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Marine mammal observations during seismic surveys in 2001 and 2002

Carolyn J Stone

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For further information please contact:

Joint Nature Conservation Committee
Dunnet House
7 Thistle Place
Aberdeen AB10 1UZ

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Contents

1. Summary

- Observations from seismic survey vessels in 2001-02 yielded 1,267 sightings of marine mammals (19,969 individuals), with a total of 24,400 hrs 56 mins spent watching. White-beaked dolphins were the most frequent species encountered, with minke whales, white-sided dolphins, killer whales and harbour porpoises also seen relatively frequently. Sightings peaked in July, with most occurring in the northern North Sea and to the west of Shetland.

- During surveys with large airgun arrays, sighting rates were significantly reduced during periods of shooting for all cetacean species combined, all baleen whales combined, all small odontocetes combined, all *Lagenorhynchus* species combined, minke whales, sperm whales, white-beaked dolphins and harbour porpoises. No significant differences were found in sighting rates throughout the course of surveys.

- Annual variations in sighting rates over a five year period were significant for a number of species, but usually with no clear trends. Sighting rates of both minke whales and killer whales generally increased, while sighting rates of pilot whales showed a dramatic decline after 1998.

- Many cetaceans, particularly small odontocetes (except white-sided dolphin), approached significantly closer to large arrays of airguns when they were silent than when they were firing.

- On surveys with large airgun arrays, those species that tended to interact with the survey vessel (e.g. by bow-riding or swimming alongside the equipment) did so less often when the airguns were firing. Small odontocetes made more alterations of course (mostly away from the vessel) and swam at speed more often when the airguns were firing. Logging, although not recorded very often in the cetaceans seen, was noted mostly during periods of shooting.

- During surveys with large airgun arrays the direction of travel relative to the ship differed significantly with seismic activity for some species or species groups, notably dolphins (except white-sided dolphins). Fewer pods were travelling towards the vessel and/ or more were travelling away from the vessel during periods of shooting.

- The influence of water depth on the degree of response to seismic activity was examined. In depths of 101-200 m more small odontocetes were found to be swimming slowly during periods of shooting, but the opposite was true in shallower or deeper waters. No other significant interaction of depth of water with seismic activity was found.

- The influence of distance from land on the degree of response to seismic activity was also examined. There was some evidence that reactions to seismic activity may be greater closer to land.

- The presence of juvenile animals was not found to have any effect on the degree of response to seismic activity.

- A comparison of surveys where different total volumes of airguns were used revealed that sighting rates of all small odontocetes combined during periods of shooting were significantly higher when larger airgun volumes were used, although sighting rates were also higher during periods of airgun silence than during periods of shooting. This could perhaps reflect some subtle difference in behaviour as array volume increases that may render them more easily detectable. Minke whales, all small odontocetes combined and *Lagenorhynchus* spp. remained further from the airguns when the total array volume was largest.

- Sightings of cetaceans occurring during the soft-start were compared with those occurring during shooting at full power or during periods of airgun silence. There was a significant difference in the proportion of pods swimming at speed, with more swimming fast when the airguns were shooting at full power than during the soft-start, and likewise more swimming fast during the soft-start than during periods of airgun silence. The proportion of animals heading towards the vessel during the soft-start was between that found during periods of shooting at full power and periods of silence. However, the proportion of animals heading away from the vessel was greatest during the soft-start.

- Sample sizes during periods of shooting were low for site surveys, but where analysis of data was possible, no significant responses to seismic activity were found.

- Compliance with the guidelines was better than in previous years in some respects, and worse in others. Some areas of particular concern were the absence of reports from some surveys, the poor standard of soft-starts on site surveys, correct procedures not being followed on some occasions when delays in shooting were required due to the close proximity of marine mammals, and continual shooting between survey lines. On surveys where it was known that there would be particular difficulties in applying the guidelines, aspects of the guidelines were frequently ignored or adapted, very rarely with any consultation with JNCC.

- The use of dedicated marine mammal observers had increased only slightly since 2000. There were still a number of surveys in areas of importance for marine mammals where dedicated marine mammal observers were not used. There were often no marine mammal observers on board the source vessel during undershoot operations. Specific requests by JNCC regarding the type or number of observers to be used were only complied with on around half of all occasions. Very few surveys used acoustic monitoring.

- A combination of an adequate duration of the watch and being skilled at detecting marine mammals meant that dedicated marine mammal observers provided better pre-shooting searches than other types of personnel. In most cases the standard of soft-starts was higher when dedicated marine mammal observers were used. The standard of pre-shooting searches and soft-starts was higher in 2001 on surveys where observers were trained, while in 2002 there was little difference except for soft-starts on site surveys, where training still resulted in improved standards.

- The quality of observations was highest when dedicated marine mammal observers were used. Dedicated marine mammal observers had higher detection rates than other types of personnel, and were better able to detect animals at distance. In addition they were better at completing the recording forms, had better identification skills and recorded a wider range of behaviours. Use of members of ships' crews was the least effective alternative. Trained personnel provided better quality data than untrained personnel.

- Recent changes to the guidelines are discussed, particularly in the light of areas of concern in 2001-02, and recommendations are made for aspects to be monitored to assess whether further changes are necessary in a future revision. Revisions to the marine mammal recording forms are presented.

2. Non-technical summary

Over 24,000 hours were spent watching for marine mammals (whales, dolphins, porpoises and seals) during seismic surveys used for oil exploration in 2001-02. There were 1,267 occasions when marine mammals were seen, with a total of 19,969 individuals recorded. White-beaked dolphins were the commonest species encountered, but minke whales, white-sided dolphins, killer whales and harbour porpoises were also seen, with other species occurring in low numbers. Most sightings occurred during July, in the northern North Sea and to the west of Shetland.

The data received were analysed to look for any potential effects of seismic activity on marine mammals. Parameters considered were the frequency of sighting of marine mammals, how close they approached to the airguns, and their behaviour and orientation. These parameters were compared between periods when seismic airguns were being used, and periods of airgun silence.

For seismic surveys using large arrays of airguns there were a number of observed effects of seismic activity on cetaceans (whales, dolphins and porpoises). Sighting rates of some species, including minke whales, sperm whales, white-beaked dolphins and harbour porpoises, were lower during periods when the airguns were firing than when they were silent. Sighting rates did not vary throughout the course of surveys. Many species, particularly dolphins and porpoises (except white-sided dolphin), approached closer to the airguns when they were silent than when they were firing. Bow-riding and other interactions with the vessel or its equipment happened less often when the airguns were firing. Fewer dolphins (except white-sided dolphins) were heading towards the vessel and/ or more were heading away from the vessel when the airguns were firing, and dolphins also showed a greater tendency to alter course and swim at speed at these times. Lying still at the water surface was recorded mostly when the airguns were firing.

Various factors that may have influenced the degree of response to seismic activity were considered. There was no clear trend in relation to depth of water. However, there was some evidence that reactions of marine mammals to the airguns firing may be greater closer to land. The presence of young animals was not found to have any effect on the degree of response to seismic activity.

Sighting rates of dolphins when airguns were firing were highest for the largest array volumes. However, sighting rates of dolphins were greatest when the airguns were silent. It may be that there is some difference in behaviour of dolphins as the volume of airguns firing increases, making them more easily visible. Minke whales and dolphins tended to stay further from the airguns when the volume of airguns firing was greater.

More cetaceans were swimming at speed during the soft-start (a procedure whereby the airguns commence firing at a low level and gradually build up to full power over a minimum period of 20 minutes) than during periods of airgun silence, and more again were swimming at speed when the airguns were firing at full power. More cetaceans were heading away from the vessel during the soft-start than at any other time.

There were few sightings of marine mammals when the airguns were firing on site surveys with low volume airguns, so analysis of the data was limited for these surveys. However, where analysis was possible, no effects of site surveys on marine mammals were observed.

Annual variations in sighting rates over a five-year period were found for some species. Most showed no clear trends, but sightings of minke whales and killer whales had increased, while sighting rates of pilot whales showed a marked decline since 1998.

Compliance with the *Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys* was better in 2001-02 than in earlier years in some respects, but worse in others. Some areas of particular concern were the absence of reports from some surveys, the poor standard of soft-starts on site surveys, correct procedures not being followed on some occasions when delays in shooting were required due to the close proximity of marine mammals, and continual shooting between survey lines. On surveys where it was known that there would be particular difficulties in applying the guidelines, aspects of the guidelines were frequently ignored or adapted, very rarely with any consultation with JNCC.

The use of dedicated marine mammal observers had increased only slightly since 2000. Some surveys in areas of importance for marine mammals did not have a dedicated marine mammal observer on board. There were often no marine mammal observers on board the source vessel (= vessel towing airguns) during undershoot operations. JNCC sometimes made specific requests regarding the type or number of observers to be used on a survey, but observers only met the criteria specified on around half of these occasions. Very few surveys used acoustic monitoring.

Compliance with the guidelines was better when dedicated marine mammal observers were used, and better when observers were trained. Dedicated marine mammal observers provided better pre-shooting searches than other types of personnel, and in most cases the standard of soft-starts was higher. The standard of pre-shooting searches and soft-starts was higher in 2001 on surveys where observers were trained; in 2002 training resulted in improved standards of soft-starts on site surveys.

The quality of observations was highest when dedicated marine mammal observers were used; they had higher detection rates, were better able to detect animals at distance, were better at completing the recording forms, had better identification skills and recorded a wider range of behaviours. Use of members of ships' crews was the least effective alternative. Trained personnel provided better quality data than untrained personnel.

Recent changes to the guidelines are discussed, particularly in the light of areas of concern in 2001-02, and recommendations are made for aspects to be monitored to assess whether further changes are necessary in a future revision. Revisions to the marine mammal recording forms are presented.

3. Introduction

Marine seismic surveys are used to determine the structure of the substrate beneath the seabed, in order to locate potential new oil and gas reserves or to monitor the status of existing reservoirs. Marine seismic surveys operate by using airguns to generate sound, mostly low frequency, which is directed at the seabed; the resulting reflections are used to map the underlying geological structures. As with many anthropogenic sources of noise in the oceans, there has been concern regarding the potential for disturbance to marine life, in particular marine mammals. Sound plays a key role in many of the natural functions of marine mammals, including feeding, navigation and social interactions (including breeding). Introduced sound in the marine environment therefore has the potential to interfere with these natural functions, as well as the potential for causing physical harm. Some countries have developed mitigation strategies to minimise the risk posed to marine mammals from acoustic activities such as seismic surveys. In the UK the Joint Nature Conservation Committee (JNCC) has developed the *Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys* (the current version is included in Appendix 1). When consent is granted by the Department of Trade and Industry (DTI) for a seismic survey to be conducted in UK waters, it is routinely made a condition of the consent that the JNCC guidelines must be followed.

The guidelines have a number of requirements governing how a seismic survey can be operated in order to minimise disturbance to marine mammals. Amongst the key requirements are that a watch for marine mammals must be maintained for at least 30 minutes prior to commencing any use of the airguns, and that their use must be delayed if marine mammals are detected within a specified (500 m) radius of the airguns, until at least 20 minutes since the last sighting. Whenever the airguns are used, regardless of whether marine mammals have been detected or not, a soft-start procedure should be employed, gradually building up the airgun power over at least 20 minutes from a low energy starting level. The lowest practicable energy levels should be used throughout the survey. In areas of importance for marine mammals, as indicated in consultation with JNCC, operators should provide appropriately qualified and experienced personnel to act as marine mammal observers. Following the survey a report should be forwarded to JNCC, including details of the implementation of the guidelines, the time spent watching for marine mammals and any sightings that occurred. Standard forms designed and periodically revised by JNCC are available for this purpose (current forms are included in Appendix 2). These forms are examined at regular intervals by JNCC, paying particular attention to any observed effects of seismic activity on marine mammals and the level of compliance with the guidelines. Previous reports have covered data from 1996 to 2000 (Stone 1997, 1998, 2000, 2001, 2003a,b). This report examines the data returned to JNCC from seismic surveys conducted in UK and adjacent waters during the years 2001-02.

4. Methods

Reports were received from 140.15 surveys in UK and some adjacent waters during 2001-02 (98.5 in 2001, 41.65 in 2002). These surveys covered 107 quadrants (1^o rectangles), including those passed in transit to or from the survey locations (Figure 1).

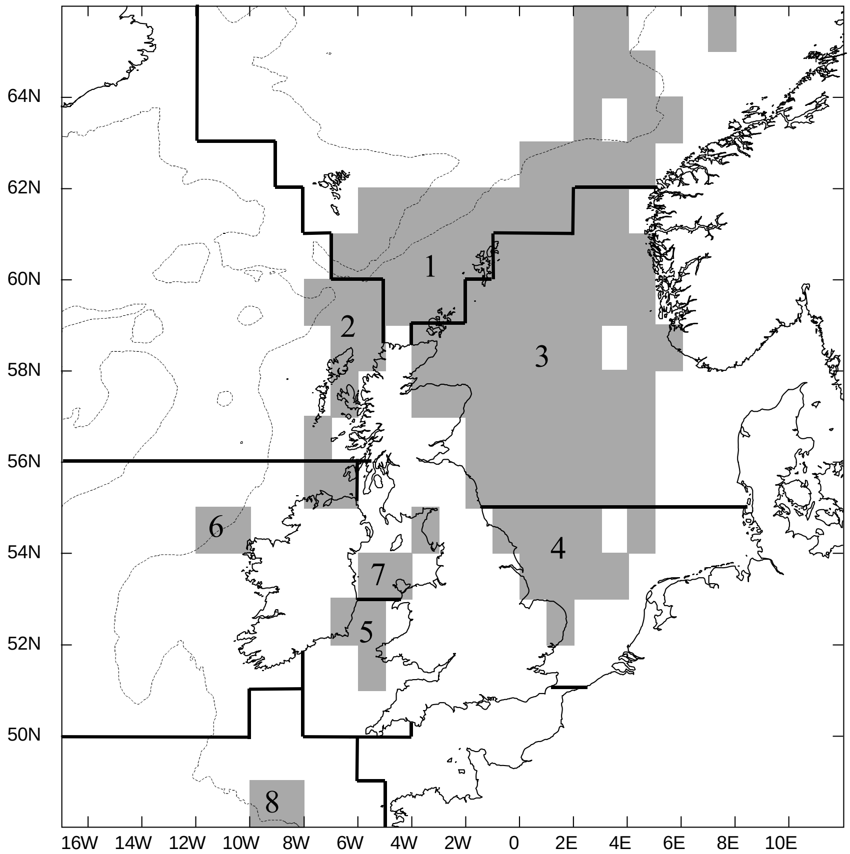


Figure 1. Quadrants where marine mammals were searched for during seismic surveys in 2001-02, with areas referred to in the text: 1) West of Shetland; 2) Rockall; 3) Northern North Sea; 4) Southern North Sea; 5) St. George's Channel and Bristol Channel; 6) West of Ireland; 7) Irish Sea; 8) South-West Approaches.

50.15 of the surveys (30.5 in 2001, 19.65 in 2002) were 2D, 3D, 4D and 4C/ OBC surveys, where the total volume of airguns ranged from 2250 cu. in. to 5595 cu. in., with most equal to or exceeding 3000 cu. in. The remaining 90 surveys (68 in 2001, 22 in 2002) were high resolution site surveys or similar surveys (e.g. pipeline route surveys) using low power equipment; these surveys are hereafter collectively termed site surveys. Where airguns were used on site surveys the total volume was 180 cu. in. or less. Due to the large variation in size of airgun arrays and the potential influence this may have on the degree of disturbance of marine mammals, the two categories of surveys (those with large airgun arrays or site surveys) were analysed separately.

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

Weather conditions can influence the ability of observers to detect marine mammals, with sighting rates increasing as sea state and swell decrease and as visibility increases. Where possible the statistical tests used compared periods of similar weather conditions. Where it was not possible to group data according to weather conditions, periods of poor weather were discarded if this was likely to influence the results; in these cases only periods with sea states of 'glassy' or 'slight' (equivalent to sea state 3 or less), 'low' swell and 'good' visibility were used.

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

5. An overview of marine mammal sightings and survey effort

There were 1,267 sightings of marine mammals, comprising 19,969 individuals (Table 1). 61% of sightings were identified to species level, with a further 10% identified as being one of a pair or group of similar species. Of those identified to species level, white-beaked dolphins were the most frequent species encountered. Minke whales, white-sided dolphins and killer whales were also seen relatively frequently. Harbour porpoises were seen with moderate frequency, while pilot whales, common dolphins and sperm whales were seen irregularly. Other species were seen infrequently. Baleen whales, sperm whales, harbour porpoises and seals were mostly seen singly or in small groups, while pilot whales, killer whales and dolphins were often seen in medium-sized or large pods. Some sightings comprised more than one species seen in association with each other. The species most commonly seen in association with other species was the white-sided dolphin, which occurred in ten of 26 mixed species sightings, most often with other dolphin species but sometimes with pilot whales.

Table 1. Summary of marine mammal sightings from seismic survey vessels, 2001-02

Species	***Number of sightings***	***Number of individuals***
Unidentified seal sp.	10	10
Grey seal	14	15
Common seal	6	6
Unidentified cetacean sp.	78 *[1]	652
Unidentified whale sp.	34	48
Unidentified large whale sp.	5	5
Humpback whale	2	7
Blue whale	1	1
Fin whale	18 *[1]	35
Sei whale	3	4
Unidentified fin/ blue whale	5	5
Unidentified fin/ sei whale	5	7
Unidentified fin/ sei/ humpback whale	6 *[1]	7
Unidentified fin/ sei/ blue/ humpback whale	35 *[1]	53
Minke whale	151 *[1]	163
Sperm whale	26	30
Unidentified medium whale sp.	22	29
Unidentified beaked whale sp.	1	2
Sowerby's beaked whale	1	1
Pilot whale	45 *[1]	1,111
Killer whale	112 *[1]	936
Unidentified dolphin sp.	223 *[1]	2,891
Unidentified dolphin sp. not porpoise	17	87
Risso's dolphin	15 *[1]	159
Bottlenose dolphin	6 *[1]	29
Unidentified unpatterned dolphin sp.*[2]	1 *[1]	6
White-beaked dolphin	153 *[1]	2,462
White-sided dolphin	119 *[1]	8,095
Unidentified *Lagenorhynchus* sp.*[3]	51 *[1]	1,502
Common dolphin	30 *[1]	1,120
Striped dolphin	3 *[1]	134
Unidentified common/ white-sided dolphin	3	16
Unidentified patterned dolphin sp.*[4]	8	192
Harbour porpoise	86 *[1]	149
Total	**1,267**	**19,969**

*[1] includes mixed species sightings

*[2] unpatterned dolphin = Risso's/ bottlenose dolphin

*[3] *Lagenorhynchus* sp. = white-beaked/ white-sided dolphin

*[4] patterned dolphin = white-beaked/ white-sided/ common/ striped dolphin

Sighting rates of marine mammals increased during the summer months, with a peak of sightings in July (Figure 2), although there was a peak in observation time during August (Figure 3). Most sightings occurred in areas Northern North Sea and West of Shetland.

