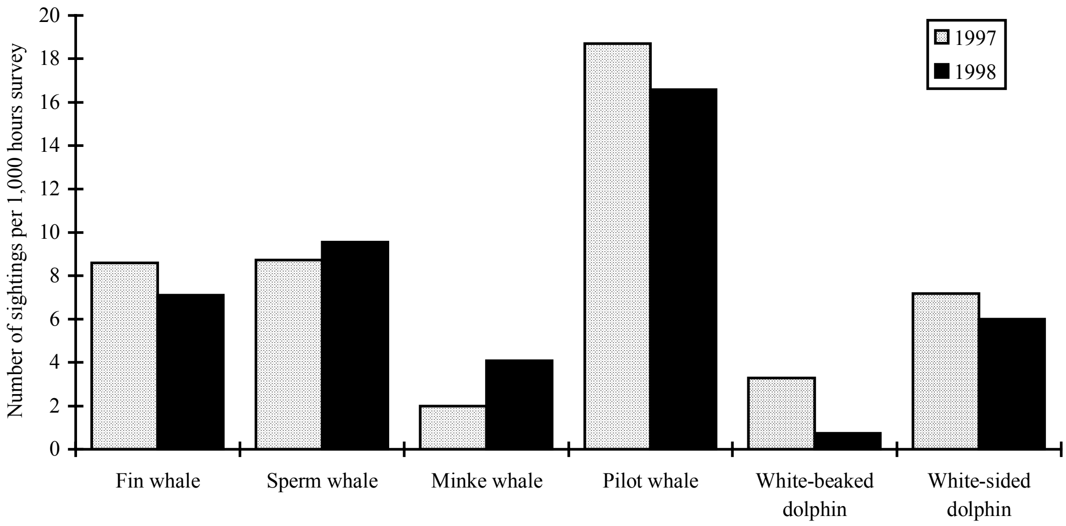


Figure 36 Sighting rates of cetaceans in 1997 and 1998 (excluding site surveys).

7.2 Distance of cetaceans from airguns

The median distance of cetacean pods from the airguns was compared for those species where distance was recorded both during periods of shooting and during periods when the airguns were not firing. Only those species where sample size exceeded ten pods were used. As cetaceans may have been easier to see at greater distances in better weather conditions, weather was again taken into account in this analysis; only sightings occurring during better weather conditions, as defined in Table 3, were used. For most species the median distance was fairly similar whether the airguns were firing or not (Figure 37). The median distance of sperm whales was much closer during periods of shooting, but permutation tests showed that this difference was not significant. In contrast, fin whales and all baleen whales combined were seen at significantly greater distances during periods of shooting ($p = 0.004$ for fin whales; $p = 0.014$ for all baleen whales combined).

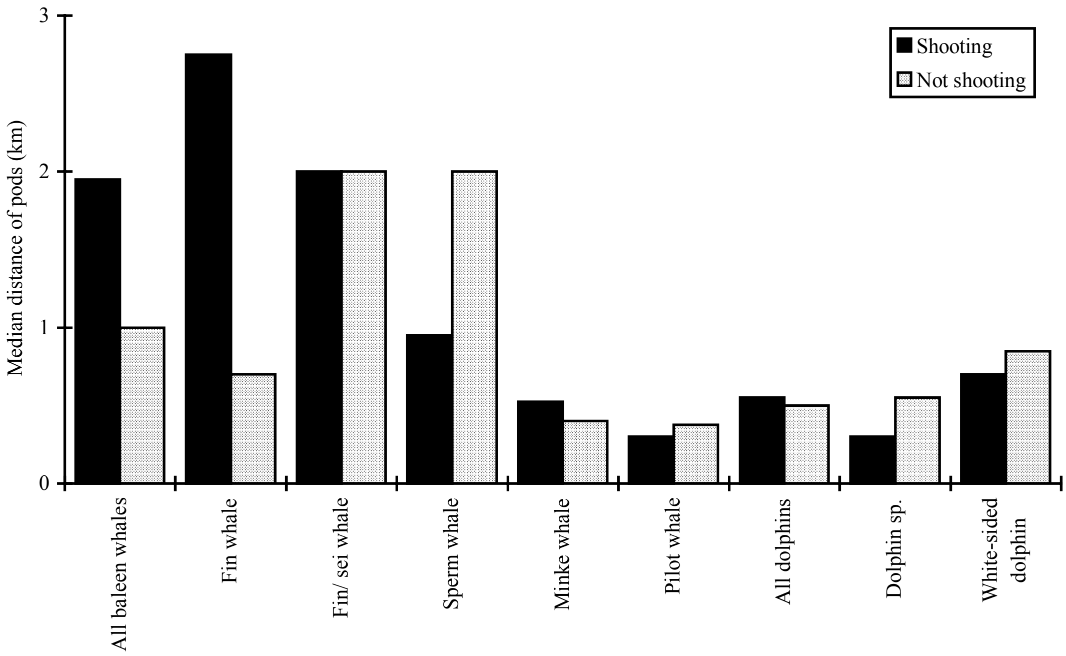


Figure 37 Median distance of cetacean pods from the airguns in relation to seismic activity (excluding site surveys).

7.3 Behaviour of cetaceans

Observers recorded any types of behaviour that were apparent - there were no limits to the types of behaviour or the number of different behaviours that could be recorded for any one sighting. For 25% of encounters, nothing other than 'normal swimming' was observed. In the remaining 75% of encounters 27 other types of behaviour were recorded, some being observed more frequently than others. Table 5 summarises the results for the more notable types of behaviour. The number of encounters where each behaviour was exhibited during periods of shooting or not shooting is expressed as a percentage of the total number of encounters at the respective seismic activity. Where types of behaviour were exhibited more frequently by particular species, the results for those individual species are shown; otherwise species were combined. Sample sizes were mostly too small to permit statistical testing of the results, but some significant results were found.

Cetacean behaviour may be difficult to assess based on surface observations, and little is known about the significance of some types of behaviour. Nevertheless, certain types of behaviour may be interpreted as natural activity e.g. feeding and logging/ resting. Feeding was observed on a number of occasions, particularly in fin whales where lunge-feeding was obvious. Feeding occurred more often when the airguns were not firing, although there were some occasions when cetaceans were feeding during periods of shooting. Low sample sizes precluded statistical testing for fin whales, but the difference in numbers of cetaceans feeding was significant when all species were combined ($\chi^2 = 4.079$, d.f. = 1, $p < 0.05$). Pilot whales were observed logging or resting more often during periods when the airguns were not firing. Conversely, sperm whales were seen logging or resting less frequently during periods when the airguns were not firing, possibly reflecting their greater tendency to dive at these times.

Table 5 Behaviour of cetaceans in relation to seismic activity (excluding site surveys).

Behaviour	*Species*	*% of encounters while shooting when behaviour was exhibited*	*% of encounters while not shooting when behaviour was exhibited*
Feeding	Fin whale	8.00	25.00
	All species combined	5.50	10.80
+ve interactions	Minke whale	0.00	18.18
	Pilot whale	6.12	10.00
	Killer whale	0.00	25.00
	Bottlenose dolphin	16.67	25.00
	White-beaked dolphin	0.00	50.00
	White-sided dolphin	9.09	6.25
	Common dolphin	25.00	33.33
	All species combined	3.21	9.06
-ve interactions	All species combined	1.83	0.70
Alteration of course	All baleen whales	5.00	3.28
	Pilot whale	16.33	1.67
	White-sided dolphin	18.18	6.25
	All species combined	6.88	3.14
Breaching or jumping	All dolphins combined	51.28	36.70
Tail/ flipper-slapping	Pilot whale	10.20	0.00
	All species combined	2.75	0.35
Fast swimming	Fin whale	4.00	15.00
	Sperm whale	6.67	5.00
	Pilot whale	14.29	13.33
	All dolphins combined	48.72	32.11
Surfacing frequently	All species combined	2.29	2.09
Surfacing infrequently	Fin whale	8.00	15.00
	All baleen whales	10.00	14.75
	Pilot whale	0.00	3.33
Diving	Fin whale	4.00	15.00
	All baleen whales	5.00	18.03
	Sperm whale	46.67	65.00
Spy-hopping	Pilot whale	6.12	10.00
Logging/ resting	Sperm whale	26.67	5.00
	Pilot whale	4.08	10.00

Seismic activity had some effect on the swimming characteristics of cetaceans. Dolphins (all species combined) showed a greater tendency to swim at fast speeds during periods of shooting, and were seen breaching or jumping more often at these times. Conversely, fin whales were observed to be swimming at fast speeds more often when the airguns were not firing. In both fin whales and all baleen whales combined, the tendency to surface infrequently when the airguns were not firing was concurrent with a greater tendency to dive at these times. This increased tendency to dive when the airguns were not firing was statistically significant for all baleen whales combined ($\chi^2 = 5.524$, d.f. = 1, $p < 0.05$). Sperm whales also dived more often when the airguns were not firing. Like the baleen whales, pilot whales were more often recorded as surfacing infrequently when the airguns were not firing. Spy-hopping in pilot whales occurred mostly when the airguns were not firing, but they only engaged in tail-slapping during periods of shooting.

White-sided dolphins and pilot whales showed a much greater tendency to alter their course during periods of shooting. Alterations of course were also more frequent during periods of shooting for all baleen whales combined and all species combined. Alterations of course during periods of shooting were mostly (40%) away from the survey vessel, with only 7% of course alterations being towards the vessel. When the airguns were not firing, 44% of course changes were towards the vessel, with 33% away from it.

Positive interactions with the survey vessel or its equipment (i.e. approaching the vessel, bow-riding, swimming alongside or following the vessel) sometimes occurred during periods of shooting. However, most species engaging in positive interactions with the vessel did so more often when the airguns were not firing. When all species were combined, positive interactions with the vessel occurred significantly more often when the airguns were not firing ($\chi^2 = 6.492$, d.f. = 1, $p < 0.05$). Negative interactions with the survey vessel (i.e. avoidance) were observed on only a few occasions, mostly during periods of shooting.

Table 6 Direction of travel of cetacean pods relative to the survey vessel in relation to seismic activity (excluding site surveys).

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		1			1	
	Not shooting	2	1	1		4	
All baleen whales combined	Shooting	3	16	18	6	27	9
	Not shooting	5	17	4	5	22	7
Large whale sp.	Shooting	1	2	4	1	3	2
	Not shooting	1			2	1	2
Fin whale	Shooting	1	5	7	2	8	2
	Not shooting	1	6	1		9	3
Fin/ sei whale	Shooting		3	5	3	6	3
	Not shooting		2	2	1	7	2
Fin/ sei/ humpback whale	Shooting		2	2		2	3
	Not shooting		3	1			1
Sperm whale	Shooting	1	3	7		3	1
	Not shooting	2	2	5	4	4	3
Minke whale	Shooting	1	4			4	
	Not shooting	3	3		1	4	
Pilot whale	Shooting	3	10	9	7	18	1
	Not shooting	10	8	4	8	25	4
Killer whale	Shooting		1	1		2	
	Not shooting	3		3	2	2	1
All dolphins combined	Shooting	4	9	6	2	12	4
	Not shooting	20	15	12	19	24	9
Dolphin sp.	Shooting	1	2	2		3	2
	Not shooting	7	4	7	8	10	7
Bottlenose dolphin	Shooting	1	2	1		2	
	Not shooting		1		2	4	1
White-sided dolphin	Shooting	1	1	3	1	3	2
	Not shooting	4	4	2	3	2	
Common dolphin	Shooting	1	2			1	
	Not shooting	5	6	2	1	4	
Total for all species	***Shooting***	***13***	***42***	***46***	***16***	***71***	***17***
	Not shooting	***44***	***43***	***32***	***41***	***84***	***28***

The direction of travel of cetaceans relative to the survey vessel was recorded by observers in a diagram and was subsequently assigned to one of six categories. Table 6 presents the results for all species where direction of travel was recorded for ten or more pods. During periods of shooting, 22% of cetacean pods encountered were heading away from the vessel, with only 6% heading

towards it. When the airguns were not firing 12% of pods were heading away from the vessel, with 16% heading towards it. Sample sizes were low, precluding statistical testing of individual species with the exception of pilot whale. Results for pilot whales were not statistically significant, but the results for all species combined were significant
(χ^2 = 25.228, d.f. = 5, $p < 0.001$). Partitioning showed that significantly more pods were heading away from the vessel when the airguns were firing, while significantly more pods were heading towards the vessel or in the same direction as it when the airguns were not firing.

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

Seismic surveys during 1998 were conducted in waters of various depths, ranging from the relatively shallow waters of the North Sea, to the deep waters to the north and west of the UK. Depth of water can influence the propagation of sound underwater, and therefore could influence the response of cetaceans to seismic activity. Observers gave their location for each day on the 'Location and Effort' forms, so for surveys where these forms were correctly completed, each day could 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 was then calculated (Table 7). The proportion of time spent shooting over the continental shelf was less than over the shelf slope or in deep waters.

The depth of water was normally recorded whenever cetaceans were seen. Median, minimum and maximum depths for each species are presented in Table 8. Most sightings of large whales occurred in deep waters or over the shelf slope, with only two sightings in shallower waters over the outer continental shelf. Minke whales, pilot whales, bottlenose dolphins, white-sided dolphins and common dolphins were also mostly seen in deep waters or over the shelf slope, with few in shallower shelf waters. Killer whales were more evenly distributed between the outer shelf and deeper waters. Risso's dolphins and harbour porpoises were seen mostly over the continental shelf, with occasional sightings over the shelf slope. White-beaked dolphins were only seen in shelf waters.

In deeper waters, relatively more cetaceans were encountered during periods of shooting than was the case in shallower waters (Table 9). Median tests showed that these results were significant for fin/ sei whales, all baleen whales combined, white-sided dolphins and all dolphins combined. The greater proportion of encounters while shooting in deeper waters could, in part, reflect the greater proportion of time spent shooting in these waters.

7.5 Sightings during the soft-start

Sightings of cetaceans during the soft-start fell into two categories: those first appearing during the soft-start, and those which had been seen prior to shooting but which were still visible when the soft-start commenced. In total, there were 18 sightings during the soft-start, six being seen beforehand and 12 not appearing until after the soft-start had commenced.

Of the 12 sightings when cetaceans were first seen during the soft-start, five occurred within 500 m of the airguns. At the time of these sightings the soft-start was well underway; in three cases power levels were approaching close to the maximum levels used. The behaviour of cetaceans which appeared close to the airguns during the soft-start gave no indications of disturbance. On three of the five occasions the cetaceans approached the survey vessel, and although one pod of pilot whales disappeared on reaching the cables, a pod of common dolphins was sufficiently tolerant of the firing to engage in bow-riding.

On the remaining seven occasions when cetaceans first appeared during the soft-start the distance from the airguns at which they were seen ranged from 700 m to 4.5 km. There were no obvious signs of disturbance. On one occasion a mixed pod of fin whales and white-sided dolphins at 700 m from the airguns were observed swimming away from the vessel, but only moved a short distance to a location where they were seen milling for most of the remainder of the soft-start, with one whale lunge-feeding.

Only one of the six cetacean sightings occurring both prior to and during the soft-start was within 500 m of the airguns (under the *Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys*, the commencement of firing must be delayed if marine mammals are detected within 500 m of the airguns). In this, and one other, instance, behaviour indicating a 'startle' response was observed as the soft-start commenced. In the first instance, a soft-start began while pilot whales were 290 m from the airguns. The pilot whales, which had been approaching the airguns, altered course to head away from the airguns. The other instance of a 'startle' response occurred at a considerably greater distance. A sperm whale was observed swimming slowly at a distance of
2 km from the airguns and dived shortly before the soft-start commenced; when the soft-start began the whale resurfaced and swam rapidly at the surface. There was one occasion when a pod of fin whales slowly increased their distance from 1.5 km away from the airguns prior to the soft-start to 2 km away by the time full power was reached, but it was not known whether these animals would have moved away regardless of seismic activity. On the remaining three occasions a degree of tolerance was observed as the soft-start commenced. A pod of white-sided dolphins at 700 m from the airguns and a pair of fin whales at 1.5 km away showed no change in their behaviour, while one individual from a pod of sperm whales approached from 600 m to 100 m from the airguns during the soft-start, apparently undisturbed.

Table 7 Proportion of time spent shooting at different depths (excluding site surveys).