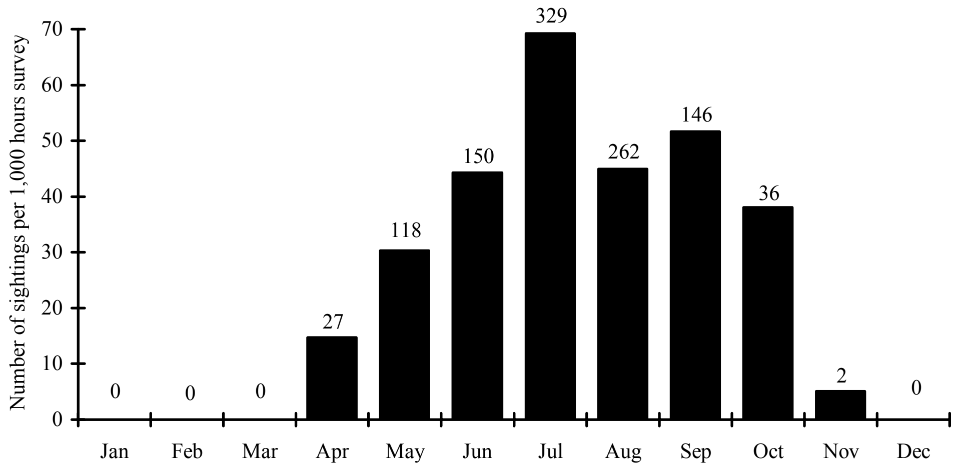


Figure 2. Sighting rates of marine mammals (including seals) per month, with number of sightings (only includes surveys where effort was correctly recorded). Data were not corrected for sea conditions or other factors affecting the ability to detect marine mammals.

The length of time spent watching for marine mammals was summed for surveys where 'Location and Effort' recording forms were completed correctly (119.65 of the 140.15 surveys). A total of 24,400 hrs 56 mins were spent watching for marine mammals during the two year period, with more time spent watching in 2001 than in 2002 (Table 2), reflecting the lower number of surveys in 2002. Most of the time spent watching for marine mammals was on surveys with large airgun arrays, and the proportion of time spent shooting was also higher on these surveys. Overall, the airguns were firing for 35.27% of the time on watch, although the proportion of time spent shooting was higher in 2002 than in 2001. Although there were more site surveys than surveys with large airgun arrays, the time spent watching for marine mammals during site surveys equated to only 25% of the total time spent watching during all surveys, reflecting the short duration of most site surveys. When the airguns were not firing the survey vessels were engaged in a variety of activities e.g. turning between survey lines, deploying, retrieving or carrying out maintenance on the airguns and streamers, waiting for weather conditions to improve, time-sharing with other seismic survey vessels, and steaming between survey areas and ports. In the case of site surveys, some of the periods when the airguns were not firing were occupied by analogue surveys for which airguns were not used, although various other items of equipment (e.g. side scan sonar, boomers and pingers) were used.

Table 2. Effort during seismic surveys in 2001-02

Type of survey	***2001***			***2002***		
	Time spent watching for marine mammals	***Time spent shooting during the watch for marine mammals***	***Proportion of time spent shooting***	***Time spent watching for marine mammals***	***Time spent shooting during the watch for marine mammals***	***Proportion of time spent shooting***
Surveys with large airgun arrays	9,954 h 51 m	3,838 h 41 m	38.56%	8,466 h 32 m	3,772 h 43 m	44.67%
Site surveys	4,766 h 46 m	797 h 32 m	16.73%	1,232 h 47 m	196 h 30 m	15.94%
Total effort	14,721 h 37 m	4,636 h 13 m	31.49%	9,679 h 19 m	3,969 h 13 m	41.01%

The time spent watching for marine mammals and the total time spent shooting during these watches peaked in August, although the proportion of time spent shooting peaked in July (Figure 3). Most survey effort was concentrated in areas Northern North Sea and West of Shetland (Figure 4), although the proportion of time spent shooting was greatest in the South-West Approaches. Survey effort was highly seasonal in both West of Shetland and the Northern North Sea (Figure 5). In the Southern North Sea there was low but regular survey effort throughout the year, while in other areas survey effort was sporadic.

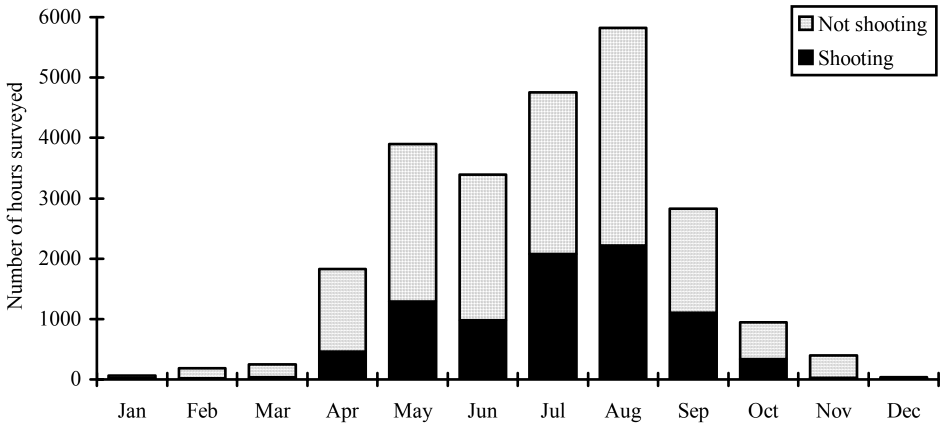


Figure 3. Length of time spent watching for marine mammals, and seismic activity during watches (only includes surveys where effort was correctly recorded).

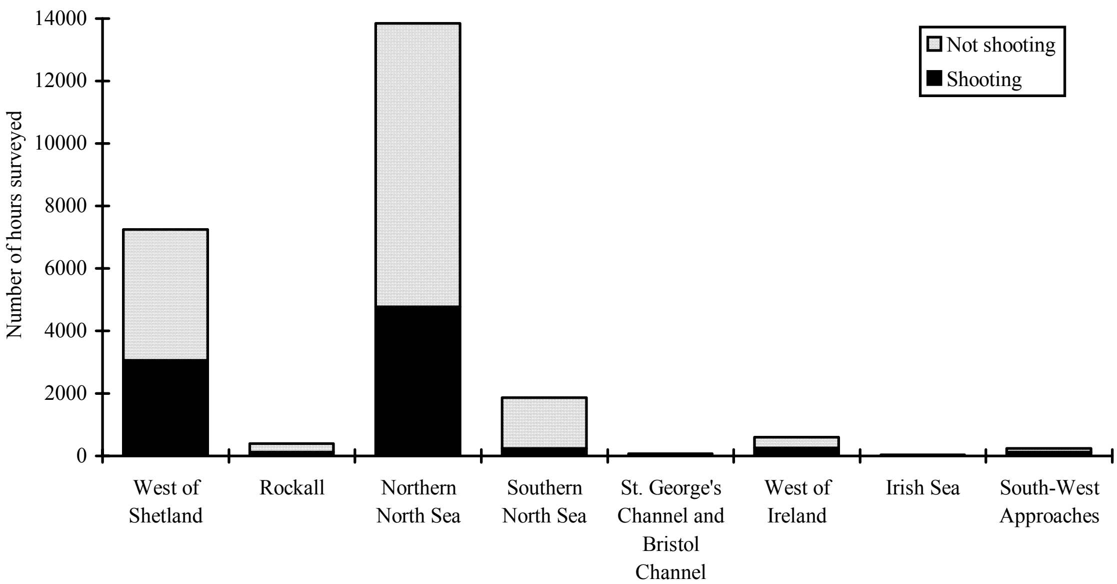


Figure 4. Length of time spent watching for marine mammals in each area, and seismic activity during watches (all months combined; only includes surveys where effort was correctly recorded).

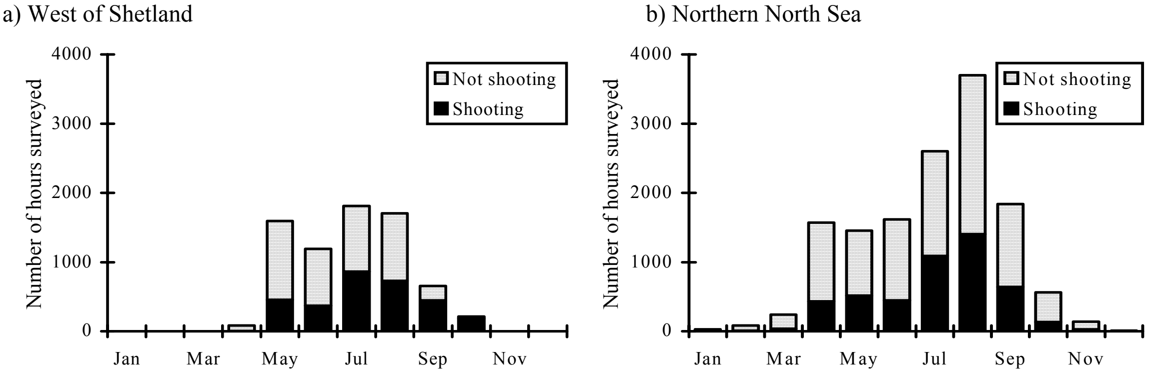
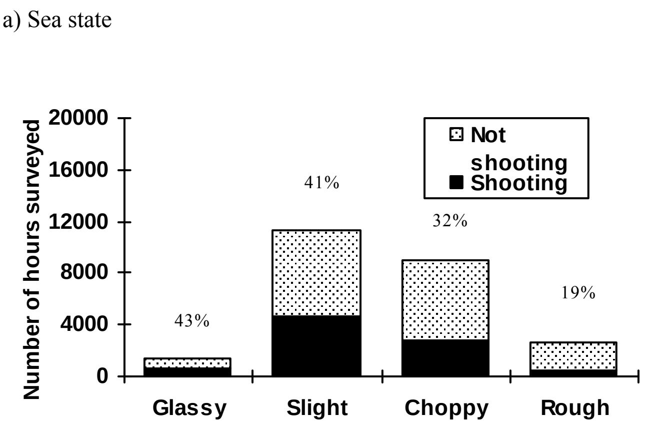
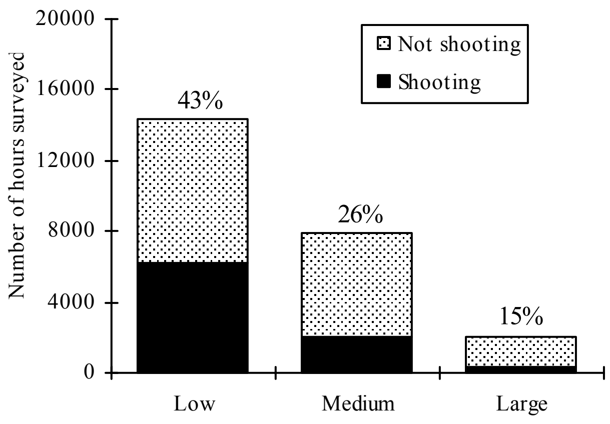


Figure 5. Comparison of survey effort throughout the year for the more frequently surveyed areas (only includes surveys where effort was correctly recorded).

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



b) Swell



c) Visibility

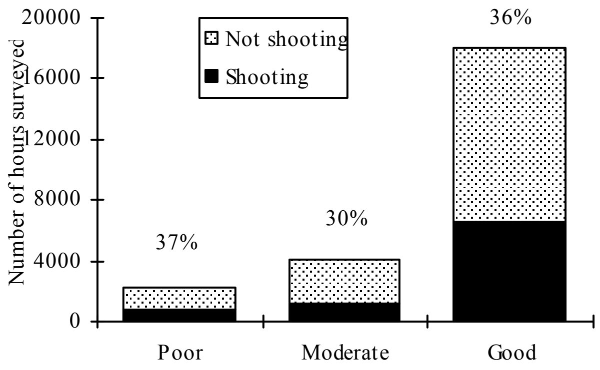


Figure 6. Length of time spent watching for marine mammals in different weather conditions in relation to seismic activity, with percentage of time spent shooting (only includes surveys where effort was correctly recorded).

6. Distribution of marine mammals

Most sightings of marine mammals occurred in clusters in the northern North Sea and to the west of Shetland (Figure 7), reflecting the locations of surveys. Smaller clusters of sightings occurred in areas where there was lower survey effort, to the west of Ireland, in the St. George's Channel, the Irish Sea and the southern North Sea.

Individual species maps (Figures 8-28) showed some interspecific variations in distribution. The large baleen whales (humpback, blue, fin, sei; Figures 9-12) were found to the north-west of the UK, from the outer continental shelf to deep waters. The same was true of sperm whales and Sowerby's beaked whale (Figures 14 & 15). The main centre of distribution of sightings of pilot whales, killer whales, Risso's dolphins and white-sided dolphins also occupied north-west waters, but in these cases their distribution extended further with low numbers of sightings to the west of Ireland and in the northern North Sea (Figures 16, 17, 19 & 22). Striped dolphins were seen in low numbers only over the continental shelf slope to the west of the UK (Figure 24). Common dolphins were seen mostly in the St. George's Channel or over the outer continental shelf to the west and north of Scotland, with a few isolated sightings in shallower waters of the northern North Sea (Figure 23).

Other species showed a preference for shallower shelf waters, with bottlenose dolphins occurring in the northern North Sea and St. George's Channel (Figure 20), and most sightings of minke whales, white-beaked dolphins and harbour porpoises also occurring in the northern North Sea (Figures 13, 21 & 25). Sightings of the latter three species occurred throughout the northern North Sea, with scattered sightings extending as far as the outer continental shelf in the case of white-beaked dolphin and harbour porpoise, and a few sightings of minke whales in deep waters both to the north of Scotland and to the west of Ireland. Harbour porpoises were also seen in the St. George's Channel and the Irish Sea, while there were occasional sightings of both this species and the minke whale in the shallow waters of the southern North Sea.

There were few sightings of seals (Figures 26-28). There were occasional but widespread sightings of grey seals throughout the northern North Sea (Figure 27), while common seals were seen mostly off the Outer Moray Firth (Figure 28). Other sightings of unidentified seals occurred in the southern North Sea and to the west of Ireland (Figure 26).

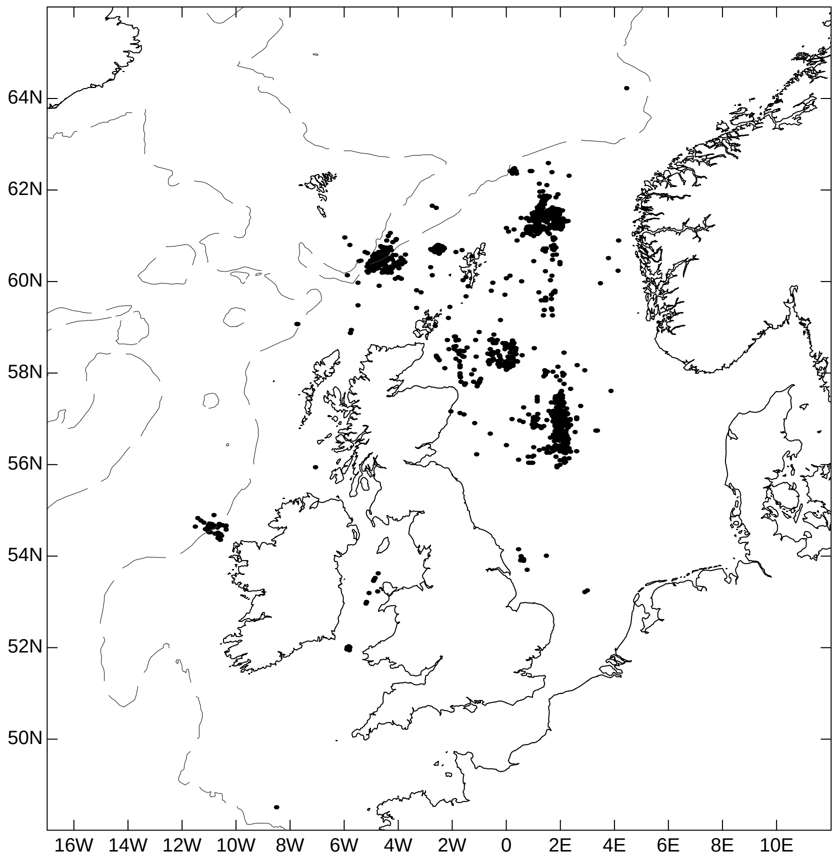


Figure 7. Sightings of marine mammals from seismic survey vessels, 2001-02

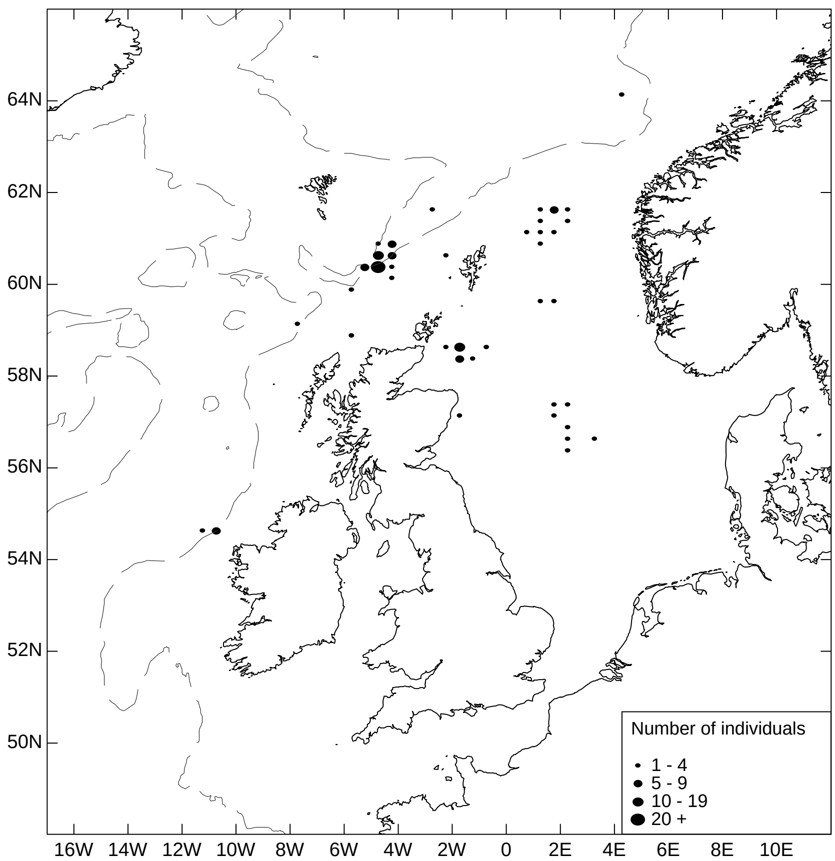


Figure 8. Distribution of unidentified whales seen from seismic survey vessels, 2001-02