Depth	***Proportion of time spent shooting***
0-200 m	28.75%
200-1,000 m	41.01%
> 1,000 m	40.94%

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.	1,000	140	1,800	19
Whale sp.	1,300	388	2,500	13
Large whale sp.	1,095	176	3,000	24
All baleen whales combined	1,108	52	3,830	145
Humpback whale	1,439.5	590	2,000	6
Blue whale	1,554.5	1,200	1,769	4
Fin whale	1,038.5	162	1,773	46
Sei whale	1,907.5	1,761	3,000	4
Sperm whale	1,608	1,000	2,163	35
Fin/ blue whale	1,400	981	1,513	5
Fin/ sei whale	1,168.5	300	1,773	36
Fin/ sei/ blue whale	1,199	1,027	1,870	3
Fin/ sei/ humpback whale	1,108	730	2,100	15
Fin/ sei/ blue/ humpback whale	803	374	1,780	6
Humpback/ sperm whale	1,635	678	2,500	6
Minke whale	1,140	52	3,830	20
Sowerby's beaked whale	1,196	1,196	1,196	1
Pilot whale	1,485	120	2,500	109
Killer whale	815.5	133	2,000	16
All dolphins combined	718	23	3,000	158
Dolphin sp.	900	69	3,000	67
Risso's dolphin	115	76	483	3
Bottlenose dolphin	567	68	1,867	15
White-beaked dolphin	88	90	140	4
White-sided dolphin	1,028.5	90	2,500	30
Lagenorhynchus sp.	838	528	1,613	4
Common dolphin	794.5	76	3,000	22
Common/ white-sided dolphin	1,380.5	1,000	1,761	2
Striped dolphin	1,800	1,800	1,800	1
Common/ striped dolphin	500	500	500	2
Patterned dolphin	115	110	120	2
Harbour porpoise	172	23	572	6

Table 9 Proportion of cetacean pods encountered while shooting, at depths exceeding or not exceeding the median depth for each species (excluding site surveys).

Species	***Sightings at depths not exceeding median depth - percentage of pods encountered while shooting***	***Sightings at depths exceeding median depth - percentage of pods encountered while shooting***	χ^2	***d.f.***	***P***
All baleen whales	44.9	69.0	7.335	1	< 0.01
Fin whale	54.5	56.5	0.028	1	n.s.
Fin/ sei whale	29.4	88.9	10.528	1	< 0.01
Sperm whale	38.9	47.1	0.021	1	n.s.
Minke whale	33.3	60.0	*	1	n.s.
Pilot whale	43.4	48.1	0.090	1	n.s.
Killer whale	11.1	42.9	*	1	n.s.
All dolphins	15.9	35.5	6.196	1	< 0.01
Bottlenose dolphin	25.0	66.7	*	1	n.s.
White-sided dolphin	15.4	64.3	4.805	1	< 0.05
Common dolphin	0.0	36.4	2.750	1	n.s.

* probability calculated using Fisher exact test

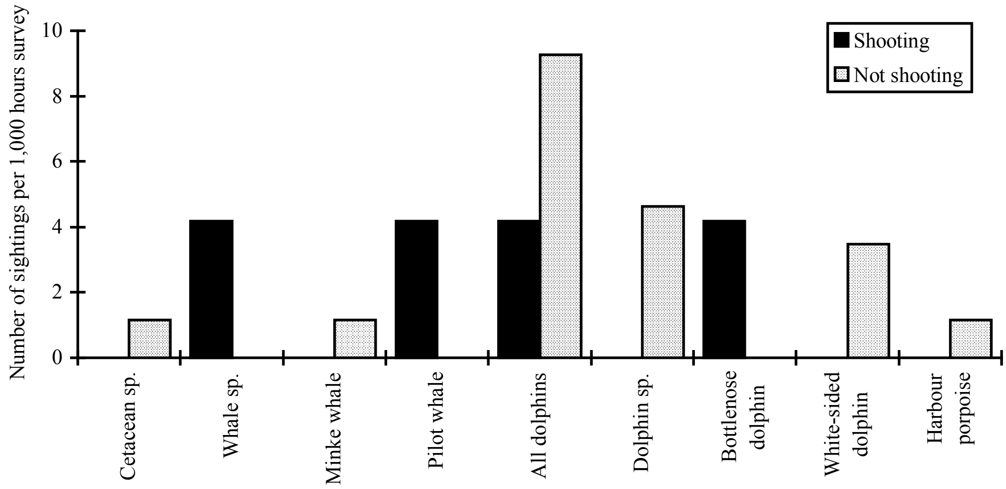


Figure 38 Sighting rates of cetaceans in relation to seismic activity during site surveys

7.6 The effects of site surveys on cetaceans

Reports were received from 18 site surveys during 1998, during which there were 29 sightings of cetaceans. The airguns were firing for 22% of the time spent watching for marine mammals, but only three sightings occurred during periods of shooting. 'Location and Effort' forms were completed correctly for ten of the 18 site surveys. The sighting rate of cetaceans per 1,000 hours of observations was calculated using these ten surveys. As sample sizes were already small, no account was taken of location, season or weather conditions.

Sighting rates of pilot whales were greater during periods of shooting on site surveys, while most dolphins were seen more frequently when the airguns were not firing (Figure 38). However, sample sizes were too small to permit statistical testing for any of the species or species groups observed.

There were too few sightings where distance was recorded to make a proper comparison between periods of shooting and not shooting. In general cetaceans came closer when the airguns were not firing. The closest any cetaceans were observed during periods of shooting was 500 m, whereas more than half of the sightings when the airguns were not firing were closer than this.

When the airguns were not firing 31% of cetacean pods were observed to be travelling towards the survey vessel, and 12% across its path. None were observed to be travelling in these directions during periods of shooting. No cetaceans were seen to be travelling away from the vessel at any time. Positive interactions with the survey vessel or its equipment (i.e. approaching the vessel, bow-riding or following the vessel) were recorded for 27% of encounters when the airguns were not firing, but were never observed during periods of shooting. Positive interactions usually involved dolphins. No negative interactions were observed at any time.

8. Compliance with guidelines

Compliance with the *Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys* was measured in several ways. The aspects considered were: 1) the level of notification and reporting of seismic surveys; 2) the maintenance of a watch for marine mammals prior to shooting; 3) the delay in commencing shooting if marine mammals were close by; and 4) the use of a soft-start procedure. Application of the guidelines is required under licence conditions in blocks licensed in the 16th and subsequent rounds of offshore licensing. However, many companies have adopted a more widespread application of the guidelines. It was assumed that if a report was received from a survey then the operator or contractor intended to comply with the guidelines during that survey, thus the maintenance of a watch, delays taken and the use of a soft-start were monitored for all surveys from which reports were received. 'Record of Operations' forms were used to obtain the necessary information - these forms were completed for 43 surveys.

8.1 Notification and reporting of surveys

JNCC received notification of and/or reports from a total of 34 seismic surveys conducted during 1998 in blocks licensed in the 16th and 17th rounds, where compliance with the guidelines (and thus notification and submission of a report) is a licence condition. Both notifications and reports were received for 19 of these surveys, while for ten surveys notifications were received but no reports and for five surveys reports alone were received. The proportion of surveys which were both notified and reported had increased from 1996 and 1997 levels (Table 10).

Table 10 Notification and reporting of seismic surveys in blocks subject to the *Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys*, 1996-1998.

Notification and/or report received	***1996***	***1997***	***1998***
Notification and report	38%	51%	56%
Notification only (no report)	17%	40%	29%
Report only (no notification)	45%	9%	15%

In 1998, notification was received of 51 additional surveys in UK waters in blocks licensed outside the 16th and 17th rounds. Reports were received from 34 surveys in UK or adjacent waters (e.g. Irish, Norwegian, Danish or German) conducted in blocks licensed outside these rounds. In addition, a number of reports were sent in from seismic survey vessels working further afield and from other platforms used by the oil industry, such as rigs, supply vessels and drillships (Appendix 3).

8.2 Watches for marine mammals

Under the guidelines, a watch for marine mammals should be maintained for at least 30 minutes before commencement of any use of the seismic sources. 'Record of Operations' forms provided information for all occasions when the airguns were used, including during the hours of darkness. Visual searches were not possible during darkness, but there were records of 1,650 occasions when the airguns were used during daylight hours. The majority (81%) of searches were of more than 30 minutes duration (Table 11). However, there were 54 occasions when there was no search for marine mammals prior to shooting commencing during daylight hours. There were also a number of instances where the search was shorter than 30 minutes.