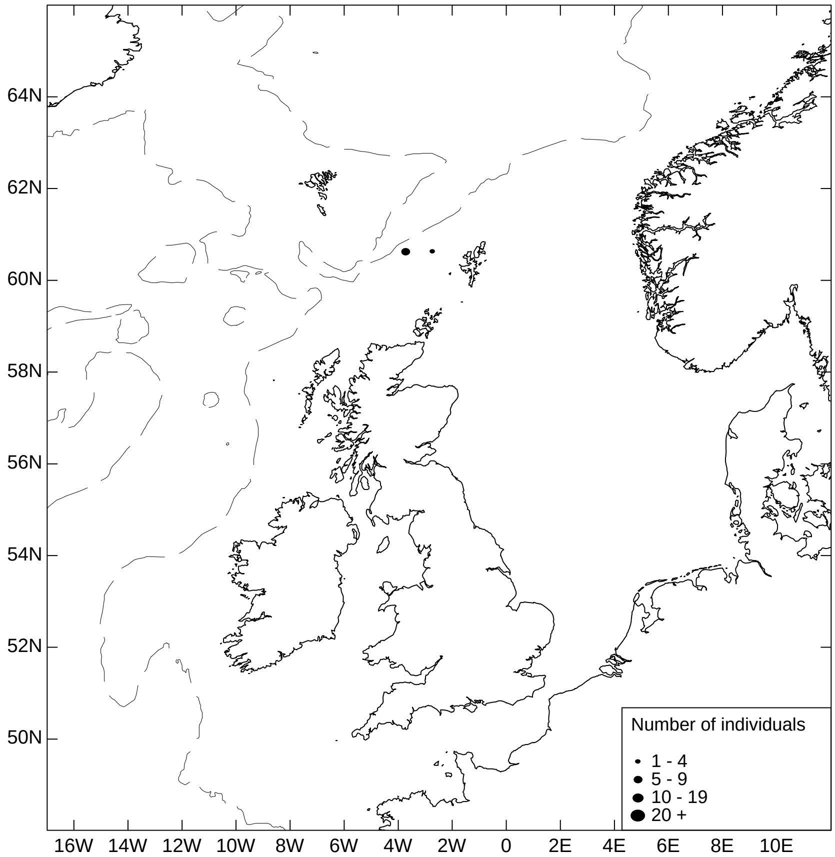


Figure 9. Distribution of humpback whales seen from seismic survey vessels, 2001-02

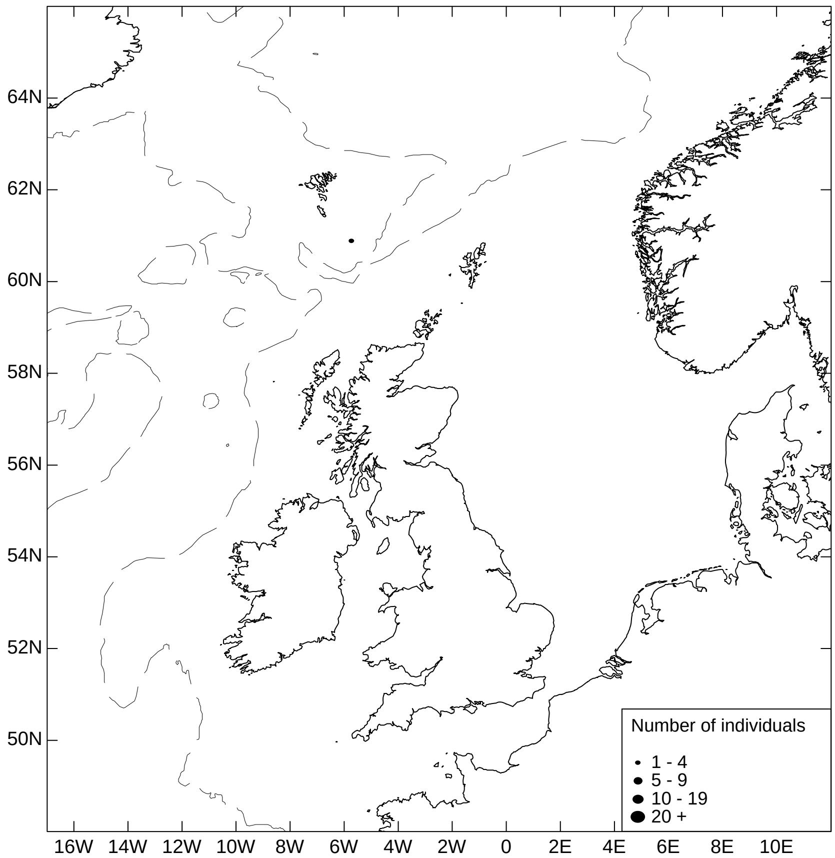


Figure 10. Distribution of blue whales seen from seismic survey vessels, 2001-02

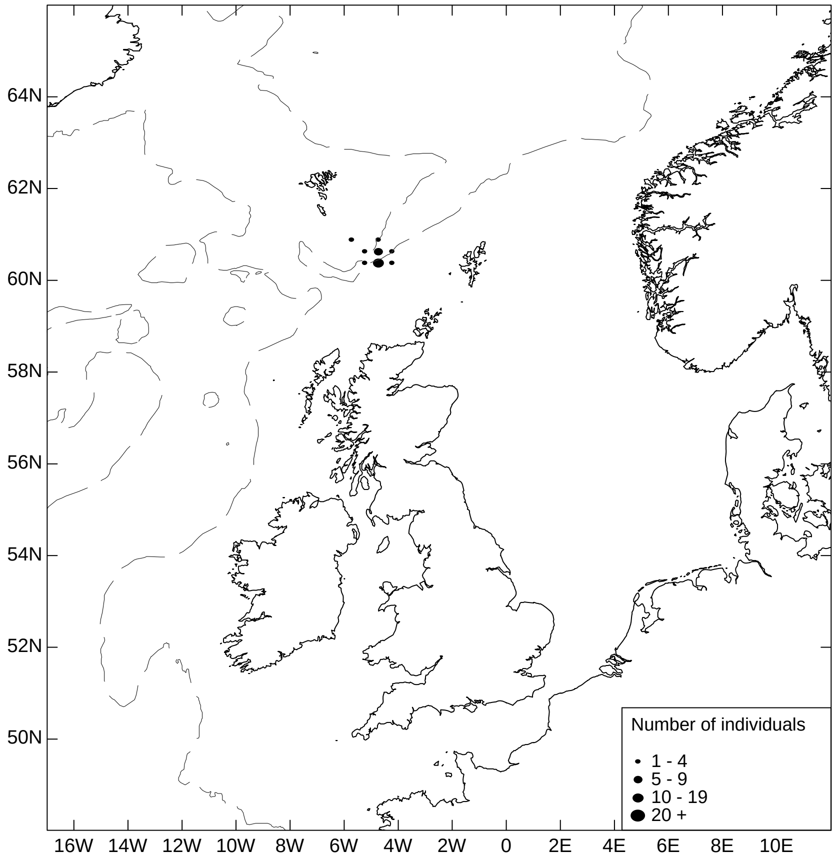


Figure 11. Distribution of fin whales seen from seismic survey vessels, 2001-02

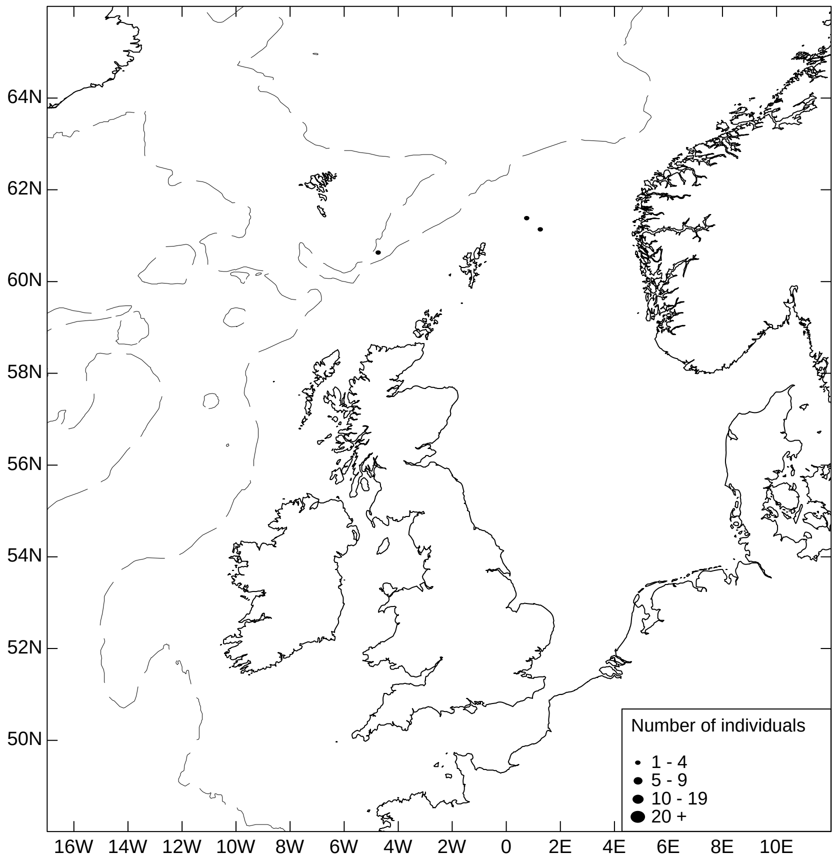


Figure 12. Distribution of sei whales seen from seismic survey vessels, 2001-02

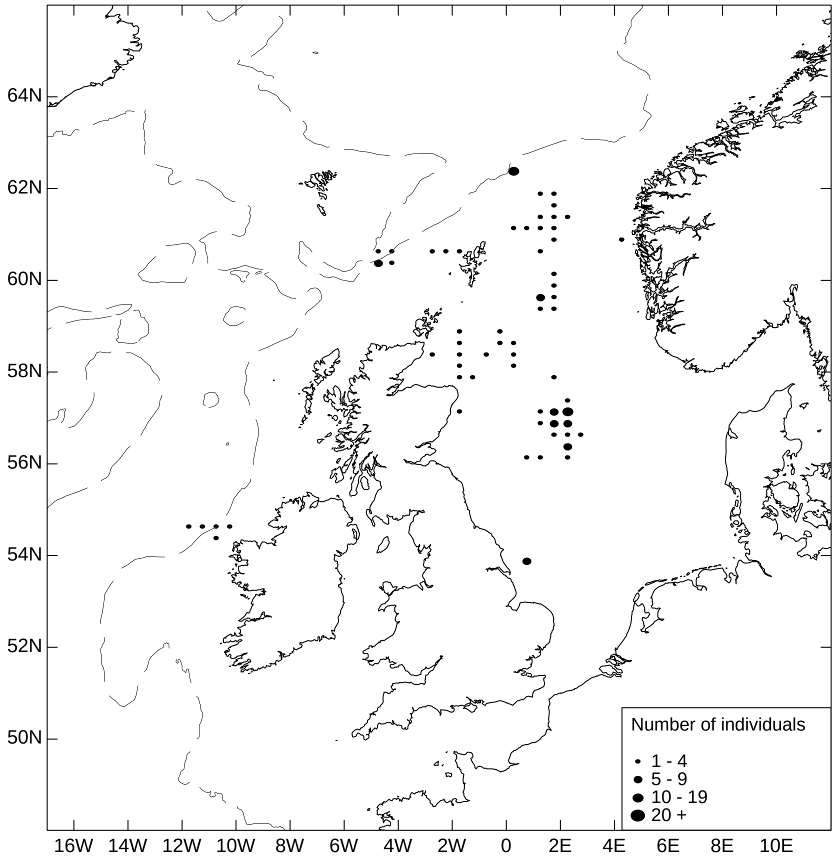


Figure 13. Distribution of minke whales seen from seismic survey vessels, 2001-02

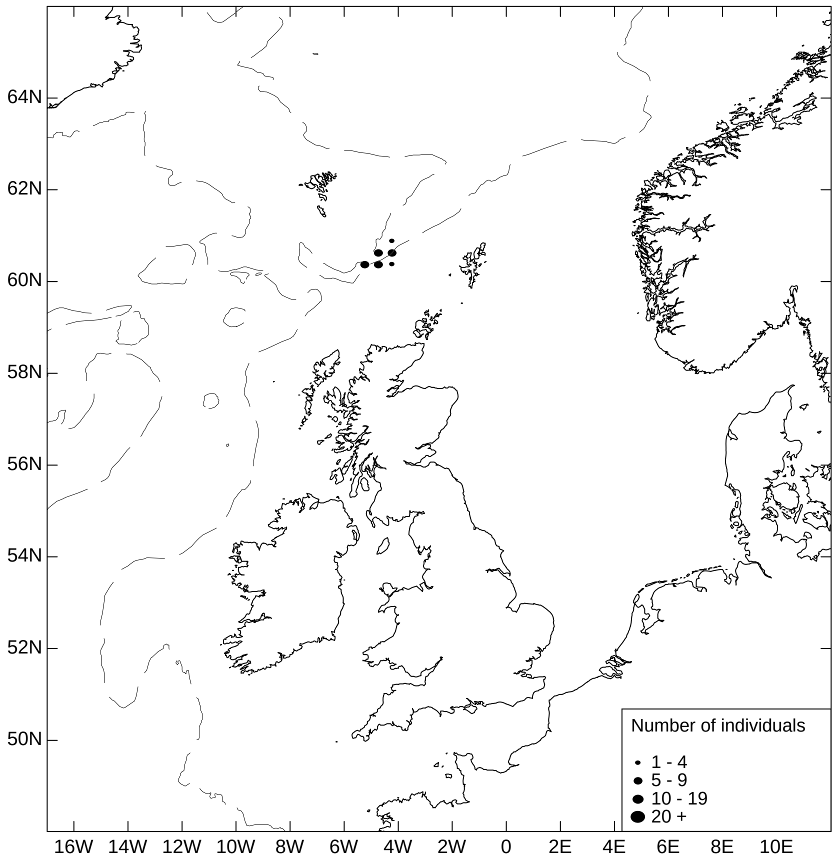


Figure 14. Distribution of sperm whales seen from seismic survey vessels, 2001-02

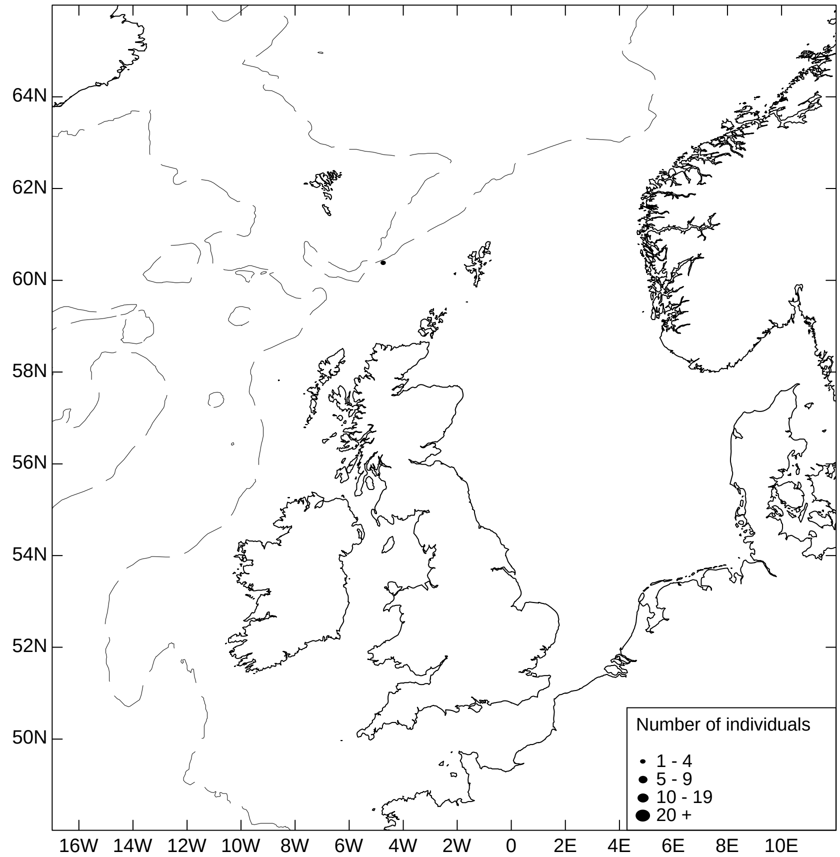


Figure 15. Distribution of Sowerby's beaked whales seen from seismic survey vessels, 2001-02

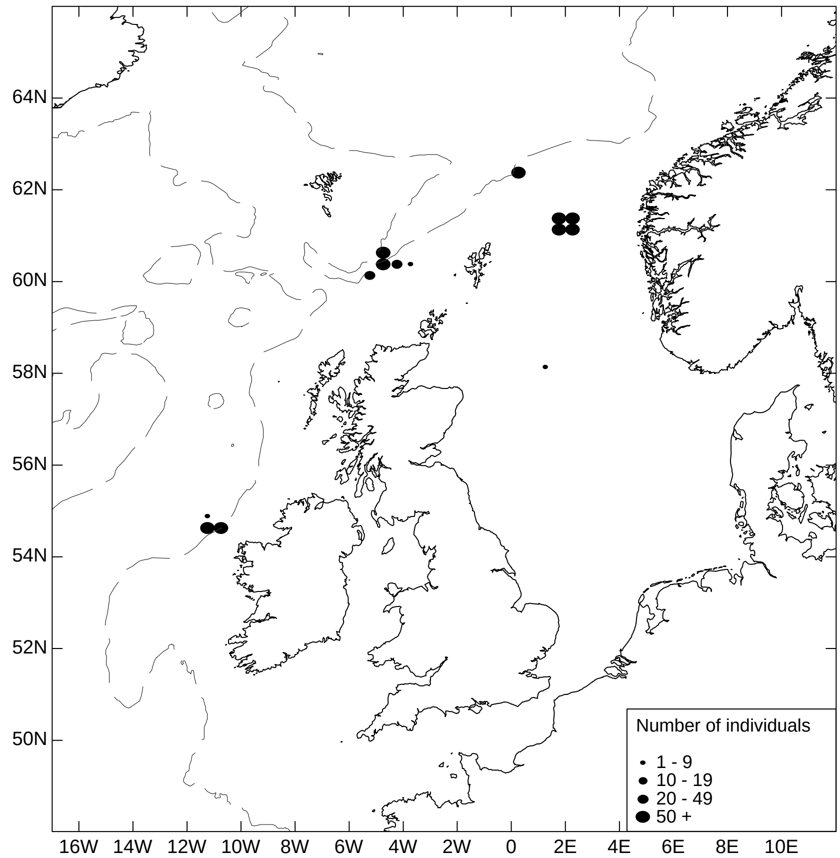


Figure 16. Distribution of pilot whales seen from seismic survey vessels, 2001-02

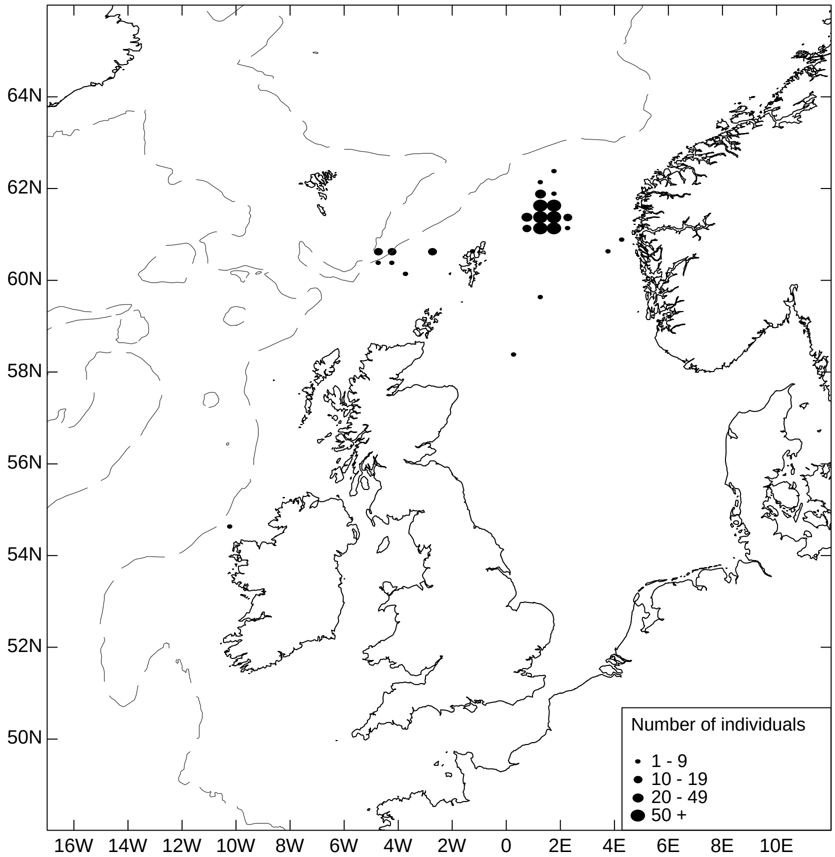


Figure 17. Distribution of killer whales seen from seismic survey vessels, 2001-02

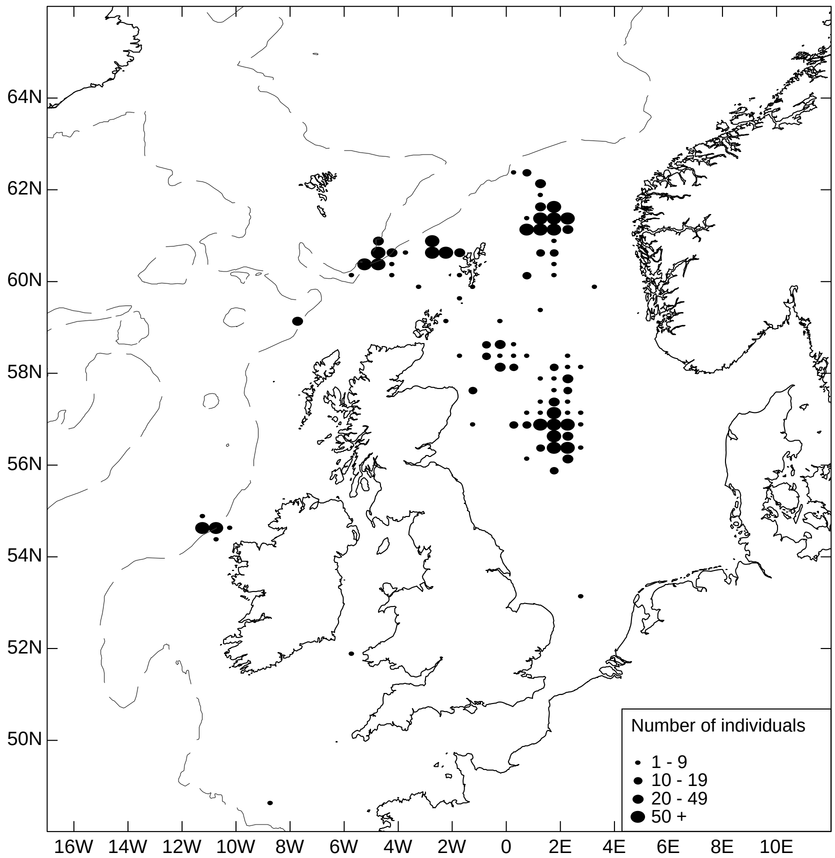


Figure 18. Distribution of unidentified dolphins seen from seismic survey vessels, 2001-02

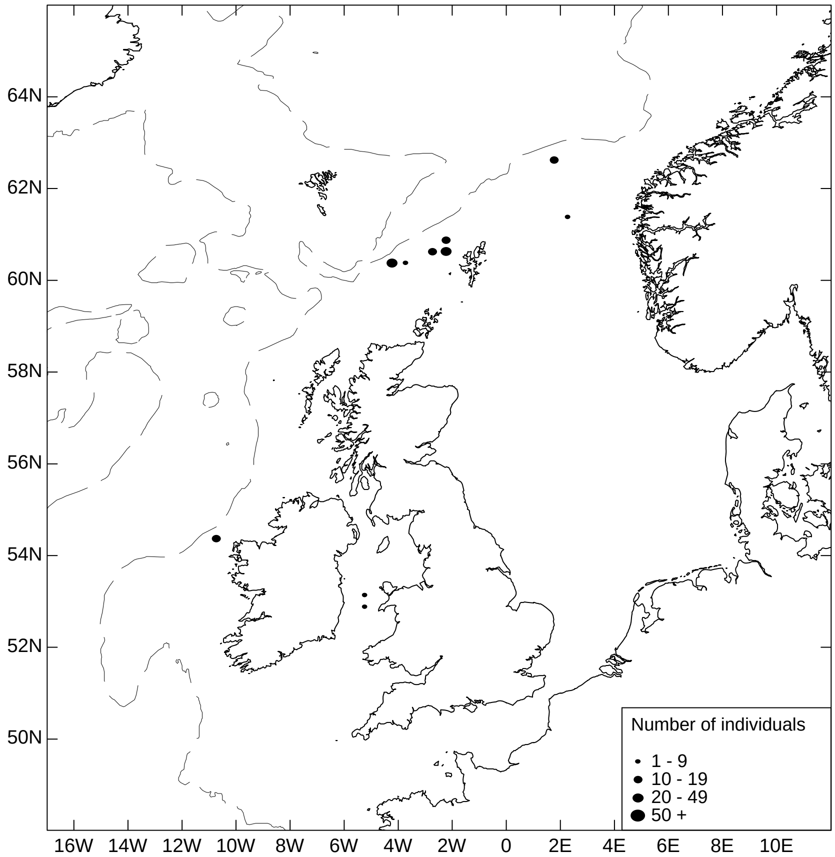


Figure 19. Distribution of Risso's dolphins seen from seismic survey vessels, 2001-02

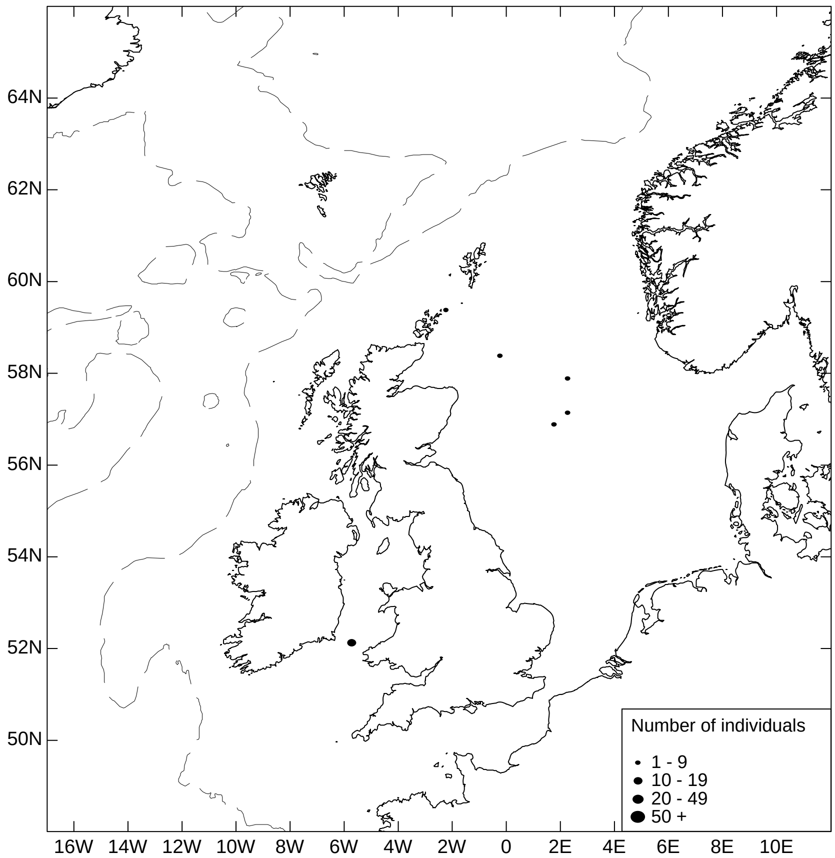


Figure 20. Distribution of bottlenose dolphins seen from seismic survey vessels, 2001-02

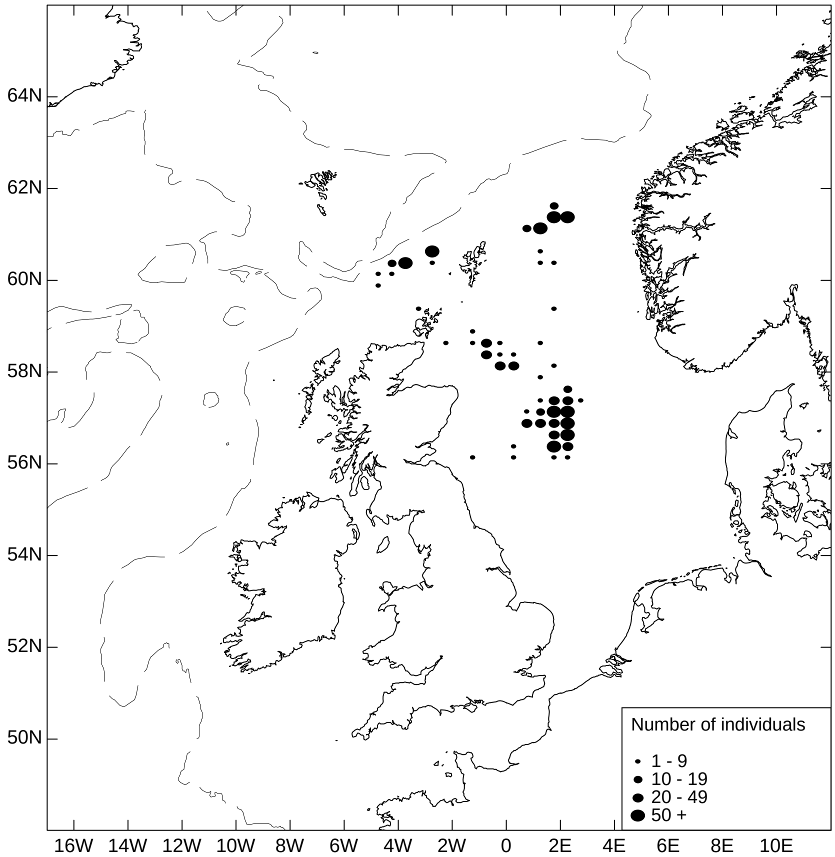


Figure 21. Distribution of white-beaked dolphins seen from seismic survey vessels, 2001-02

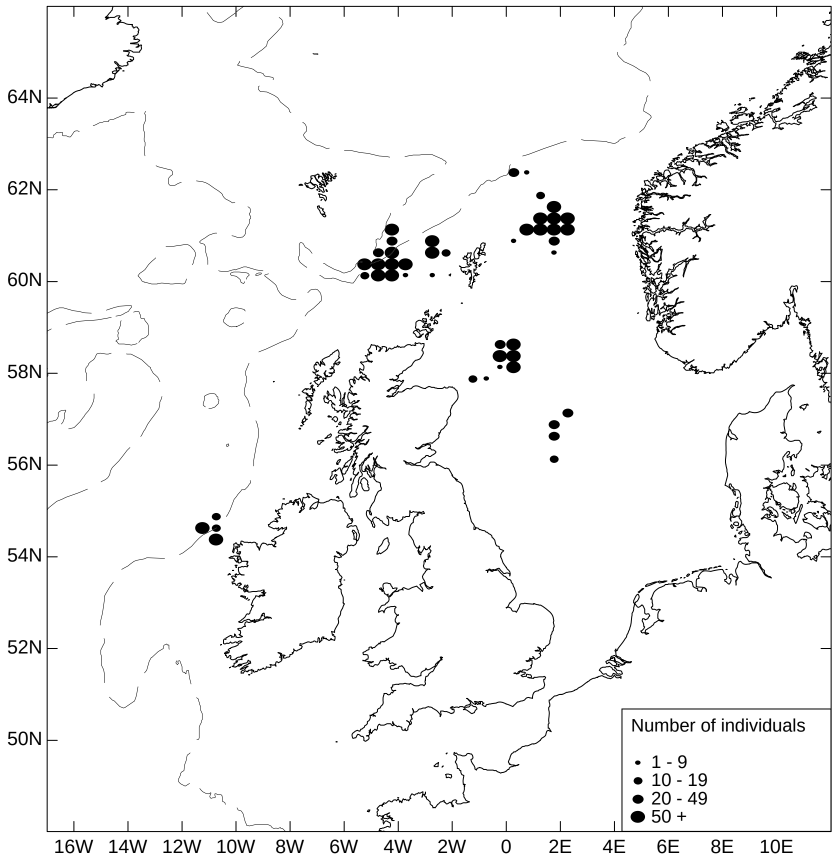


Figure 22. Distribution of white-sided dolphins seen from seismic survey vessels, 2001-02

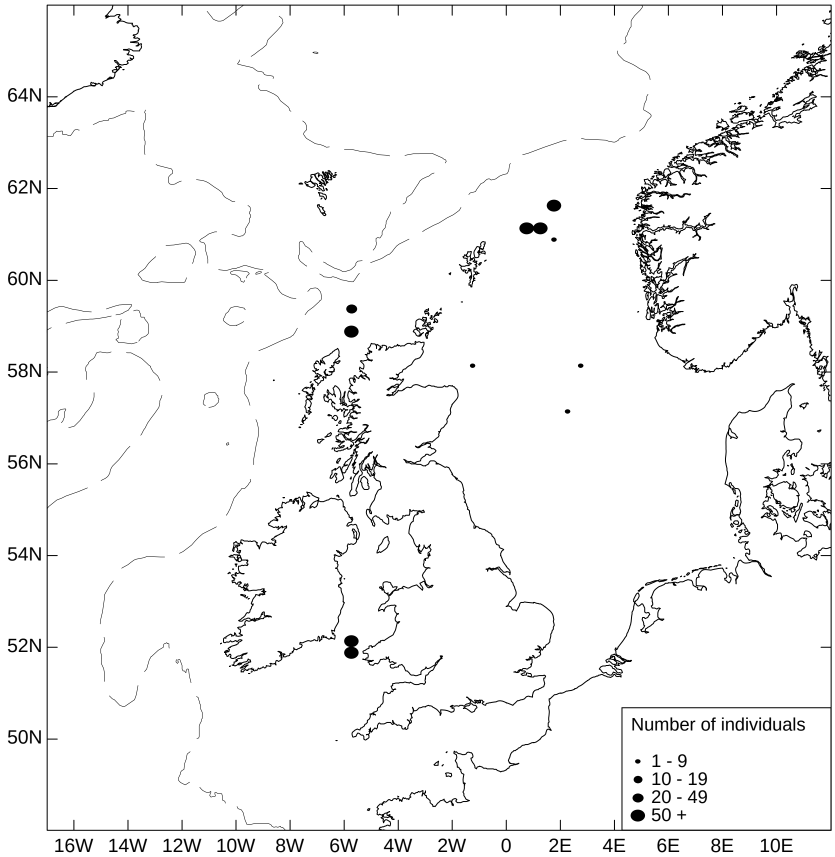


Figure 23. Distribution of common dolphins seen from seismic survey vessels, 2001-02

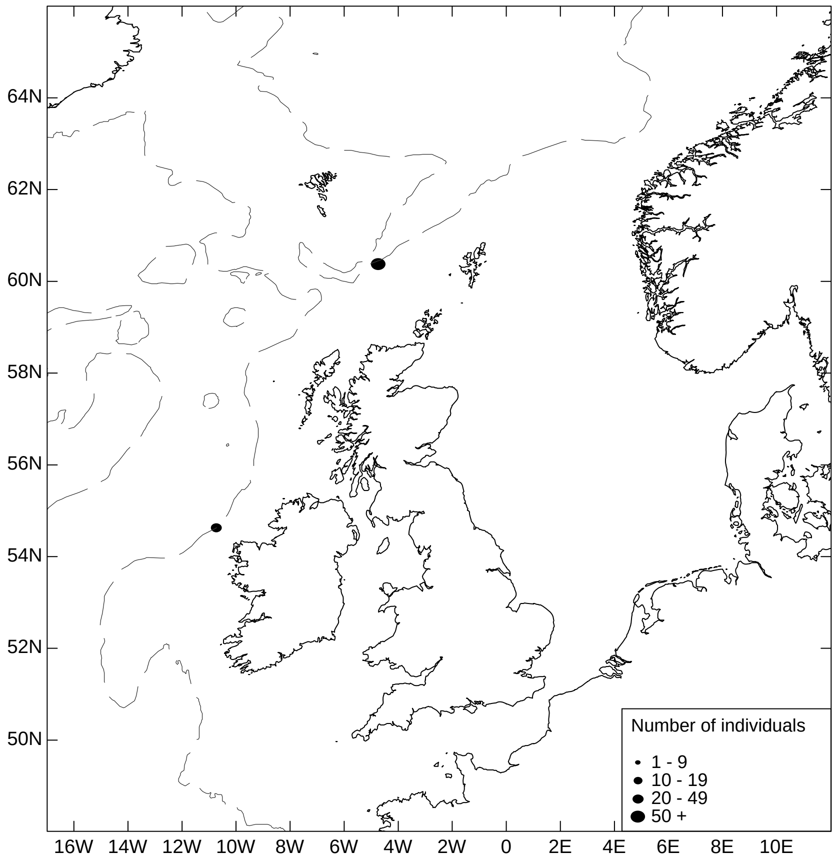


Figure 24. Distribution of striped dolphins seen from seismic survey vessels, 2001-02