Reduced duration of searches was more common during surveys in blocks licensed prior to the 16th round of offshore licensing. In 16th/17th round blocks, where compliance with the guidelines is a licence condition, 88% of pre-shooting searches met or exceeded the required minimum duration (30 minutes). On 35 out of 926 occasions there was no pre-shooting search in these blocks, while on 81 occasions the search was shorter than 30 minutes.

8.3 Delays in shooting

There is the facility on the 'Record of Operations' forms to record whether marine mammals were present prior to shooting commencing, and what action was taken if necessary. In addition, 'Record of Sighting' forms were cross-referenced with the 'Record of Operations' forms to reveal any relevant sightings that were not noted on the 'Record of Operations' forms.

There were 12 occasions when marine mammals were seen within 500 m of the airguns when shooting was due to
commence (Table 12). On five of these occasions the distance of the animals from the airguns was uncertain as 'Record of Sighting' forms were not completed, but as some action was taken on these occasions it was assumed that the distance was 500 m or less. Two of the 12 instances occurred in blocks licensed prior to the 16th round of offshore licensing, or in blocks outside UK waters, thus compliance with the guidelines was not a licence condition. The remaining ten instances occurred in blocks licensed in the 16th or 17th rounds, where compliance with the guidelines was required.

On the ten occasions where compliance with the guidelines was a licence condition, shooting should have been delayed until at least 20 minutes after the animals were last seen. Shooting should then have commenced with a soft-start of at least 20 minutes duration (excepting some site surveys where power levels remained low throughout). Correct procedures were followed on two of the ten occasions; on one occasion shooting was delayed by 22 minutes and then a soft-start of 21 minutes was employed, while on the second occasion shooting was delayed by 28 minutes and then started without a soft-start (this instance occurred during a site survey). On six occasions, although some action was taken, it fell short of the required standards either because there was no delay or because the subsequent soft-start was too short. On two occasions there was apparently no attempt to take any action to minimise disturbance to the nearby marine mammals.

On one of the occasions when no action was taken there was an error on the 'Record of Operations' form - the time of the first sighting of the animals had been entered instead of the time of the last sighting, making it appear that the animals were last seen 20 minutes prior to shooting commencing (which would have been acceptable), rather than 15 minutes as was actually the case.

On one of the occasions when action was taken which did not follow the required procedures, the marine mammals appeared so close to the time when the soft-start was due to begin that the marine mammal observer was unable to inform the crew of their presence before the airguns commenced firing. In this instance, after consultation with the crew, the soft-start was extended to 55 minutes.

Table 11 Duration of pre-shooting searches for marine mammals

Duration of search	*16th and 17th round blocks*		*Other blocks*		*All surveys combined*	
No search	35	(3.8%)	19	(2.6%)	54	(3.3%)
1-9 minutes	11	(1.2%)	13	(1.8%)	24	(1.5%)
10-19 minutes	26	(2.8%)	37	(5.1%)	63	(3.8%)
20-29 minutes	44	(4.8%)	137	(18.9%)	181	(11.0%)
30 minutes or more	810	(87.5%)	518	(71.5%)	1,328	(80.5%)

Table 12 Marine mammal sightings occurring within 500 m of the airguns at times when shooting was due to commence

Species	*Distance from airguns (metres)*	*Action taken*	*Minutes after last sighting when firing began*	*Duration of soft-start (minutes)*	*Sighting noted on 'Record of Operations' form*	*Block licence*
Fin/ sei whale	200	None	10	30	Yes	17th round
Humpback/ sperm whale	300	None	15	34	No	Irish
Pilot whale	100	None	15	19	Yes	17th round
Pilot whale	290	Prolonged soft-start	< 1	55	Yes	17th round
Dolphin sp.	300	Delayed shooting	22	21	Yes	17th round
Dolphin sp.	500	Delayed shooting	75	18	Yes	17th round
White-sided dolphin	10	Delayed shooting	28	0 (site survey)	Yes	16th round
Species unknown	?	Delayed shooting	?	17	Yes	17th round
Species unknown	?	Delayed shooting	?	19	Yes	17th round
Species unknown	?	"Circled on approach"	?	19	Yes	17th round
Species unknown	?	"Circled on approach"	?	127	Yes	17th round
Species unknown	?	Delayed shooting	9	18	Yes	Not 16th/17th round

On one survey there were two occasions when it was recorded that the vessel "circled on approach". On these occasions, rather than following the guidelines, the airguns were kept firing at low power during turns in order to allow seismic operations to continue in an area of high cetacean abundance. It was feared that if the guns were stopped between survey lines, the presence of cetaceans (and thus the requirement for a delay before commencing shooting for the next line) would have made it impossible to restart the guns. Continuous shooting between survey lines is regarded as contrary to the principles of the guidelines and is not an accepted practice (Stone 1998a), but there was no record that JNCC was consulted about the decision to adopt this practice. Prior to this practice being adopted there were only two delays in shooting on this survey due to the presence of cetaceans, and in both cases the subsequent soft-start had been shorter than the required minimum duration of 20 minutes.

8.4 Soft-starts

Whenever the airguns are used there should be a soft-start procedure, with the power building up gradually from a low energy level to full power over at least 20 minutes. However, the guidelines recognise that on some site surveys the seismic sources always remain at low power levels, and in these cases the soft-start may be waived. The duration of soft-starts for site surveys was therefore analysed separately from other surveys. Occasions when the airguns never reached full power (e.g. during some testing or if shooting was aborted during the soft-start) were disregarded in the analysis.

During 1998 some site surveys did not use a soft-start, but others used a short soft-start as their equipment allowed, with an average duration of nine minutes in 16th/17th round blocks, and three minutes in other blocks. For larger scale surveys in 16th/17th round blocks, where the soft-start should always have been at least 20 minutes in duration, the mean duration was 27 minutes (Table 13). For these surveys, most (80.9%) soft-starts were between 20 and 40 minutes duration. However, 14.2% of soft-starts were either absent or shorter than 20 minutes. The standard of soft-starts in other blocks was lower than in 16th/17th round blocks. In other blocks the mean duration of soft-starts for larger scale surveys was 26 minutes, 67.3% of soft-starts were between 20 and 40 minutes duration and 27.4% were shorter than 20 minutes.

Absent or short soft-starts were a more common occurrence when fishery liaison representatives were used as observers than when dedicated marine mammal observers were employed (26.2% of soft-starts were absent or shorter than 20 minutes when fishery liaison representatives were used, compared to 3.1% when dedicated marine mammal observers were used).

On three occasions there was no soft-start. On one occasion the soft-start was omitted due to time-sharing, although on later occasions during the same survey soft-starts commenced as the other vessel approached the end of a survey line. On another occasion there was no soft-start when a line which had been aborted was re-commenced, even though there had been a gap of 79 minutes since shooting had stopped. On the third occasion no reason was given for the absence of a soft-start.

At the other extreme, there were some lengthy soft-starts, the maximum duration being 220 minutes. No reasons were given for these long soft-starts, which occurred in only a small number of cases. Less than 1% of all soft-starts were longer than one hour.

Table 13 Soft-starts used during seismic surveys in 1998 (excluding site surveys).

Parameter	*16th/ 17th round blocks*	*Other blocks*
Minimum duration (minutes)	0	6
Maximum duration (minutes)	127	220
Mean duration (minutes)	27	26
Sample size	941	810
Number of occasions when there was:		
no soft-start	3	0
soft-start < 20 minutes	131	222
soft-start > 1 hour	10	7

9. Discussion

9.1 Distribution of cetaceans

To a large extent, the distribution of cetaceans observed during seismic surveys in 1998 reflected the location and timing of surveys. Although there were a number of seismic surveys in the northern North Sea, many of these occurred during spring and early summer. Peak numbers of cetacean sightings occurred in July, when survey effort was concentrated in the areas West of Shetland and Rockall. As a result, most sightings occurred in these areas.