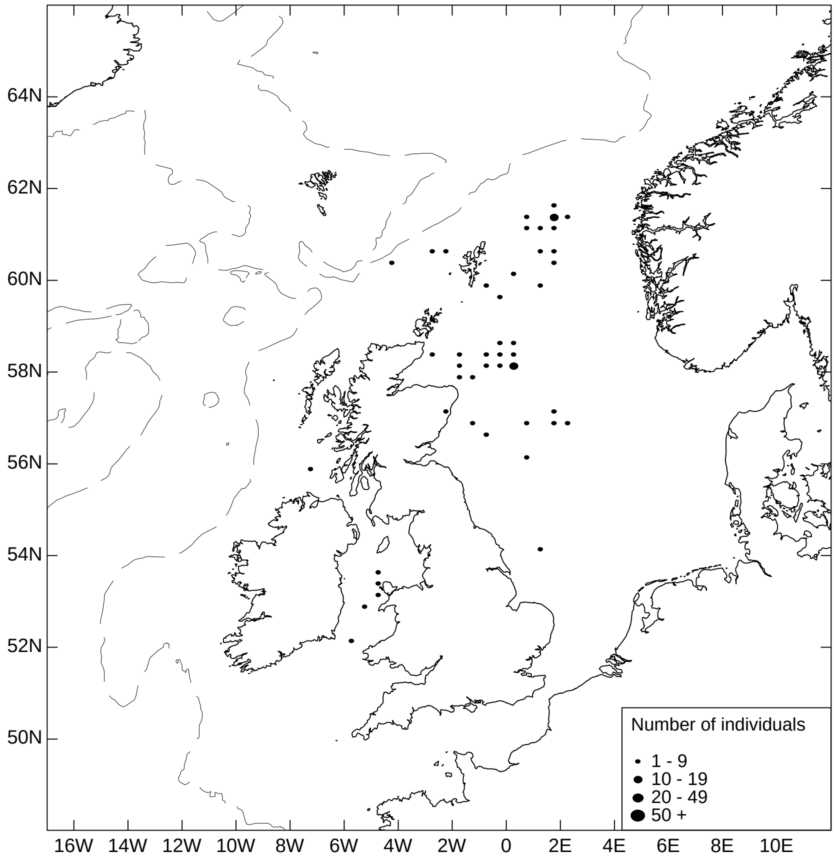


Figure 25. Distribution of harbour porpoises seen from seismic survey vessels, 2001-02

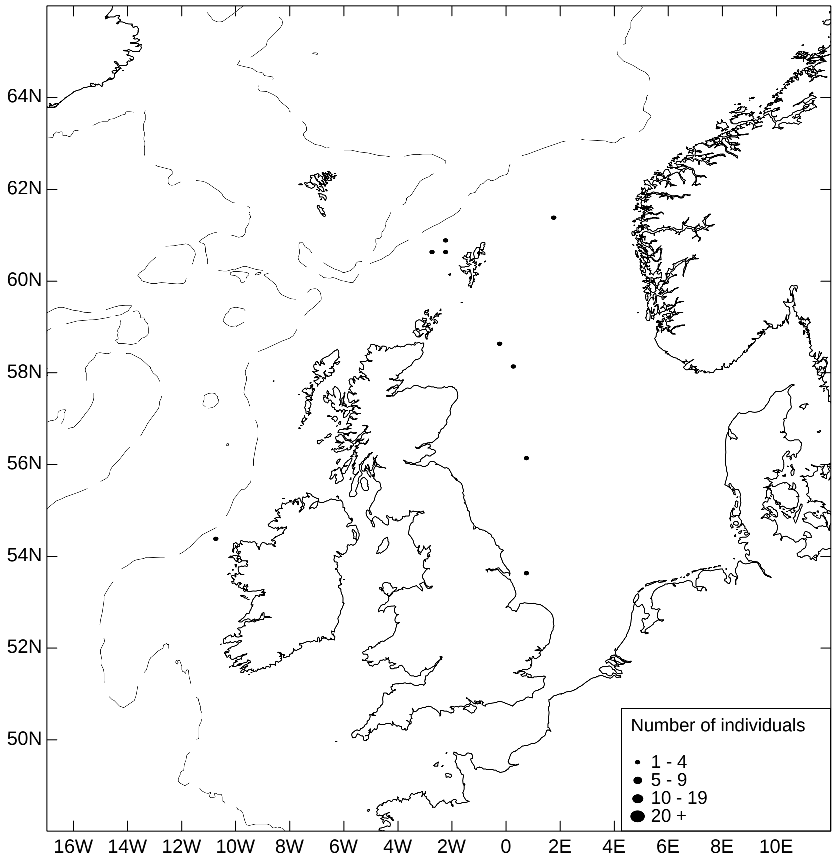


Figure 26. Distribution of unidentified seals seen from seismic survey vessels, 2001-02

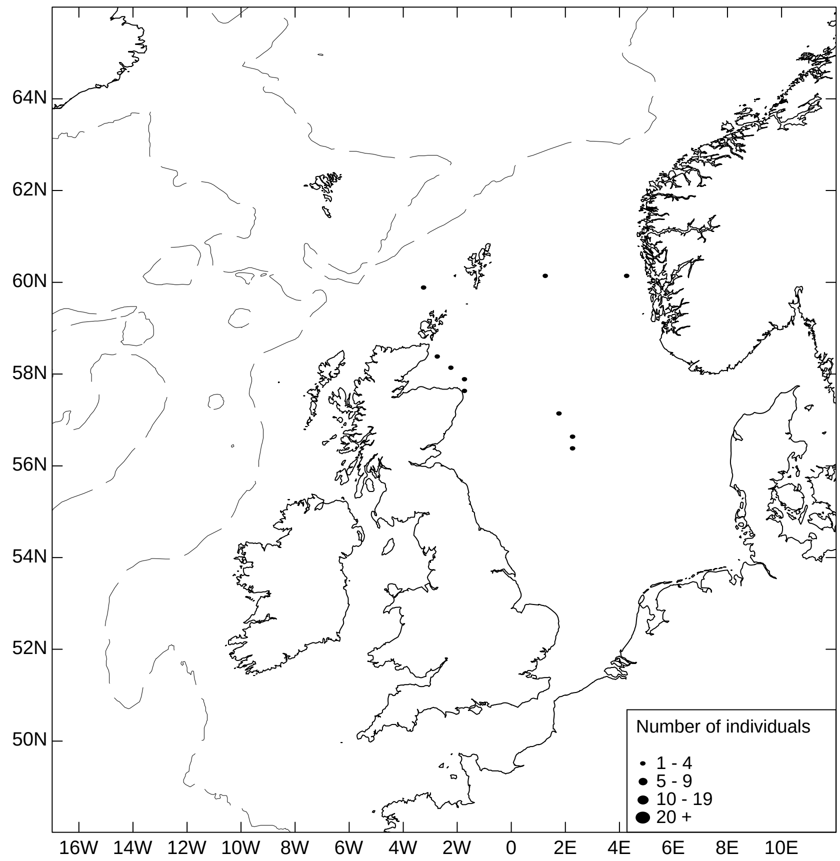


Figure 27. Distribution of grey seals seen from seismic survey vessels, 2001-02

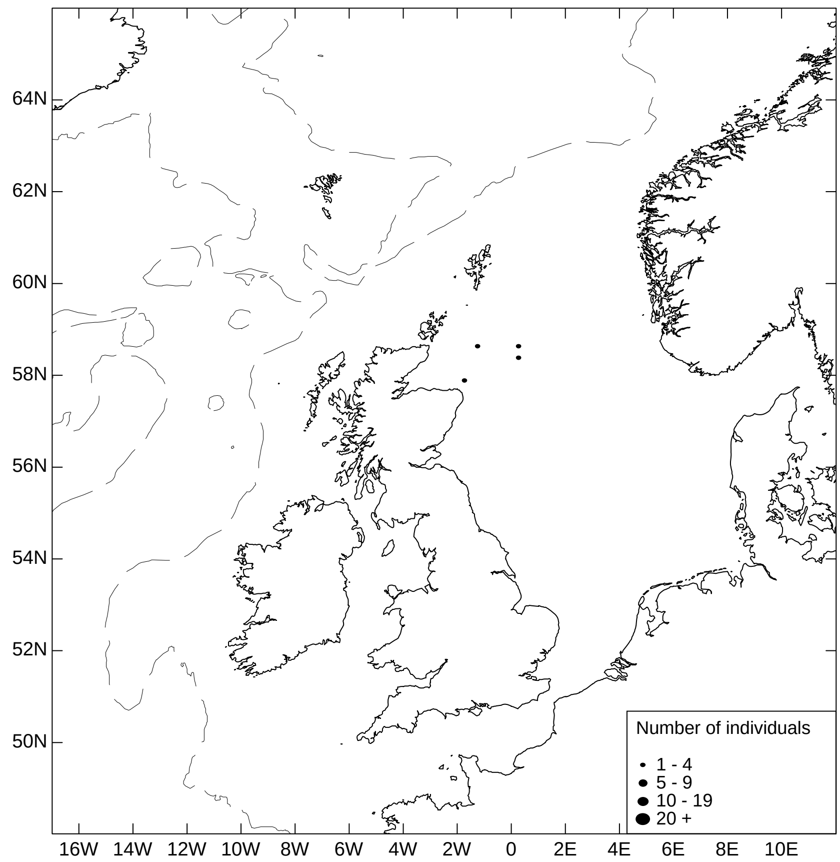


Figure 28. Distribution of common seals seen from seismic survey vessels, 2001-02

7. Seasonal abundance and migration of marine mammals

There were some seasonal variations in the distribution of some species, but these mostly reflected variations in the location of surveys. However, the occurrence of pilot whales to the east of Shetland between October and December may not have been entirely effort-related. Similarly, the move in sightings of grey seals from the central and western and eastern fringes of the northern North Sea in early summer (April, May) to more northern and western areas in mid to late summer (July, August) may not have been entirely effort-related.

The direction of travel of most species showed no definite trends. However, there were some indications that more minke whales were heading in easterly directions during the summer (June to September) than in other directions. The most frequent direction of travel of white-beaked dolphins during July was south, while in August more were travelling north and east. In June and July white-sided dolphins showed a tendency to be travelling south-west.

Some species showed seasonal peaks of occurrence. Of the more commonly seen species, sighting rates of killer whales and white-sided dolphins peaked in June, sighting rates of minke whales and harbour porpoises peaked in July, while those of pilot whales and white-beaked dolphins peaked in October (Figure 29).

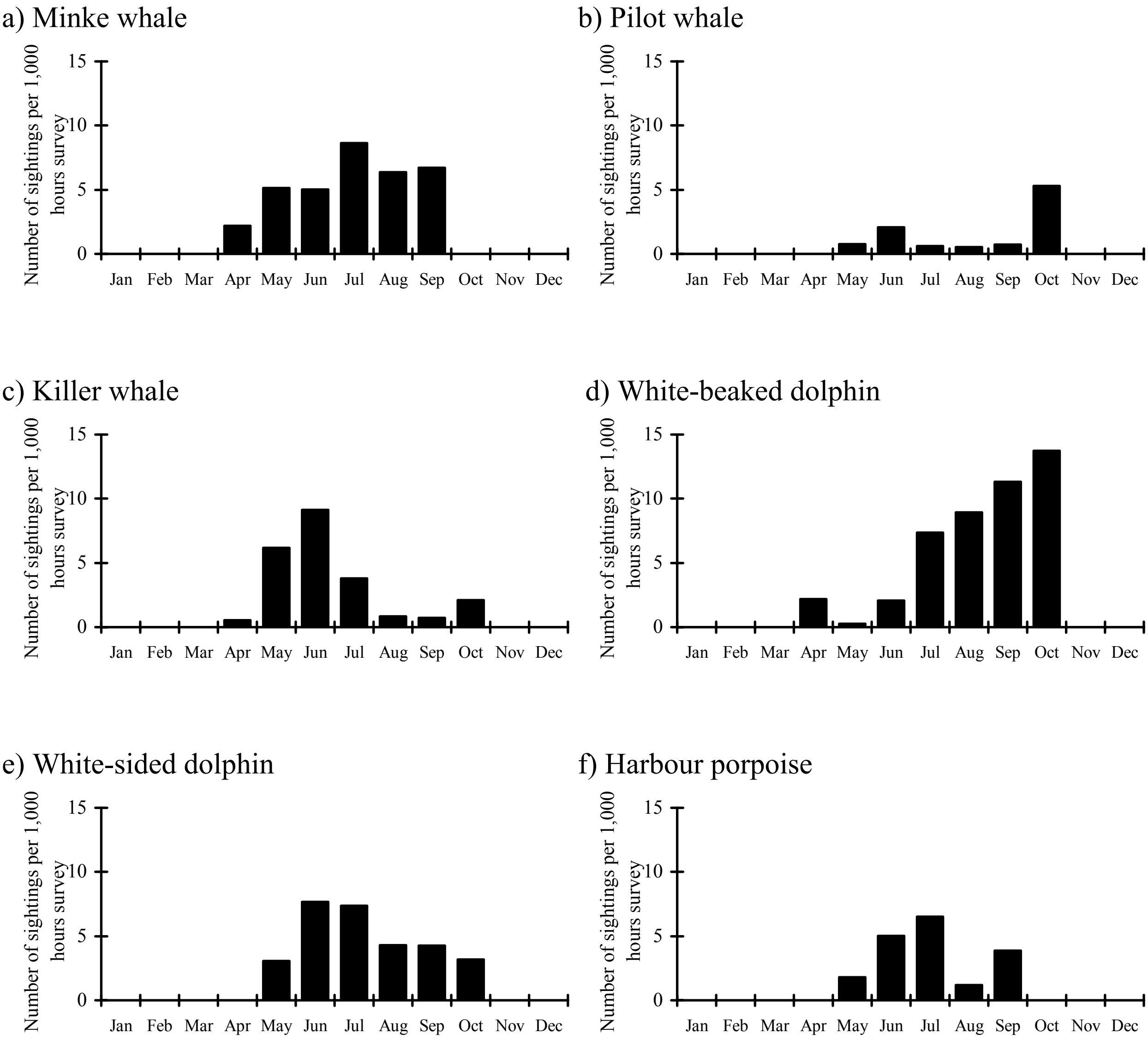


Figure 29 Sighting rates of cetaceans per month (only includes surveys where effort was correctly recorded).

8. Effects of seismic activity on marine mammals

8.1 Sighting rate of marine mammals

Sighting rates of marine mammals were calculated per 1,000 hours of observations (for those surveys where effort was recorded correctly) and compared between periods of shooting and periods when the airguns were not firing. Variations in sighting rate due to weather conditions, location, season or observer ability were controlled by comparing matched pairs of sighting rates (shooting/ not shooting) for watches conducted during similar weather conditions on each day of each survey.

During surveys with large airgun arrays, sighting rates were significantly reduced during periods of shooting for all cetacean species combined, all baleen whales combined, all small odontocetes combined, all *Lagenorhynchus* species combined, minke whales, sperm whales, white-beaked dolphins and harbour porpoises (Figure 30; Table 3). The other species or species groups tested showed no significant difference in sighting rate with seismic activity. Sample sizes for site surveys were small, but sighting rates did not differ significantly between periods of shooting and not shooting for any of the species or species groups tested (Figure 31; Table 3).

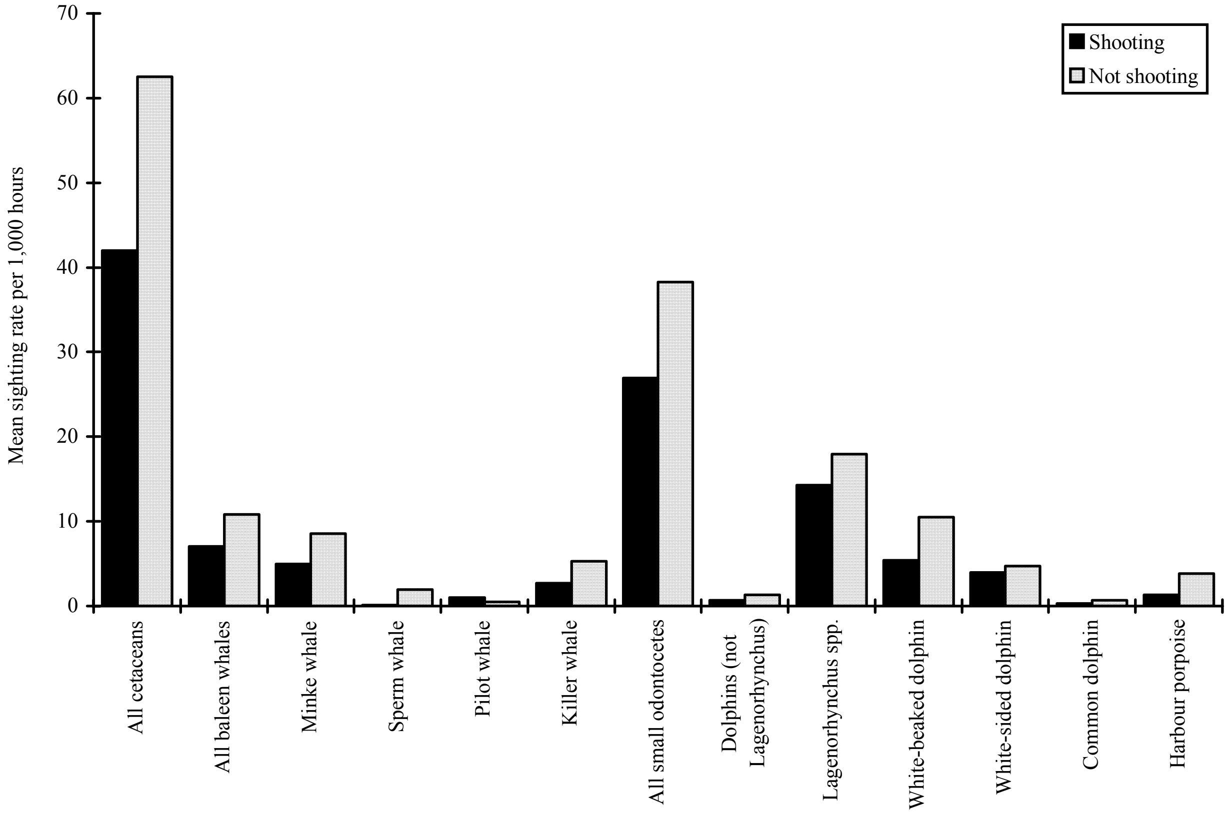


Figure 30. Sighting rates of marine mammals in relation to seismic activity (excluding site surveys).

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

Species	***Surveys with large airgun arrays***			***Site surveys***		
	z	***n***	***P***	***z***	***n***	***P***
All cetaceans combined	4.896	371	<0.00003	-0.273	28	n.s.
All baleen whales combined	2.104	95	0.0179	-0.155	10	n.s.
Minke whale	2.327	76	0.0099	-	-	-
Sperm whale	2.090	10	0.0183	-	-	-
Pilot whale	-1.153	13	n.s.	-	-	-
Killer whale	1.389	39	n.s.	-	-	-
All small odontocetes combined	4.222	264	<0.00003	0.153	18	n.s.
Dolphins (not *Lagenorhynchus*)*[1]	0.625	15	n.s.	-	-	-
Lagenorhynchus spp.*[2]	3.578	149	0.00016	-0.317	12	n.s.
White-beaked dolphin	2.674	83	0.0038	-	-	-
White-sided dolphin	1.538	48	n.s.	-0.415	9	n.s.
Common dolphin	0.314	6	n.s.	0.730	4	n.s.
Harbour porpoise	2.439	30	0.0073	-	-	-

*[1] includes Risso's dolphins, bottlenose dolphins, common dolphins, striped dolphins and any unidentified combination thereof
*[2] includes white-beaked dolphins, white-sided dolphins and unidentified *Lagenorhynchus* sp.

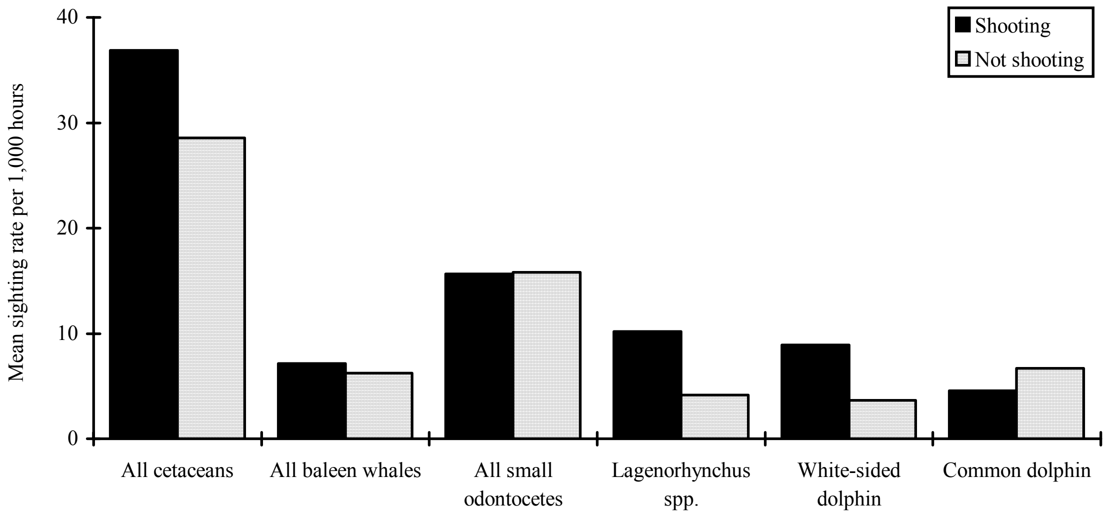


Figure 31. Sighting rates of marine mammals in relation to seismic activity during site surveys

Table 4. Areas and seasons of peak abundance of marine mammals used for selection of subsets of data in some analyses

Species	***Months***	***Areas***
All cetaceans combined	Jun - Sep	West of Shetland Rockall Northern North Sea West of Ireland
All baleen whales combined	Jun - Sep	West of Shetland Rockall Northern North Sea
Fin whale	Jun - Sep	West of Shetland Rockall
Minke whale	Jun - Sep	West of Shetland Rockall Northern North Sea West of Ireland
Sperm whale	May - Aug	West of Shetland Rockall West of Ireland
Pilot whale	May - Sep	West of Shetland Rockall West of Ireland South-West Approaches
Killer whale	Apr - Aug	West of Shetland Rockall Northern North Sea
All small odontocetes combined	Jun - Sep	West of Shetland Rockall Northern North Sea
Dolphins (not *Lagenorhynchus*)	Jun - Sep	West of Shetland Rockall Northern North Sea St. George's Channel and Bristol Channel West of Ireland
Risso's dolphin	Jul - Sep	Rockall St. George's Channel and Bristol Channel West of Ireland
Lagenorhynchus spp.	Jun - Sep	West of Shetland Rockall Northern North Sea
White-beaked dolphin	Jun - Sep	West of Shetland Northern North Sea
White-sided dolphin	Jun – Sep	West of Shetland Rockall Northern North Sea
Common dolphin	Jun – Sep	Rockall St. George's Channel and Bristol Channel West of Ireland
Harbour porpoise	Jul – Sep	West of Shetland Northern North Sea St. George's Channel and Bristol Channel

Sighting rates were compared throughout the course of surveys to test for short-term exclusion from survey areas due to continued seismic activity. To control for the effects of location, season and weather conditions only data collected in periods of good weather during surveys conducted in areas and months of peak marine mammal occurrence were used. The areas and seasons selected for each species or species group are noted in Table 4 and were established using various sources of effort-related data (e.g. Bloor *et al.* 1996; Clark and Charif 1998; JNCC 1995; NERC 1998; Northridge *et al.* 1995; Pollock *et al.* 1997, 2000; Reid *et. al* 2003; Skov *et al.* 1995). Up to 13 weeks were tested for surveys with large airgun arrays and up to six weeks for site surveys, which were of shorter duration. For both types of survey the variations in sighting rate over the weeks tested did not differ significantly for any species or species group (Table 5).

Table 5. Statistical significance of variation in sighting rate throughout the course of surveys, using Kruskal-Wallis one-way analysis of variance (KW = Kruskal-Wallis statistic; n = sample size; d.f. = degrees of freedom; P = probability; n.s. = not significant; - = insufficient data).

Species	***Surveys with large airgun arrays***				***Site surveys***			
	KW	***n***	***d.f.***	***P***	***KW***	***n***	***d.f.***	***P***
All cetaceans combined	8.941	105	12	n.s.	7.875	9	5	n.s.
All baleen whales combined	9.238	105	12	n.s.	7.875	9	5	n.s.
Minke whale	9.254	105	12	n.s.	-	-	-	-
Killer whale	6.503	103	12	n.s.	-	-	-	-
All small odontocetes combined	11.969	105	12	n.s.	7.875	9	5	n.s.
Lagenorhynchus spp.	8.472	105	12	n.s.	3.502	9	5	n.s.
White-beaked dolphin	8.166	105	12	n.s.	-	-	-	-
White-sided dolphin	11.376	105	12	n.s.	-	-	-	-
Harbour porpoise	6.066	70	9	n.s.	-	-	-	-

To examine any longer term effects of seismic activity within UK waters the sighting rate of the more frequently seen species was compared over a five year period. Only data from periods of good weather conditions during months and seasons of peak marine mammal abundance (Table 4) were used. The annual variations in sighting rates were significant for all species tested except harbour porpoise (Table 6). Sighting rates of both minke whales and killer whales generally increased over the five year period, while sighting rates of pilot whales showed a dramatic decline after 1998 (Figure 32). Although there were significant variations, the other species tested showed no clear trends in sighting rate throughout the five year period.

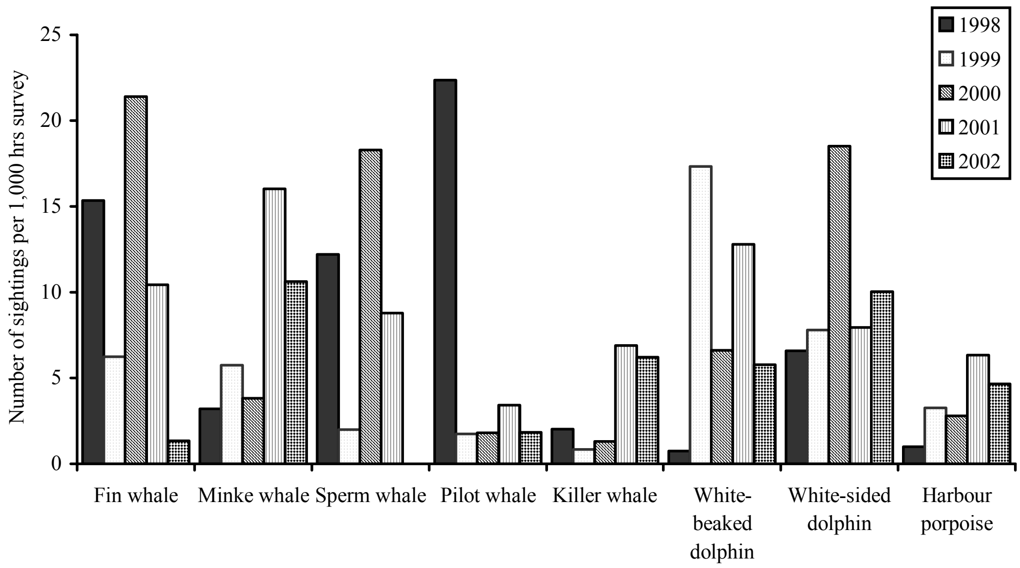


Figure 32. Annual variation in sighting rate of marine mammals, 1998-2002

Table 6. Statistical significance of annual variation in sighting rates of marine mammals, 1998-2002 (n = sample size; d.f. = degrees of freedom; P = probability; n.s. = not significant).

Species	χ^2	***n***	***d.f.***	***P***
Fin whale	27.413	56	4	<0.001
Minke whale	34.975	106	4	<0.001
Sperm whale	33.325	55	4	<0.001
Pilot whale	74.511	56	4	<0.001
Killer whale	19.469	54	4	<0.001
White-beaked dolphin	36.420	107	4	<0.001
White-sided dolphin	20.774	127	4	<0.001
Harbour porpoise	6.541	40	4	n.s.

8.2 Distance of marine mammals from the airguns

The median closest distance of approach of marine mammals to the airguns was compared between periods of shooting and not shooting. The influence of weather on the ability of observers to detect animals at distance was controlled by selecting only sightings during good weather conditions. There was considerable inter-observer variation in the distance at which marine mammals were detected, so only data from observers who had demonstrated a capability of detecting marine mammals at distances exceeding 500 m were used.

Where sample sizes permitted testing, on surveys with large airgun arrays the median distance of marine mammals was significantly closer when the airguns were silent for all cetaceans combined and for all individual species or species groups of small odontocetes with the exception of white-sided dolphins (Figure 33; Table 7). For all species where a significant difference in distance was observed, the apparent displacement during periods of shooting was at least 500 m. Sample sizes restricted analysis for site surveys to all cetaceans combined and all small odontocetes combined, but no significant differences in distance were found in either case (Figure 34; Table 7).

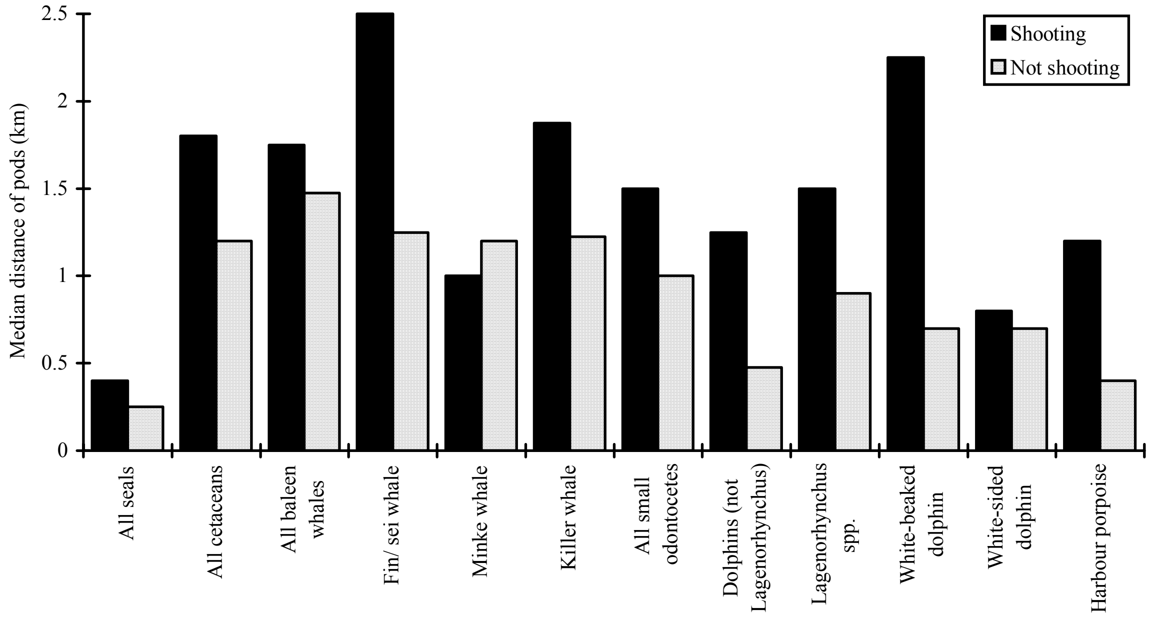


Figure 33. Median distance of marine mammals from the airguns in relation to seismic activity (excluding site surveys).

Table 7. Statistical significance of difference in distance of marine mammals from the airguns in relation to seismic activity (z = Wilcoxon statistic; n = sample size; P = probability; n.s. = not significant; - = insufficient data).

Species	***Surveys with large airgun arrays***			***Site surveys***		
	z	***n***	***P***	***z***	***n***	***P***
All seals combined	1.257	10	n.s.	-	-	-
All cetaceans combined	3.540	520	<0.00023	0.698	41	n.s.
All baleen whales combined	1.017	104	n.s.	-	-	-
Fin/ sei whale*[1]	1.619	10	n.s.	-	-	-
Minke whale	0.492	80	n.s.	-	-	-
Killer whale	1.157	50	n.s.	-	-	-
All small odontocetes combined	2.896	290	0.0019	0.789	27	n.s.
Dolphins (not *Lagenorhynchus*)	2.135	14	0.0162	-	-	-
Lagenorhynchus spp.	2.525	130	0.0057	-	-	-
White-beaked dolphin	2.627	54	0.0043	-	-	-
White-sided dolphin	0.995	46	n.s.	-	-	-
Harbour porpoise	2.855	30	0.0021	-	-	-

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

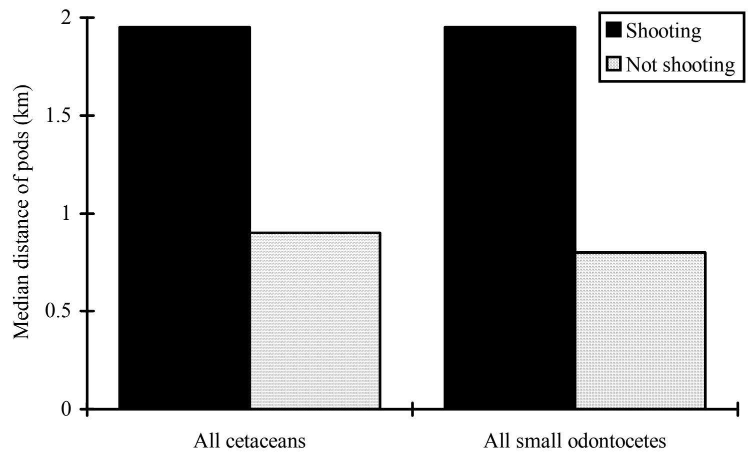


Figure 34. Median distance of marine mammals from the airguns in relation to seismic activity during site surveys

The proportion of sightings of small odontocetes occurring within a given range of large airgun arrays was reduced during periods of shooting for distances out to approximately 1.5 km from the source (Figure 35). These differences were statistically significant (Kolmogorov-Smirnov test; χ^2 approximation = 13.607, d.f. = 2, $p < 0.01$). For medium and large cetaceans there were no significant differences in the proportion of sightings within a given range of large airgun arrays (χ^2 approximation = 2.220, d.f. = 2). Sample sizes during periods of shooting on site surveys were too small to permit a similar comparison.

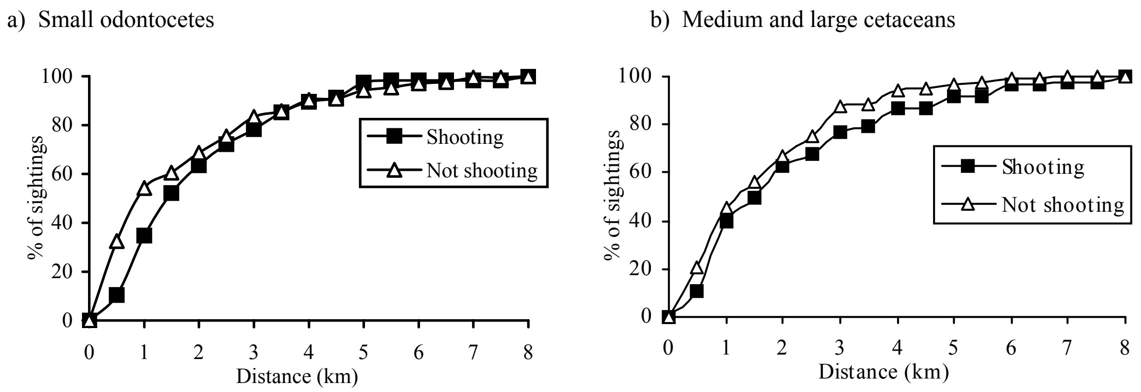


Figure 35. Proportion of marine mammal sightings occurring within specified distances of the airguns, in relation to seismic activity (excluding site surveys).