Allowing for the inequality of survey effort, cetacean distribution largely concurred with previous knowledge. Amongst the most frequently seen species were those which are known to inhabit the deep north-western waters where survey effort was intensive during the summer months, such as the large whales and pilot whales. Whaling records show that fin and sperm whales were caught most often just beyond the edge of the continental shelf (Evans 1990; Thompson 1928), while more recently acoustic studies have found fin, blue and humpback whales in offshore waters to the north and west of the UK (Clark & Charif 1998). Similarly, pilot whales are known to be common in north-western waters (Bloor *et al.* 1996; JNCC 1995; Skov *et al.* 1995), whilst also occurring to the south-west of the UK (Evans 1980, 1992; JNCC 1995).

The only large whale showing any evidence of migratory movements was the sperm whale. Males of this species are known to move northwards towards polar regions in the summer, with females and juveniles occasionally coming into northern waters (Evans 1980). At some point the return journey southwards must begin. Observations during seismic surveys suggested that in 1998 some sperm whales began moving southwards in June, and by July the southwards movement was well established.

Killer whales and white-sided dolphins also occurred mostly to the north-west of the UK, which again fits with known distribution patterns. Killer whales are most abundant in colder waters (Evans 1992). White-sided dolphins around the UK have a predominantly northern and western distribution (Evans 1992; JNCC 1995).

For some species the fact that more sightings occurred to the north-west of the UK than elsewhere was clearly a reflection of the level of survey effort. Whilst minke whales were not seen exclusively in north-western waters, it might have been expected that more would have been seen in areas such as the northern North Sea if survey effort had been more equally distributed. Northridge *et al.* (1995) found the main concentrations of minke whales to be around the Hebrides and off the north-east coast of England, with a preference for coastal waters being apparent. Similarly, more bottlenose dolphins might have been expected in the northern North Sea, particularly near the Moray Firth, where there is a resident population of this species. However, offshore populations of bottlenose dolphins, as seen during these seismic surveys, are known to exist (e.g. Skov *et al.* 1995).

Common dolphins and striped dolphins might have been expected to occur in the South-West Approaches if survey effort in that area had been greater. Common dolphins have a predominantly south-westerly distribution around the UK (JNCC 1995); although they occurred in the area West of Ireland, none were seen further south, probably due to the low survey effort in the South-West Approaches. Common dolphins are also known to occur in more northern waters (Skov *et al.* 1995), so the concentration around Rockall was not unusual. Sightings of striped dolphins around the UK mostly occur in the South-West Approaches (Evans 1980), although a northwards expansion has been noted in recent years (Evans 1992). The only sighting of striped dolphins occurred in the area West of Ireland, where survey effort was greater than in the South-West Approaches.

Some species which are relatively common in UK waters were nevertheless seen infrequently. Northridge *et al.* (1995) found that white-beaked dolphins occurred mostly relatively close inshore around the coasts of Scotland, with a more scattered distribution throughout the northern North Sea between July and September. Survey effort in close inshore waters was relatively low, which may in part explain the low number of sightings of white-beaked dolphins during seismic surveys in 1998. Low survey effort in inshore waters around the Hebrides may also account for the low number of sightings of Risso's dolphins, which are known to occur there (Evans 1992; JNCC 1995). Harbour porpoises have a widespread distribution in UK waters (JNCC 1995; Northridge *et al.* 1995), but are often difficult to detect due to their small size and shy nature.

One Sowerby's beaked whale was seen in deep waters to the north-west of the Hebrides. This species is rarely seen at sea, but more intensive seabird and cetacean surveys in waters to the north-west of the Hebrides in recent years have resulted in a number of beaked whale sightings in this area (Pollock pers. comm.).

9.2 The effects of seismic activity on cetaceans

Since the introduction of the *Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys* (originally the *Guidelines for minimising acoustic disturbance to small cetaceans*), observations forwarded to JNCC have been analysed in an attempt to assess the effects of seismic activity on cetaceans. A pattern has been emerging indicating that the small odontocetes, such as white-beaked and white-sided dolphins, may be more susceptible to disturbance from seismic activity than the large baleen whales, such as fin whales, although the latter have shown some responses to seismic activity (Stone 1996, 1997a, b, 1998a, b). The present results are less clear, in many cases neither confirming nor contradicting previous trends.

In previous years, fewer white-sided dolphins were encountered during periods of shooting than when the airguns were not firing, and those that were seen during periods of shooting occurred at greater distances from the airguns (Stone 1996, 1997a, b, 1998a). In 1998 sighting rates of white-sided dolphins did not differ significantly with seismic activity, nor did the distance at which they were seen. There have been some indications that white-sided dolphins may be more tolerant of seismic activity when they are in association with other species such as pilot whales (Stone 1997b, 1998a, b). A high proportion of white-sided dolphin pods encountered in 1998 during periods of shooting were in association with other species, while few such associations were observed when the airguns were not firing. If white-sided dolphins are more tolerant of seismic activity when accompanied by other species, then the disproportionately large number of associations with other species during periods of shooting could have masked any effects of seismic activity. The only indication of any response to seismic activity by white-sided dolphins was that more pods altered their course when the airguns were firing.

Sample sizes of other small odontocetes were insufficient to compare sighting rates or the distance from the airguns in relation to seismic activity. However, there were a few indications that seismic activity may have been having some effect on small odontocetes. Fewer bottlenose dolphins, white-beaked dolphins and common dolphins engaged in positive interactions with the survey vessel during periods of shooting. Furthermore, dolphins tended to swim faster and engage in breaching and jumping more during periods of shooting, although the significance of this is not clear. In previous studies, common dolphins and white-beaked dolphins have shown some response to seismic activity (Goold 1996; Stone 1997a, 1998a). Pilot whales, a medium-sized odontocete, have shown conflicting results in previous years. On some occasions more pilot whales have been seen when the airguns were not firing (Stone 1997b, 1998b), while on other occasions more have been seen during periods of shooting (Stone 1998a) or there has been no significant difference (Stone 1997a). In 1998 there was no significant difference in the number of pilot whales encountered whether the airguns were firing or not, nor was there a significant difference in the distance at which they were seen. In 1997 some more subtle effects of seismic activity were observed in pilot whales, such as an increased tendency to swim at a faster speed during periods of shooting (Stone 1998a). In 1998 fast swimming speeds were observed only marginally more often when the airguns were firing, but some other subtle effects were observed. Alterations of course away from the vessel occurred much more often during periods of shooting, as did tail-slapping, which was never observed when the airguns were not firing. Tail-slapping is sometimes considered to be a sign of aggression (e.g. Martin 1990). Pilot whales are naturally curious animals, but they were observed spy-hopping less often during periods of shooting and were slightly less likely to engage in positive interactions with the survey vessel at these times. In addition, fewer were observed logging or resting during periods of shooting.

The sperm whale is the largest odontocete occurring in UK waters. Results in 1998 were similar to those in 1997 (Stone 1998a); in both years sighting rates and the distance at which sperm whales were seen from the airguns did not differ significantly with seismic activity. However, there was one difference between the two years: in 1997 sperm whales were observed to dive more frequently when the airguns were firing, whereas in 1998 they were seen diving more often when the airguns were not firing. There was no obvious explanation for this difference, but the trend in 1998 fits more closely with the results for other large whales, which in both years were observed to dive more often when the airguns were not firing. Sperm whales were observed to be swimming at fast speeds marginally more often when the airguns were firing. Logging or resting was observed less often when the airguns were not firing, possibly reflecting the increased tendency to dive below the surface at these times. In other studies sperm whale abundance has decreased in response to seismic activity (Mate, Stafford & Ljungblad 1994). They have also been found to stop vocalising during periods of seismic activity (Bowles *et al.* 1994), and possible negative effects on their communication have been noted (Rankin & Evans 1998).

The only positively identified baleen whale seen sufficiently often to assess the effects of seismic activity was the fin whale. Sighting rates of fin whales did not differ significantly with seismic activity. The only instance previously where sighting rates of fin whales did differ significantly was in 1996 (Stone 1997a), when sighting rates were higher during periods of shooting. As weather conditions were not taken into account in that year the increase in sightings probably reflected the fact that shooting generally occurred during better weather conditions, making cetaceans easier to detect. Although numbers of fin whales seen in 1998 did not differ with seismic activity, the distance at which they were seen did differ significantly. Fin whales were further away from the airguns when they were firing, which corresponds with results found in 1996 (Stone 1997a). Whereas in 1996 this trend could have been a consequence of the tendency to shoot in better weather conditions, in the present study weather conditions were taken into account when considering the distance of fin whales from the airguns. Some behavioural effects of seismic activity were also observed for fin whales. They were observed feeding less often during periods of shooting. Diving and surfacing infrequently occurred more often when the airguns were not firing.