8.3 Behaviour of marine mammals

Observers recorded any types of behaviour that were apparent during encounters with marine mammals. The frequency of occurrence of each recorded behaviour was compared between periods of shooting and not shooting and the results were tested for all behaviours and species where sample sizes were sufficient. The number of encounters where each behaviour was exhibited during periods of shooting or not shooting is expressed as a percentage of the total number of encounters at the respective seismic activity. The resulting percentage thus indicates the tendency of animals to engage in a particular behaviour in relation to seismic activity.

On surveys with large airgun arrays, positive interactions with the vessel or its equipment (e.g. bow-riding, approaching close to the vessel, swimming alongside the vessel or its associated equipment, following the vessel or swimming close ahead of the vessel) occurred significantly more frequently when the airguns were silent than during periods of shooting for all species or species groups tested (Table 8). As well as a reluctance to engage in interactions with the vessel or its equipment during periods of shooting, for all cetaceans combined and all small odontocetes combined there was also a greater tendency to alter course at these times, mostly away from the vessel. Fast swimming was recorded significantly more often during periods of shooting for all cetaceans combined and all small odontocetes combined. Logging, where animals lie motionless at the water surface, sometimes interpreted as "resting" by observers, was also noted more often during periods of shooting for all cetaceans combined. There were no significant differences in the frequency of occurrence of any other types of behaviour in relation to seismic activity on surveys with large airguns arrays. For site surveys, small sample sizes prohibited analysis of most types of behaviour, but where analysis was possible no significant response to seismic activity was apparent (Table 9).

Table 8. Behaviour of marine mammals in relation to seismic activity, excluding site surveys (n = sample size; P = probability; n.s. = not significant).

Behaviour	***Species***	***% of encounters while shooting when behaviour was exhibited***	***% of encounters while not shooting when behaviour was exhibited***	χ^2	***n***	***P***
Feeding	All cetaceans combined	10.05	9.75	0.024	105	n.s.
	Killer whale	20.00	27.69	0.589	26	n.s.
	All small odontocetes combined	14.63	10.32	2.156	72	n.s.
	Lagenorhynchus spp.	20.88	14.06	1.766	46	n.s.
	White-beaked dolphin	26.83	13.76	2.929	26	n.s.
	White-sided dolphin	20.00	14.81	0.338	15	n.s.
+ve interactions	All cetaceans combined	3.02	11.09	20.151	86	<0.001
	All small odontocetes combined	3.90	14.99	14.855	69	<0.001
	Lagenorhynchus spp.	7.69	27.60	11.540	60	<0.001
	White-beaked dolphin	14.63	44.95	7.465	55	<0.01
Alteration of course	All cetaceans combined	5.28	1.20	15.207	29	<0.001
	All small odontocetes combined	6.34	1.72	8.908	20	<0.01
Breaching, jumping or somersaulting	All cetaceans combined	28.64	26.24	0.532	289	n.s.
	All small odontocetes combined	42.93	37.84	0.893	242	n.s.
	Lagenorhynchus spp.	57.14	42.71	2.716	134	n.s.
	White-beaked dolphin	58.54	39.45	2.433	67	n.s.
	White-sided dolphin	57.14	44.44	0.694	44	n.s.
Tail/ flipper-slapping	All cetaceans combined	1.76	1.50	0.106	17	n.s.
Spy-hopping	All cetaceans combined	2.26	0.90	3.272	15	n.s.
Porpoising	All cetaceans combined	14.57	12.74	0.621	143	n.s.
	All small odontocetes combined	26.34	20.39	2.155	137	n.s.
	Lagenorhynchus spp.	38.46	30.21	1.282	93	n.s.
	White-beaked dolphin	34.15	18.35	3.286	34	n.s.
	White-sided dolphin	51.43	51.85	0.001	46	n.s.
Fast swimming	All cetaceans combined	35.68	26.84	6.466	321	<0.05
	All baleen whales combined	11.39	4.85	2.479	14	n.s.
	Minke whale	12.96	6.67	1.343	12	n.s.
	Killer whale	27.50	12.31	3.155	19	n.s.
	All small odontocetes combined	50.73	37.59	5.603	257	<0.05
	Lagenorhynchus spp.	57.14	41.67	3.167	132	n.s.
	White-beaked dolphin	48.78	33.03	1.977	56	n.s.
	White-sided dolphin	68.57	51.85	1.016	52	n.s.
	Harbour porpoise	38.89	36.54	0.019	26	n.s.
Slow swimming	All cetaceans combined	18.59	22.79	2.068	226	n.s.
	All baleen whales combined	22.78	32.04	1.368	51	n.s.
	Minke whale	24.07	33.33	0.916	38	n.s.
	Pilot whale	60.71	53.85	0.072	24	n.s.
	Killer whale	25.00	40.00	1.621	36	n.s.
	All small odontocetes combined	12.20	18.43	3.243	100	n.s.
	Lagenorhynchus spp.	8.79	17.71	3.313	42	n.s.
	White-beaked dolphin	4.88	17.43	3.353	21	n.s.
	White-sided dolphin	11.43	18.52	0.682	14	n.s.
	Harbour porpoise	38.89	26.92	0.638	21	n.s.
Milling	All cetaceans combined	3.52	1.95	2.419	27	n.s.
	All small odontocetes combined	3.41	2.70	0.235	18	n.s.
Surfacing frequently	All cetaceans combined	3.52	2.55	0.807	31	n.s.
Surfacing infrequently	All cetaceans combined	8.54	11.09	1.600	108	n.s.
	All baleen whales combined	22.78	29.13	0.684	48	n.s.
	Minke whale	27.78	37.33	0.860	43	n.s.
	All small odontocetes combined	2.44	5.41	2.714	27	n.s.
Diving	All cetaceans combined	2.76	4.95	2.874	44	n.s.
	All baleen whales combined	6.33	12.62	1.786	18	n.s.
Logging/ "resting"	All cetaceans combined	4.77	2.25	4.971	34	<0.05

Widely dispersed group	All cetaceans combined	4.52	5.85	0.816	57	n.s.
	Killer whale	10.00	18.46	1.168	16	n.s.
	All small odontocetes combined	4.88	5.65	0.150	33	n.s.
	Lagenorhynchus spp.	6.59	6.77	0.003	19	n.s.
	White-sided dolphin	11.43	16.67	0.397	13	n.s.
Close together group	All cetaceans combined	2.76	1.95	0.734	24	n.s.

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

Behaviour	***Species***	***% of encounters while shooting when behaviour was exhibited***	***% of encounters while not shooting when behaviour was exhibited***	χ^2	***n***	***P***
Breaching, jumping or somersaulting	All cetaceans combined	34.78	20.13	1.937	38	n.s.

The direction of travel of marine mammals relative to the survey vessel was recorded by observers in a diagram and was subsequently assigned to one of six categories. During surveys with large airgun arrays the direction of travel differed significantly with seismic activity for all cetaceans combined, *Lagenorhynchus* spp., dolphins excluding *Lagenorhynchus* spp., and white-beaked dolphins (Table 10). In all cases partitioning showed that fewer pods were travelling towards the vessel and/ or more were travelling away from the vessel during periods of shooting. For site surveys no significant differences were found in the direction of travel of animals in relation to seismic activity (Table 11).

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

Species	*Seismic activity*	*Towards ship*	*Away from ship*	*Crossing path of ship*	*Parallel to ship in same direction*	*Parallel to ship in opposite direction*	*Milling or variable*	χ^2	*n*	*d.f.*	*P*
All cetaceans combined	Shooting	7.73%	25.69%	28.73%	9.39%	24.86%	3.59%	29.158	991	5	<0.001
	Not shooting	13.83%	15.90%	22.73%	14.79%	27.50%	5.25%				
All baleen whales combined	Shooting	2.74%	19.18%	34.25%	8.22%	32.88%	2.74%	6.097	171	4	n.s.
	Not shooting	6.12%	15.31%	26.53%	20.41%	28.57%	3.06%				
Minke whale	Shooting	1.96%	13.73%	39.22%	11.76%	31.37%	1.96%	3.727	125	4	n.s.
	Not shooting	6.76%	13.51%	31.08%	20.27%	25.68%	2.70%				
Pilot whale	Shooting	25.00%	17.86%	25.00%	0.00%	28.27%	3.57%	0.052	41	1	n.s.
	Not shooting	23.08%	0.00%	23.08%	0.00%	46.15%	7.69%				
Killer whale	Shooting	5.56%	19.44%	27.78%	11.11%	27.78%	8.33%	1.340	96	4	n.s.
	Not shooting	8.33%	11.67%	30.00%	11.67%	31.67%	6.67%				
All small odontocetes combined	Shooting	8.76%	29.38%	26.29%	11.34%	20.62%	3.61%	3.091	585	5	n.s.
	Not shooting	17.65%	16.11%	22.25%	13.30%	25.32%	5.37%				
Dolphins (not *Lagenorhynchus*)	Shooting	10.00%	40.00%	20.00%	20.00%	10.00%	0.00%	5.400	30	1	<0.05
	Not shooting	30.00%	10.00%	15.00%	0.00%	35.00%	10.00%				
Lagenorhynchus spp.	Shooting	12.09%	25.27%	34.07%	4.40%	17.58%	6.59%	18.164	281	5	<0.01
	Not shooting	26.32%	11.58%	25.79%	11.58%	19.47%	5.26%				
White-beaked dolphin	Shooting	19.51%	36.59%	19.51%	4.88%	17.07%	2.44%	16.399	150	5	<0.01
	Not shooting	38.53%	11.93%	18.35%	15.60%	11.93%	3.67%				
White-sided dolphin	Shooting	8.57%	8.57%	51.43%	0.00%	20.00%	11.43%	2.212	89	2	n.s.
	Not shooting	12.96%	5.56%	38.89%	1.85%	31.48%	9.26%				
Harbour porpoise	Shooting	5.88%	41.18%	11.76%	17.65%	23.53%	0.00%	4.106	69	2	n.s.
	Not shooting	5.77%	28.85%	19.23%	3.85%	36.54%	5.77%				

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

Species	*Seismic activity*	*Towards ship*	*Away from ship*	*Crossing path of ship*	*Parallel to ship in same direction*	*Parallel to ship in opposite direction*	*Milling or variable*	χ^2	*n*	*d.f.*	*P*
All cetaceans combined	Shooting	18.18%	13.64%	9.09%	4.55%	27.27%	27.27%	4.960	164	3	n.s.
	Not shooting	20.42%	9.15%	19.72%	8.45%	30.99%	11.27%				
All small odontocetes combined	Shooting	18.18%	18.18%	9.09%	9.09%	9.09%	36.36%	3.322	87	1	n.s.
	Not shooting	32.89%	9.21%	23.68%	5.26%	21.05%	7.89%				

8.4 Factors influencing the degree of disturbance of marine mammals

8.4.1 Depth of water

Seismic surveys in 2001-02 were conducted in a range of water depths. The location recorded on the 'Location and Effort' forms (where these were completed correctly) was used to assign each watch to one of five depth categories: 1) shallow continental shelf waters (0-50 m); 2) mid continental shelf waters (51-100 m); 3) outer continental shelf waters (101-

200 m); 4) shelf slope (201-1,000 m); 5) deep waters (> 1,000 m). Most time was spent in continental shelf waters, but the proportion of time spent shooting was greatest in deep waters (Table 12). Sightings of some species (e.g. sperm whale, beaked whales) were restricted to deeper waters over the continental shelf slope and beyond, while others (e.g. common seal, bottlenose dolphin) were only seen in continental shelf waters. Many species (e.g. killer whale, white-sided dolphin) were seen in a range of depths.

Table 12. Effort at different depths

Depth	*Surveys with large airgun arrays*		*Site surveys*	
	Total effort	*Proportion of time spent shooting*	*Total effort*	*Proportion of time spent shooting*
0-50 m	277 h 55 m	38.72%	1,745 h 20 m	9.58%
51-100 m	5,263 h 55 m	37.68%	802 h 19 m	16.24%
101-200 m	9,134 h 43 m	42.28%	1,838 h 14 m	25.31%
201-1,000 m	3,482 h 09 m	46.64%	762 h 14 m	9.61%
> 1,000 m	72 h 10 m	57.20%	273 h 34 m	28.14%

Sighting rates were calculated for each depth zone for each day of each survey with large airgun arrays, for periods when the airguns were firing and when they were silent (Table 13). To control for bias due to location, season or weather conditions, only watches conducted during good weather conditions in months and areas of peak marine mammal occurrence were used. A log transformation was used before performing a two-way analysis of variance; while the sighting rate of some species was shown to vary significantly with depth, there was no significant interaction between depth of water and seismic activity (Table 14).

Table 13. Mean of log (sighting rate per 1,000 hrs + 1) in relation to depth of water and seismic activity, excluding site surveys

Species	*Seismic activity*	*Depth of water*				
		0-50 m	*51-100 m*	*101-200 m*	*201-1,000 m*	*>1,000 m*
All baleen whales combined	Shooting Not shooting	0.000 0.000	0.155 0.161	0.077 0.147	0.216 0.203	0.000 0.000
Minke whale	Shooting Not shooting	0.000 0.000	0.155 0.161	0.077 0.131	0.090 0.077	0.000 0.000
Killer whale	Shooting Not shooting	0.000 0.000	0.000 0.000	0.048 0.114	0.037 0.099	0.000 0.000
All small odontocetes combined	Shooting Not shooting	0.000 2.665	0.360 0.424	0.259 0.285	0.421 0.438	0.000 0.000
Dolphins (not *Lagenorhynchus*)	Shooting Not shooting	0.000 0.000	0.000 0.000	0.019 0.029	0.063 0.054	0.000 0.000
Lagenorhynchus spp.	Shooting Not shooting	0.000 0.000	0.227 0.268	0.103 0.164	0.189 0.261	0.000 0.000
White-beaked dolphin	Shooting Not shooting	0.000 0.000	0.193 0.186	0.016 0.043	0.037 0.114	0.000 0.000
White-sided dolphin	Shooting Not shooting	0.000 0.000	0.000 0.015	0.068 0.089	0.132 0.139	0.000 0.000
Harbour porpoise	Shooting Not shooting	0.000 0.000	0.000 0.058	0.052 0.107	0.021 0.000	0.000 0.000

Table 14. Two-way analysis of variance of log (sighting rate per 1,000 hrs + 1) in relation to depth of water and seismic activity, excluding site surveys (d.f. = degrees of freedom; P = probability).

Species	*Depth of water*			*Seismic activity*			*Depth of water x seismic activity interaction*		
	d.f.	*F ratio*	*P*	*d.f.*	*F ratio*	*P*	*d.f.*	*F ratio*	*P*
All baleen whales combined	4	1.328	n.s.	1	0.004	n.s.	4	0.277	n.s.
Minke whale	4	0.935	n.s.	1	0.003	n.s.	4	0.218	n.s.
Killer whale	4	2.507	0.041	1	0.042	n.s.	4	0.433	n.s.
All small odontocetes combined	4	2.614	0.034	1	3.574	n.s.	4	1.254	n.s.
Dolphins (not *Lagenorhynchus*)	4	2.094	n.s.	1	0.000	n.s.	4	0.076	n.s.
Lagenorhynchus spp.	4	1.907	n.s.	1	0.025	n.s.	4	0.026	n.s.
White-beaked dolphin	4	6.439	0.000	1	0.016	n.s.	4	0.301	n.s.
White-sided dolphin	4	3.545	0.007	1	0.004	n.s.	4	0.013	n.s.
Harbour porpoise	4	1.809	n.s.	1	0.025	n.s.	4	0.505	n.s.

The closest distance of approach of marine mammals to the airguns was also compared for each of the five depth zones, during periods of shooting and not shooting on surveys with large airgun arrays (Table 15). As weather conditions could affect observers' ability to detect marine mammals at distance, only sightings detected during good weather conditions were used. A two-way analysis of variance on log-transformed data showed that while distance from the airguns varied significantly with depth of water for all baleen whales combined, there was no significant interaction of depth of water with seismic activity for any of the species tested (Table 16).

Table 15. Median closest distance of marine mammals from the airguns in relation to depth of water and seismic activity, excluding site surveys (- = not encountered in depth zone at that seismic activity).

Species	***Seismic activity***	***Depth of water***				
		0-50 m	***51-100 m***	***101-200 m***	***201-1,000 m***	***>1,000 m***
All baleen whales combined	Shooting Not shooting	- -	1,300 m 1,200 m	1,000 m 800 m	3,000 m 3,000 m	2,000 m 2,500 m
Minke whale	Shooting Not shooting	- -	1,300 m 1,200 m	1,000 m 800 m	900 m 3,000 m	300 m 3,000 m
White-beaked dolphin	Shooting Not shooting	- -	2,850 m 800 m	2,250 m 350 m	775 m 750 m	- -

Table 16. Two-way analysis of variance of closest distance from the airguns in relation to depth of water and seismic activity, excluding site surveys (d.f. = degrees of freedom; P = probability).

Species	***Depth of water***			***Seismic activity***			***Depth of water x seismic activity interaction***		
	d.f.	***F ratio***	***P***	***d.f.***	***F ratio***	***P***	***d.f.***	***F ratio***	***P***
All baleen whales combined	3	3.915	0.011	1	0.203	n.s.	3	0.531	n.s.
Minke whale	3	0.739	n.s.	1	1.061	n.s.	3	1.398	n.s.
White-beaked dolphin	2	0.230	n.s.	1	1.917	n.s.	2	0.266	n.s.

The proportion of marine mammals exhibiting various behaviours when shooting or not shooting was compared between the different depth zones for surveys with large airgun arrays. Due to the small number of sightings in very shallow waters, the first two depth zones were combined. For all small odontocetes combined, the proportion swimming slowly varied significantly with depth and seismic activity (Table 17). Partitioning and analysis of residuals showed that significantly more animals were swimming slowly while the airguns were firing in the 101-200 m depth zone, while in the other depth zones fewer animals were swimming slowly when the airguns were firing. The results for all other behaviours and species/ species groups proved to be non-significant.

Table 17. Behaviour of marine mammals in relation to depth of water and seismic activity, excluding site surveys (- = not encountered in depth zone at that seismic activity; n = sample size; P = probability; n.s. = not significant).