Although other species of baleen whale were not seen sufficiently frequently to assess the effects of seismic activity on the individual species, when all baleen whales were combined sighting rates were found to be significantly higher during periods of shooting. However, the distance of pods from the airguns was significantly greater at these times. Baleen whales were observed to dive less often when the airguns were firing. A reduced tendency to dive during periods of shooting may increase the probability of detecting these animals, which may account for the higher sighting rates during periods of shooting.

Although sighting rate is the most obvious parameter to consider when assessing the effects of seismic activity, when used alone it may be inadequate as an indicator of disturbance. There are several reasons why sighting rates may not differ significantly with seismic activity even though cetaceans may be disturbed. Firstly, cetaceans may have no choice but to remain in an area if there is no suitable alternative (Richardson *et al.* 1995). This may be of particular importance where neighbouring areas are also subject to seismic activity, as is often the case in UK waters. Secondly, individual cetaceans may leave the area but sighting rates may remain the same due to new individuals passing through. Thirdly, even if numbers of cetaceans are reduced due to seismic activity there may be some effect on their behaviour which renders them more easily visible, thus falsely inflating sighting rates during periods of shooting.

Increased sighting rates during periods of seismic activity due to a change in behaviour of cetaceans may have been the case when all baleen whales were combined. As mentioned above, lower numbers of baleen whales diving during periods of shooting meant that more remained detectable at the surface, possibly influencing the results. Similarly, when individual species were considered, fin whales and sperm whales were also found to dive less often when the airguns were firing, and the resultant increase in the ease of detection of these species during periods of shooting may have led to bias in the results. Furthermore, fin whales, all baleen whales and pilot whales were more often recorded as surfacing infrequently when the airguns were not firing than when they were firing. Like diving, this may indicate a greater tendency to remain submerged when the airguns were not firing, and by implication a greater tendency to remain near the surface during periods of shooting, thus increasing sighting rates then. Although sighting rates of fin whales, sperm whales and pilot whales were similar regardless of seismic activity and those of baleen whales (all species combined) were higher when the airguns were firing, this may not have been an accurate means of comparing the number of whales present if more animals were submerged when the airguns were not firing. It has been speculated that cetaceans may remain near the water surface during periods of seismic activity because sound levels near the surface are reduced due to the Lloyd mirror effect (cancellation of direct and surface-reflected signals). McCauley *et al.* (1998) put forward this idea as an explanation for humpback whales spending much time at the surface during a period of seismic activity.

Although it is possible that sighting rates during periods of shooting were influenced by a tendency of cetaceans to remain near the surface, it is equally possible that any such bias may have been small and insignificant. The lack of adverse effects of seismic activity on the sighting rates of baleen whales (all species combined), fin whales, fin/sei whales, sperm whales, pilot whales, dolphins (all species combined) and white-sided dolphins may have simply indicated a tolerance of seismic activity.

Variations in abundance are not the only way in which cetaceans may be affected by seismic activity. Other effects may be detected even if sighting rates remain the same. In this study, more subtle effects were observed in many of the species examined. For example, fin whales and all baleen whales were found to remain further from the airguns during periods of shooting. As mentioned above, their diving behaviour was affected, as was that of sperm whales. Dolphins swam faster and breached or jumped more often, while pilot whales engaged in tail-slapping more often when the airguns were firing. Various species were more likely to alter course away from the survey vessel during periods of shooting, and correspondingly positive interactions with the vessel occurred less frequently during periods of shooting. Most of the more frequently occurring species showed some kind of response to seismic activity, but it is difficult to assess the importance of these responses. For example, does an alteration of course away from the survey vessel represent a minor and temporary diversion, or does it have consequences (e.g. taking the animals away from a source of food) which make it a more serious threat?

Although these effects were observed, responses to seismic activity were generally less than has been demonstrated in previous years, at least in terms of effects on sighting rates and distance from the airguns. It is possible that cetaceans may habituate to noise as a result of repeated exposure to an acoustic source; alternatively they may become increasingly sensitive to acoustic disturbance (Richardson *et al.* 1995). There is no evidence to date of any increased sensitivity, but it would be premature to speculate that species such as white-sided dolphins are habituating to noise from seismic surveys.

There may have been other reasons why cetaceans were apparently more tolerant of seismic activity in 1998 than in previous years. Sample sizes were lower in 1998 than in 1997, which may have led to non-significant results. Alternatively, cetaceans may tolerate seismic activity because it is of some benefit to them to remain in the area. One obvious example of this is if there is seismic activity in an area where food is abundant. In 1998 many more cetaceans were observed to be feeding than in 1997 (Stone 1998a), particularly fin whales. Although it is possible that seismic activity may affect prey abundance (e.g. Engås *et al.* 1996; Turnpenny & Nedwell 1994), the continued presence of feeding cetaceans in areas of prolonged seismic activity suggested that prey abundance was not affected. The presence of prey in areas subject to seismic activity in 1998 may have led to an increased tolerance of seismic activity when compared to previous years.

There are other potential effects of seismic activity which were beyond the scope of this study. The present study considered only short-term effects. Although there was a remarkable similarity in sighting rates of fin whales, pilot whales and white-sided dolphins between 1997 and 1998, it may be many years before any long-term effects become apparent. However, the reduction in sightings of white-beaked dolphins in 1998 seems unlikely to be due to continued seismic activity. Sightings of white-beaked dolphins have been more frequent during seismic surveys in 1999 (Stone 1999), so the most likely explanation for the reduction in sightings in 1998 is that survey effort was relatively low in the areas and months of peak occurrence of this species. Other potential effects of seismic activity which were not measured include auditory damage and effects on vocal activity; cessation of vocalisation has sometimes been noted in response to seismic activity (Bowles *et al.* 1994; Richardson 1997). Alterations of respiration and dive cycles have sometimes been observed (Ljungblad *et al.* 1988; Richardson *et al.* 1985), in some instances at considerable distances from the source (Richardson, Würsig & Greene 1986). A previous analysis of data from both 1997 and 1998 revealed that blow intervals of fin whales at distances of 1 km or less from the airguns were significantly shorter during periods of seismic activity (Stone 1998b).

It is difficult to be certain what level of threat is posed to cetaceans by seismic activity. Although some effects were observed, some cetaceans continued to feed during periods of seismic activity, some were seen relatively close to the survey vessel, and some even engaged in positive interactions with it. This might indicate that at least some individuals are unaffected by seismic activity. So far there is little to indicate that seismic activity poses a major threat, but it is possible that more serious effects, such as auditory damage or physiological effects, remain undetected. Similarly, long-term effects on distribution, migration, and the ability to feed and breed successfully could seriously effect the viability of populations. Although the effects observed in this study only indicate some short-term behavioural responses there is no reason to be complacent when so much remains unknown.

It is important that the *Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys* are still followed by all surveys using higher energy seismic sources, including site surveys. Data from site surveys in both 1997 and 1998 has been too limited to draw firm conclusions. In 1997 there were indications that some species, such as pilot whales, may be tolerant of the airguns used in site surveys, but that other species, such as dolphins, may be more sensitive (Stone 1998a). During 1998 there were very few encounters with cetaceans when the airguns were firing during site surveys, perhaps indicating some sensitivity. Even when considering the larger set of data from seismic surveys with higher power sources, there are still species for which little is known. Thirty-five species of cetacean have been recorded in the north-east Atlantic, yet for at least 24 of these there is little or no information on the effects of seismic activity on them. The precautionary approach of the guidelines should, therefore, continue to be followed.

9.3 Quality of observations

There was a general improvement in the ability of observers to complete the recording forms correctly in 1998 when compared to previous years. 'Location and Effort' forms were completed correctly for 78% of surveys, showing a steady improvement from 60% in 1996 and 72% in 1997. In 1998 'Record of Operations' forms were used for the first time. Eight of the surveys from which reports were received commenced before these forms were issued in April, or very soon thereafter. 'Record of Operations' forms were completed for 43 (86%) of the remaining 50 surveys, with few problems.

'Record of Sighting' forms also showed some improvements from previous years. In 1997 35% of these forms either contained no description of the animals seen, or gave a description that was insufficient to confirm the observer's identification, resulting in the identification being downgraded. In 1998 this proportion dropped to 25%. This was mainly due to a drop in the number of forms with no descriptions, from 12% in 1997 to 3% in 1998. The proportion of sightings which were not identified beyond the broad categories of 'cetacean', 'whale', 'large whale', 'dolphin' or 'seal' remained similar, at 23% in 1997 and 24% in 1998. There was a decrease in the small proportion of sightings where the identification was definitely wrong i.e. did not agree with the description given or was proved wrong by examining video footage of the sighting. Wrong identifications decreased from 5% in 1997 to 2% in 1998.

Over half (54%) of the 56 observers used in 1998 had received some training. Trained observers were less likely to misunderstand or not use the recording forms, and their identification skills were generally of a higher standard than those of untrained observers. The importance of descriptions is addressed during training seminars, consequently trained observers provided fewer records with descriptions that were insufficient to confirm their identification - 22% of sightings by trained observers had to be downgraded, compared to 38% of sightings by observers who had not attended training seminars. Trained observers used the broad identification categories ('cetacean', 'whale', 'large whale', 'dolphin' or 'seal') less often than untrained observers, and were less likely to make wrong identifications. Improved identification skills as more observers become trained may result in higher sample sizes for some species in future years, which would be beneficial when analysing the data.

Correct identification enables accurate analysis of the effects of seismic activity on marine mammals, but is not necessary for the operation of the *Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys*. It is far more important that observers are skilled at detecting marine mammals and take action when necessary. The ability of observers to detect marine mammals varied greatly. A comparison of sighting rates revealed that dedicated marine mammal observers were much more efficient at detecting marine mammals than other personnel, such as fishery liaison representatives or members of the ship's crew. Using only the areas and months of peak marine mammal occurrence (June to August in areas West of Shetland and Rockall) the mean number of sightings per 1,000 hours was 122.46 for dedicated marine mammal observers and 16.69 for other personnel.

Although there have been some improvements in the quality of observations, there is still room for further improvement. The areas for improvement differ according to the type of observer. It would be reasonable to expect dedicated marine mammal observers to be of a higher standard than personnel whose main duties are to perform other functions. Dedicated marine mammal observers were generally better than other observers at detecting marine mammals, and were more likely to ensure that the guidelines were adhered to (see section 9.4). These aspects are of primary importance, and operators and contractors should be encouraged to continue to use dedicated observers. However, with the exception of one experienced observer, their identification skills were not always of the high standard that might be expected (although by no means poor) and there were some minor misunderstandings of the recording forms. Some dedicated observers had not undergone any training - these observers could expect that training would improve their identification skills as well as address any misunderstandings of the recording forms. Most fishery liaison representatives used as observers during 1998 had undergone training. The main area of concern for these observers, and other personnel who were carrying out marine mammal observations as a secondary function, is that their rate of sightings was generally low. These observers should ensure that they are keeping a vigilant watch, at least during the 30 minute period prior to shooting commencing. Although descriptions have improved, all observers should seek to improve their descriptions of marine mammals further, thus reducing the number of records where identifications have to be downgraded. Future training should continue to address this.

9.4 Compliance with guidelines

It is pleasing that some operators or contractors are willing to consult JNCC when planning the timing of their surveys. For instance, in 1997 indications were that overall numbers of cetaceans in the Rockall area peaked earlier in the summer than in West of Shetland. In 1998, partly due to consultation with JNCC, survey effort in these areas followed the reverse pattern, peaking in West of Shetland earlier in the summer than in Rockall. Planning surveys in this way reduces the likelihood of encounters with cetaceans, and therefore reduces the potential for acoustic disturbance.

The procedure for notifying JNCC of seismic surveys is generally working well, with more notifications being received for surveys in 1998 than in previous years. However, there is still room for improvement in the level of reporting. For approximately one-third of the surveys occurring in 16th and 17th round blocks in 1998 no reports were received. Nevertheless, the co-operation of the industry was evident from the reports received from surveys in blocks licensed outside the 16th and 17th rounds. The fact that 'Record of Operations' forms were used for 86% of surveys occurring since they were first issued in April 1998 also demonstrates the increasing willingness of the industry to provide information. In comparison, 'Location and Effort' forms were used for 60% of surveys when they were first issued in 1996.

The guidelines require that in areas of importance for marine mammals operators should seek to provide the most appropriately qualified and experienced personnel to act as marine mammal observers. Reports were received from 21 surveys in areas considered important for marine mammals, but dedicated observers were used for only seven of these surveys. Although this represents a substantial increase from previous years in the number of surveys where dedicated observers were used, the majority of surveys in areas of importance for marine mammals still did not have appropriately qualified and experienced personnel on board. Observers on four of the 21 surveys had received no training.

On most occasions, the watch for marine mammals prior to shooting was of adequate duration. However, this watch was sometimes shorter than required. There are several possible reasons why this may have happened, assuming that the observers were not unwilling to watch for the minimum 30 minutes. Observers may have been unaware of the minimum duration of the watch specified in the guidelines. Alternatively, inadequate communication between the seismic crew and the observer may have meant that in some cases the observer was not given sufficient advance warning of the intention to start shooting. In many cases there was no dedicated marine mammal observer on board survey vessels; as a consequence marine mammal observations were carried out by personnel with other duties placing demands on their time, such as fishery liaison representatives or officers of the watch. There may have been occasions when these other duties may have limited the ability of these personnel to maintain an adequate watch for marine mammals.

Before the 'Record of Operations' forms were introduced, there was little information on how frequently delays in shooting are required under the guidelines. From the little information that was available on this aspect of the operation of the guidelines, it was assumed that delays were required only infrequently. Information received on the 'Record of Operations' forms in 1998 supported this assumption. Out of a total of 522 sightings of marine mammals, there were only 12 occasions when the sightings occurred within 500 m of the airguns prior to shooting commencing, circumstances where a delay would be required if the survey was being operated in compliance with the guidelines.

Two of the 12 occasions when marine mammals were seen within 500 m of the airguns prior to shooting commencing occurred outside 16th/17th round blocks, and it is not known whether full compliance with the guidelines was intended on these surveys. On the other ten occasions compliance with the guidelines was compulsory due to the location of the surveys in blocks licensed under the 16th and 17th rounds of offshore licensing. However, it is disappointing to note that in spite of the infrequent requirement for a delay, correct procedures were followed on only two occasions. On six further occasions there was some attempt to minimise disturbance to the marine mammals, although these attempts fell short of the required standard. However, of the ten occasions when delays were compulsory, there were two occasions when no action was taken to minimise acoustic disturbance to the marine mammals that had recently been seen.

The reasons why no action was taken in these instances are not known. It may have been that a delay was suggested but that the crew refused to comply, although there were no indications in the reports from these surveys that delays were even considered. Alternatively, the observers may not have informed the seismic crew that a delay was necessary. This may have been because they were unaware that they were in a situation where a delay was required, either through lack of awareness of the guidelines (which is unlikely as the observers had attended training courses within the two months prior to these incidents), or through lack of awareness of the impending shooting at the time of the sighting (again unlikely as the observers recorded the activity of the ship on the 'Record of Sighting' forms as "heading for a line"). Another possible scenario is that the observers may not have informed the seismic crew that a delay was necessary because they were apprehensive about doing so, bearing in mind the cost implications of any delay. It is interesting to note that on the two occasions when correct procedures were followed dedicated marine mammal observers were used, whereas on the two occasions when no action was taken fishery liaison representatives were acting as marine mammal observers. Apart from the obvious benefits of using dedicated marine mammal observers, the fact that an operator or contractor has requested their presence on board demonstrates a commitment to compliance with the guidelines. This instils confidence in the observer to remind the crew of their obligations under the guidelines, and also sends a message to the crew that the issue of disturbance to marine mammals is to be taken seriously. The use of personnel whose primary function is to undertake other duties may inadvertently send the message that marine mammals are of secondary importance.

A reluctance to 'interfere' with seismic operations may also explain why soft-starts were short or absent more often when fishery liaison representatives were used as observers than when dedicated marine mammal observers were on board. Although most soft-starts were of a satisfactory duration, the proportion of short or absent soft-starts was unacceptable; overall approximately one in seven soft-starts in 16th/17th round blocks were of less than 20 minutes duration. It must be remembered that there may be marine mammals submerged below the vessel, and pressure at depth has little effect on their ability to hear (Ridgway *et al.* 1998); these animals must be protected from acoustic disturbance by increasing the power level gradually over an appropriate period of time. The importance of the soft-start is underlined by the 'startle' response that was exhibited by a sperm whale at a distance of 2 km from the airguns. A delay in shooting is not required for marine mammals further than 500 m from the airguns, and yet in some cases animals may be disturbed by seismic activity at considerable ranges. Commencing shooting at low power levels should help to lessen the impact for all mammals in the vicinity.

The practice of continuous shooting between survey lines in areas where marine mammals occur frequently, as a means of avoiding delays in shooting as required by the guidelines, has been discussed previously (Stone 1998a). It should be re-stated that the normal practice of ceasing firing between survey lines and then using a soft-start when re-commencing, with a delay in shooting if marine mammals are within 500 m, is the correct procedure under the guidelines. Marine mammals may have no choice but to remain in an area subjected to seismic activity, for example if the habitat there provided better feeding opportunities than elsewhere. Ceasing firing between survey lines allows these animals some respite from acoustic disturbance. Continuous shooting aims to deter such animals and relieves the operator or contractor of the need to take any action if marine mammals are present, which is contrary to the principles of the guidelines. The guidelines operate on the principle that marine mammals and seismic surveys can co-exist if appropriate measures are taken, with periods of no noise. There is a risk that the frequent presence of marine mammals may necessitate many delays during the course of a survey, but it seems that this risk is small. As noted above, in 1998 there were only 12 occasions (out of 522 sightings) when the circumstances were such that a delay in shooting would have been required if the survey was being operated in compliance with the guidelines. If compliance with the guidelines causes operational difficulties on a particular survey, then JNCC should be consulted.

9.5 Considerations for future revisions to guidelines

Some soft-starts during 1998 were rather long (maximum 220 minutes) and may be considered excessive, adding to noise pollution in the oceans. The purpose of the soft-start is to avoid causing physical damage or severe disturbance to marine mammals which may be close to the airguns but undetected, and to allow them time to move away from the source before full power levels are reached. At the same time, the longer the airguns are firing for, the more potential there is for acoustic disturbance. A balance must be struck between allowing animals sufficient time to move away as the power builds up and avoiding unnecessary excess noise production. The guidelines specify a minimum duration of 20 minutes for the soft-start to allow time for the animals to move away. Whilst slightly longer soft-starts allowing time for the animals to move further away are to be welcomed, a recommended maximum duration of the soft-start should perhaps also be specified.

Some observers during 1998 questioned whether shooting should stop if marine mammals were seen within 500 m of the airguns once the soft-start had commenced. Under the guidelines there is no requirement to cease firing while shooting is underway, but the situation of sightings during the soft-start is not specifically addressed. Cessation of the soft-start if an animal appears distressed may be an option, but this would rely on the judgement of the observer and could be rather subjective, particularly as many types of behaviour are not fully understood for marine mammals. There were no indications during 1998 that marine mammals appearing close to the airguns once the soft-start had commenced were adversely affected. It would seem illogical if firing at low power must cease if marine mammals appear close to the airguns, while in the same circumstances firing at full power is allowed to continue. There may, however, be a case for not increasing power levels if marine mammals are close by. Individual animals tolerating firing at a lower power level may not necessarily tolerate firing at increased power levels. This approach would fit with the precautionary principles on which the guidelines are based. If this approach were to be adopted, the circumstances under which power should be maintained at a constant level without further increases, and the circumstances under which the build-up of power levels could re-commence, would need to be defined.

Inevitably, this approach would have cost implications for the operators and contractors, although perhaps not as severe as if firing were to cease altogether if marine mammals appeared close by during the soft-start. One disadvantage of requiring any sort of action during the soft-start is that it may act as an incentive for operators or contractors to make the soft-start as short as possible, and furthermore they may choose to begin the soft-start well in advance of the start of a line to allow time for any action that may be required. Thus a soft-start of minimum duration may occur well before the start of a line, with the airguns continuing to fire at full power between the end of the soft-start and the beginning of the line, the end result being that more time is spent shooting and hence the potential for acoustic disturbance is greater. Full consideration should be given to scenarios such as this if the guidelines are to include any requirement for action during the soft-start.

The guidelines should include a requirement that there should be no shooting which is not necessary for the normal operations of a seismic survey or for a soft-start. There is currently no requirement to cease firing if marine mammals are detected once shooting is underway; some operators or contractors have interpreted this as meaning that delays in commencing shooting may be avoided by firing continuously between survey lines, albeit at low power levels. A requirement prohibiting unnecessary shooting should help to make it clear that continuous shooting is not an acceptable alternative to delays in shooting.

Future revisions of the guidelines should perhaps give some consideration to the consequences of time-sharing, where two or more seismic survey vessels operating in adjacent areas take turns to shoot to avoid causing seismic interference to each other. Crews often co-operate in such a way that as soon as one vessel stops shooting another is in a position to start immediately. Furthermore, depending on the relative position of the vessels, at times there is no need for time-sharing and vessels may shoot simultaneously. When vessels are time-sharing, the potential for continuous man-made noise over large areas of the sea, and therefore the potential for acoustic disturbance to marine mammals, is great.

During consultations with interested parties when the guidelines were last being revised, it was suggested that some species should be given special treatment, in particular the northern right whale, which is an endangered species. Affording special treatment, such as cessation of firing, to a particular species relies on the ability of the observer to identify that species correctly. However, as more operators and contractors are seeking to use competent and experienced observers unreliable identification should become less of an obstacle. Future revisions of the guidelines could encourage operators or contractors to consider whether extra protection could be given to species such as the northern right whale on a voluntary basis where appropriate.

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12. Appendices

Appendix 1	Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys
Appendix 2	Marine mammal recording forms and guide to using recording forms
Appendix 3	Additional reports received by JNCC during 1998
Appendix 4	Scientific names of species mentioned in the text

Appendix 1

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.

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

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

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

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

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

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

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

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

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

USEFUL CETACEAN IDENTIFICATION GUIDES:

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

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

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

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

Appendix 2

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.

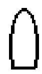
Date	Block number	Number of daylight hours during which a watch for marine mammals was kept	Length of time seismic guns were shooting during the watch	Wind force (Beaufort) and direction	Sea state Choose from: G = glassy S = slight C = choppy R = rough	Swell Choose from: O = low M = medium L = large	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 3

Additional reports received by JNCC during 1998

Seismic survey vessels and associated guard vessels operating outside Europe:

Bligh	Gulf of Suez
Jeff Chouest	off Namibia
OGS Explora	off Mozambique and South Africa
Telco Timor	off Angola, Gabon and Equatorial Guinea
Seabulk Wyoming	off Congo and Cabinda
Western Anchorage	off Angola, Cabinda, Congo, Nigeria, and Equatorial Guinea
Western Cove	off Mauritania, Angola, and Namibia
Western Wave	Somali Basin, off Mozambique and Pakistan

Other vessels and platforms operating in UK waters:

Botnica (survey vessel - construction)	West of Shetland (Schiehallion)
CSO Wellservicer	West of Shetland (Schiehallion)
Grampian Frontier (support vessel)	West of Shetland (Foinaven)
Henry Goodrich	West of Shetland
Iolair (semi submersible vessel)	West of Shetland (Schiehallion)
Jack Bates (rig)	West of Shetland
Norskald (drillship)	West of Shetland & Rockall
Schiehallion FPSO	West of Shetland (Schiehallion)
Sovereign Explorer (rig)	West of Shetland
Smit Semi 1	West of Shetland (Foinaven)
Viking Defender (standby vessel)	West of Shetland

Appendix 4

Scientific names of species mentioned in the text

Grey seal	*Halichoerus grypus*
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*
Sowerby's beaked whale	*Mesoplodon bidens*
Pilot whale	*Globicephala melas*
Killer whale	*Orcinus orca*
Risso's dolphin	*Grampus griseus*
Bottlenose dolphin	*Tursiops truncatus*
White-beaked dolphin	*Lagenorhynchus albirostris*
White-sided dolphin	*Lagenorhynchus acutus*
Common dolphin	*Delphinus delphis*
Striped dolphin	*Stenella coeruleoalba*
Harbour porpoise	*Phocoena phocoena*