Behaviour	*Species*	*Seismic activity*	*% of encounters when behaviour was exhibited*						
			0-100 m	*101-200 m*	*201-1,000 m*	*> 1,000 m*	χ^2	*n*	*P*
Fast swimming	All cetaceans combined	Shooting Not shooting	41.53 29.00	39.11 27.99	29.51 25.00	11.76 16.67	2.739	319	n.s.
	All small odontocetes	Shooting Not shooting	52.00 34.86	54.44 40.52	46.43 37.50	25.00 40.00	2.521	255	n.s.
	Lagenorhynchus spp.	Shooting Not shooting	53.66 36.56	65.00 45.90	40.00 44.83	- 55.56	5.887	132	n.s.
	White-beaked dolphin	Shooting Not shooting	50.00 30.77	66.67 42.86	0.00 30.00	- -	1.115	56	n.s.
	White-sided dolphin	Shooting Not shooting	50.00 66.67	73.08 50.00	57.14 42.86	- 71.43	3.215	52	n.s.
Breaching, jumping or somersaulting	All cetaceans combined	Shooting Not shooting	42.37 38.53	26.82 23.13	18.03 9.62	14.71 21.67	4.003	288	n.s.
	All small odontocetes	Shooting Not shooting	53.33 45.71	36.67 35.95	35.71 12.50	62.50 55.00	4.396	241	n.s.
	Lagenorhynchus spp.	Shooting Not shooting	63.41 47.31	57.50 47.54	30.00 6.90	- 77.78	1.692	134	n.s.
	White-beaked dolphin	Shooting Not shooting	62.50 41.03	50.00 52.38	33.33 0.00	- -	0.701	67	n.s.
Slow swimming	All cetaceans combined	Shooting Not shooting	11.02 19.48	19.55 20.52	24.59 33.65	32.35 26.67	5.297	225	n.s.
	All baleen whales	Shooting Not shooting	34.78 52.94	14.29 20.51	13.33 23.08	26.32 23.53	0.478	51	n.s.
	All small odontocetes	Shooting Not shooting	4.00 13.71	18.89 16.34	14.29 35.71	12.50 25.00	9.187	99	<0.05
Surfacing infrequently	All cetaceans combined	Shooting Not shooting	7.63 6.49	9.50 15.30	6.56 14.42	8.82 5.00	0.728	107	n.s.

Sample sizes for site surveys were too small to permit examination of any interaction between seismic activity and depth of water.

8.4.2 Distance from land

The location recorded on the 'Location and Effort' forms was also used to assign each watch to one of four categories of distance from land: 1) 0-50 km; 2) 51-100 km; 3) 101-200 km; 4) > 200 km. Most time was spent between 101 and 200 km from land (Table 18). On surveys with large airgun arrays the proportion of time spent shooting was greatest over 200 km from land, while on site surveys the proportion of time spent shooting was least in this zone.

Table 18. Effort in relation to distance from land

Distance from land	*Surveys with large airgun arrays*		*Site surveys*	
	Total effort	*Proportion of time spent shooting*	*Total effort*	*Proportion of time spent shooting*
0-50 km	3,225 h 42 m	46.30%	1,814 h 39 m	16.45%
51-100 km	6,579 h 25 m	42.67%	1,327 h 00 m	19.21%
101-200 km	7,108 h 51 m	36.49%	2,658 h 24 m	15.97%
> 200 km	1,487 h 25 m	48.17%	199 h 30 m	8.02%

Sighting rates were calculated for each distance band for each day of each survey with large airgun arrays, for periods when the airguns were firing and when they were silent (Table 19). To control for bias due to location, season or weather conditions, only watches conducted during good weather conditions in months and areas of peak marine mammal occurrence were used. A log transformation was used before performing a two-way analysis of variance; while the sighting rate of a number of species was shown to vary significantly with distance from land, there was only one species (white-beaked dolphin) where there was a significant interaction of distance from land with seismic activity (Table 20). In this case, sighting rates of white-beaked dolphins were lower during periods of shooting than during periods of airgun silence in all distance bands but the furthest from land (> 200 km), where sighting rates were highest during periods of shooting.

Table 19. Mean of log (sighting rate per 1,000 hrs + 1) in relation to distance from land and seismic activity, excluding site surveys

Species	*Seismic activity*	*Distance from land*			
		0-50 km	*51-100 km*	*101-200 km*	*> 200 km*
All baleen whales combined	Shooting Not shooting	0.122 0.154	0.038 0.060	0.154 0.208	0.471 0.407
Minke whale	Shooting Not shooting	0.106 0.136	0.037 0.061	0.095 0.130	0.471 0.407
Killer whale	Shooting Not shooting	0.017 0.076	0.072 0.155	0.011 0.023	0.000 0.000
All small odontocetes combined	Shooting Not shooting	0.251 0.377	0.306 0.246	0.303 0.460	0.753 0.418
Dolphins (not *Lagenorhynchus*)	Shooting Not shooting	0.064 0.018	0.028 0.048	0.000 0.021	0.000 0.000
Lagenorhynchus spp.	Shooting Not shooting	0.124 0.247	0.127 0.122	0.150 0.279	0.471 0.227
White-beaked dolphin	Shooting Not shooting	0.018 0.036	0.012 0.056	0.114 0.199	0.304 0.000
White-sided dolphin	Shooting Not shooting	0.070 0.136	0.088 0.024	0.045 0.091	0.000 0.074
Harbour porpoise	Shooting Not shooting	0.045 0.071	0.039 0.074	0.020 0.059	0.000 0.095

Table 20. Two-way analysis of variance of log (sighting rate per 1,000 hrs + 1) in relation to distance from land and seismic activity, excluding site surveys (d.f. = degrees of freedom; P = probability).

Species	*Distance from land*			*Seismic activity*			*Distance from land x seismic activity interaction*		
	d.f.	*F ratio*	*P*	*d.f.*	*F ratio*	*P*	*d.f.*	*F ratio*	*P*
All baleen whales combined	3	9.925	0.000	1	0.065	n.s.	3	0.223	n.s.
Minke whale	3	11.165	0.000	1	0.025	n.s.	3	0.187	n.s.
Killer whale	3	5.801	0.001	1	2.269	n.s.	3	0.804	n.s.
All small odontocetes combined	3	2.787	0.040	1	0.173	n.s.	3	2.253	n.s.
Dolphins (not *Lagenorhynchus*)	3	1.379	n.s.	1	0.005	n.s.	3	1.091	n.s.
Lagenorhynchus spp.	3	2.681	0.046	1	0.000	n.s.	3	2.069	n.s.
White-beaked dolphin	3	6.991	0.000	1	1.258	n.s.	3	3.549	0.014
White-sided dolphin	3	0.815	n.s.	1	0.901	n.s.	3	1.781	n.s.
Harbour porpoise	3	0.196	n.s.	1	2.823	n.s.	3	0.148	n.s.

The closest distance of approach of marine mammals to the airguns was also compared for each of the distance bands, during periods of shooting and not shooting on surveys with large airgun arrays (Table 21). As weather conditions could affect observers' ability to detect marine mammals at distance, only sightings detected during good weather conditions were used. A two-way analysis of variance on log-transformed data showed that while distance from the airguns varied significantly with distance from land or seismic activity for some of the species tested, the only significant interaction of distance from land with seismic activity was for all small odontocetes combined (Table 22). Small odontocetes approached closer to the airguns when they were silent than when they were shooting, but the difference was most extreme closest to land.

Table 21. Median closest distance of marine mammals from the airguns in relation to distance from land and seismic activity, excluding site surveys (- = not encountered in distance band at that seismic activity).

Species	*Seismic activity*	*Distance from land*			
		0-50 km	*51-100 km*	*101-200 km*	*> 200 km*
All baleen whales combined	Shooting Not shooting	1,000 m 2,000 m	900 m 1,900 m	2,000 m 1,200 m	2,000 m 1,000 m
Minke whale	Shooting Not shooting	1,000 m 2,000 m	800 m 1,250 m	850 m 1,000 m	2,000 m 1,000 m
Killer whale	Shooting Not shooting	150 m 1,350 m	2,000 m 1,100 m	1,500 m 3,250 m	- -
All small odontocetes combined	Shooting Not shooting	2,000 m 375 m	1,450 m 950 m	2,000 m 1,200 m	3,000 m 2,750 m
Lagenorhynchus spp.	Shooting Not shooting	910 m 350 m	1,150 m 900 m	800 m 800 m	3,350 m 2,500 m
White-sided dolphin	Shooting Not shooting	810 m 300 m	1,000 m 800 m	550 m 900 m	- -

Table 22. Two-way analysis of variance of closest distance from the airguns in relation to distance from land and seismic activity, excluding site surveys (d.f. = degrees of freedom; P = probability).

Species	*Distance from land*			*Seismic activity*			*Distance from land x seismic activity interaction*		
	d.f.	*F ratio*	*P*	*d.f.*	*F ratio*	*P*	*d.f.*	*F ratio*	*P*
All baleen whales combined	3	0.097	n.s.	1	1.250	n.s.	3	1.364	n.s.
Minke whale	3	0.304	n.s.	1	0.511	n.s.	3	1.270	n.s.
Killer whale	2	4.344	0.019	1	1.228	n.s.	2	2.028	n.s.
All small odontocetes combined	3	5.722	0.001	1	8.707	0.003	3	2.870	0.037
Lagenorhynchus spp.	3	4.255	0.007	1	5.235	0.024	3	0.318	n.s.
White-sided dolphin	2	1.416	n.s.	1	0.883	n.s.	2	2.113	n.s.

The proportion of marine mammals exhibiting various behaviours when shooting or not shooting was compared between the different distance bands for surveys with large airgun arrays. All cetaceans combined, all small odontocetes combined, and *Lagenorhynchus* spp. were found to be breaching, jumping or somersaulting more often when the airguns were firing than when they were silent, with the greatest difference being apparent closer to land (Table 23). When all cetaceans were combined, within 100 km of land fewer were observed to be surfacing infrequently when the airguns were firing, but this was not the case at greater distances from land. The results for all other behaviours and species/ species groups were non-significant.

Table 23. Behaviour of marine mammals in relation to distance from land and seismic activity, excluding site surveys (- = not encountered in distance band at that seismic activity; n = sample size; P = probability; n.s. = not significant).

Behaviour	*Species*	*Seismic activity*	*% of encounters when behaviour was exhibited*						
			0-50 km	*51-100 km*	*101-200 km*	*> 200 km*	χ^2	*n*	*P*
Fast swimming	All cetaceans combined	Shooting Not shooting	42.25 28.07	34.25 23.40	32.12 26.33	40.91 48.65	3.711	321	n.s.
	All small odontocetes	Shooting Not shooting	59.46 38.03	49.28 37.39	47.22 32.83	51.85 78.26	2.516	257	n.s.
	Lagenorhynchus spp.	Shooting Not shooting	78.57 45.83	50.00 37.25	57.58 37.86	50.00 78.57	2.290	132	n.s.
	White-sided dolphin	Shooting Not shooting	70.00 61.54	66.67 38.10	71.43 100.00	- -	3.468	52	n.s.
Breaching, jumping or somersaulting	All cetaceans combined	Shooting Not shooting	35.21 20.18	20.55 19.15	27.74 32.38	47.73 43.24	13.250	289	<0.01
	All small odontocetes	Shooting Not shooting	40.54 26.76	34.78 33.04	45.83 42.42	59.26 56.52	8.826	242	<0.05
	Lagenorhynchus spp.	Shooting Not shooting	64.29 37.50	53.57 39.22	48.48 42.72	75.00 64.29	7.880	134	<0.05
	White-sided dolphin	Shooting Not shooting	60.00 46.15	55.56 40.91	57.14 47.37	- -	1.626	44	n.s.

Slow swimming	All cetaceans combined	Shooting	26.76	20.55	15.33	9.09	3.004	226	n.s.
		Not shooting	22.81	25.53	20.64	21.62			
	All baleen whales	Shooting	11.76	27.27	25.00	28.57	0.168	51	n.s.
		Not shooting	18.18	28.00	36.17	55.56			
	All small odontocetes	Shooting	18.92	13.04	9.72	7.41	1.644	100	n.s.
		Not shooting	23.94	17.39	18.18	8.70			
Surfacing infrequently	All cetaceans combined	Shooting	7.04	7.53	10.95	6.82	6.189	108	<0.05
		Not shooting	16.67	14.47	6.76	5.41			
	All baleen whales	Shooting	23.53	45.45	18.18	14.29	1.307	48	n.s.
		Not shooting	31.82	52.00	17.02	22.22			
	Minke whale	Shooting	16.67	55.56	26.92	14.29	1.244	43	n.s.
		Not shooting	40.00	70.59	23.53	22.22			

Sample sizes for site surveys were again too small to permit examination of any interaction between seismic activity and distance from land.

8.4.3 Presence of juveniles

Sighting rates were calculated for each day of each survey with large airgun arrays for pods where juveniles were present and pods where there were definitely no juveniles, for periods when the airguns were firing and when they were silent (Table 24). To control for bias due to location, season or weather conditions, only watches conducted during good weather conditions in months and areas of peak marine mammal occurrence were used. A log transformation was used before performing a two-way analysis of variance. Sighting rates of some species varied with seismic activity or the presence of juveniles (Table 25). However, no significant interaction of the presence of juveniles with seismic activity was found for any of the species or species groups tested.

Table 24. Mean of log (sighting rate per 1,000 hrs + 1) in relation to presence of juveniles and seismic activity, excluding site surveys

Species	*Seismic activity*	*No juveniles present*	*Juveniles present*
Killer whale	Shooting	0.010	0.014
	Not shooting	0.056	0.043
All small odontocetes combined	Shooting	0.149	0.099
	Not shooting	0.257	0.103
Lagenorhynchus spp.	Shooting	0.068	0.067
	Not shooting	0.124	0.079
White-beaked dolphin	Shooting	0.047	0.034
	Not shooting	0.072	0.035
White-sided dolphin	Shooting	0.009	0.034
	Not shooting	0.023	0.038

Table 25. Two-way analysis of variance of log (sighting rate per 1,000 hrs + 1) in relation to presence of juveniles and seismic activity, excluding site surveys (d.f. = degrees of freedom; P = probability).

Species	*Presence of juveniles*			*Seismic activity*			*Presence of juveniles x seismic activity interaction*		
	d.f.	*F ratio*	*P*	*d.f.*	*F ratio*	*P*	*d.f.*	*F ratio*	*P*
Killer whale	1	0.144	n.s.	1	9.837	0.002	1	0.524	n.s.
All small odontocetes combined	1	14.399	0.000	1	4.426	0.036	1	3.802	n.s.
Lagenorhynchus spp.	1	1.294	n.s.	1	2.815	n.s.	1	1.183	n.s.
White-beaked dolphin	1	2.768	n.s.	1	0.791	n.s.	1	0.605	n.s.
White-sided dolphin	1	3.160	n.s.	1	0.699	n.s.	1	0.181	n.s.

The closest distance of approach of marine mammals to the airguns was also compared for pods with or without juveniles present, during periods of shooting and not shooting on surveys with large airgun arrays (Table 26). As weather conditions could affect observers' ability to detect marine mammals at distance, only sightings detected during good weather conditions were used. A two-way analysis of variance on log-transformed data showed that some species were significantly further from the airguns when they were shooting (Table 27). In addition, some species were recorded significantly closer to the airguns when juveniles were present, regardless of seismic activity, probably reflecting the greater ease of detection of small juvenile animals at close distances. However, there were no cases where a significant interaction of presence of juveniles with seismic activity was apparent.

Table 26. Median closest distance of marine mammals from the airguns in relation to presence of juveniles and seismic activity, excluding site surveys

Species	*Seismic activity*	*No juveniles present*	*Juveniles present*
Killer whale	Shooting Not shooting	2,000 m 1,675 m	600 m 1,000 m
All small odontocetes combined	Shooting Not shooting	1,500 m 1,000 m	1,000 m 450 m
Lagenorhynchus spp.	Shooting Not shooting	3,500 m 950 m	775 m 440 m
White-beaked dolphin	Shooting Not shooting	3,500 m 500 m	900 m 350 m
White-sided dolphin	Shooting Not shooting	950 m 800 m	675 m 440 m

Table 27. Two-way analysis of variance of closest distance from the airguns in relation to presence of juveniles and seismic activity, excluding site surveys (d.f. = degrees of freedom; P = probability).

Species	*Presence of juveniles*			*Seismic activity*			*Presence of juveniles x seismic activity interaction*		
	d.f.	*F ratio*	*P*	*d.f.*	*F ratio*	*P*	*d.f.*	*F ratio*	*P*
Killer whale	1	4.953	0.032	1	0.221	n.s.	1	0.639	n.s.
All small odontocetes combined	1	6.828	0.010	1	12.386	0.001	1	0.489	n.s.
Lagenorhynchus spp.	1	10.403	0.002	1	9.649	0.002	1	0.465	n.s.
White-beaked dolphin	1	2.488	n.s.	1	8.121	0.007	1	0.007	n.s.
White-sided dolphin	1	1.130	n.s.	1	0.474	n.s.	1	0.030	n.s.

The proportion of marine mammals exhibiting various behaviours when shooting or not shooting was compared between pods with and without juveniles present for surveys with large airgun arrays. The results for all behaviours and species/ species groups tested were non-significant (Table 28).

Table 28. Behaviour of marine mammals in relation to presence of juveniles and seismic activity, excluding site surveys (n = sample size; P = probability; n.s. = not significant).

Behaviour	***Species***	***Seismic activity***	***% of encounters when behaviour was exhibited***		χ^2	***n***	***P***
			No juveniles present	***Juveniles present***			
Feeding	All cetaceans combined	Shooting Not shooting	8.33 7.59	12.73 16.98	0.249	71	n.s.
	All small odontocetes	Shooting Not shooting	14.13 6.94	13.89 9.71	0.005	40	n.s.
	Lagenorhynchus spp.	Shooting Not shooting	21.62 8.89	19.23 13.21	0.003	28	n.s.
Fast swimming	All cetaceans combined	Shooting Not shooting	32.84 25.39	36.36 24.53	0.022	220	n.s.
	All small odontocetes	Shooting Not shooting	53.26 37.50	47.22 32.35	0.226	169	n.s.
	Lagenorhynchus spp.	Shooting Not shooting	59.46 40.00	53.85 33.96	0.099	90	n.s.
Breaching, jumping or somersaulting	All cetaceans combined	Shooting Not shooting	22.06 19.63	43.64 29.25	0.365	175	n.s.
	All small odontocetes	Shooting Not shooting	36.96 31.48	63.89 39.71	0.588	152	n.s.
	Lagenorhynchus spp.	Shooting Not shooting	62.16 34.44	61.54 41.51	0.028	92	n.s.
	White-beaked dolphin	Shooting Not shooting	64.00 36.67	54.55 28.57	0.072	52	n.s.
Slow swimming	All cetaceans combined	Shooting Not shooting	19.61 23.82	25.45 32.08	0.000	179	n.s.
	All small odontocetes	Shooting Not shooting	10.87 17.59	13.89 30.88	0.019	74	n.s.

Sample sizes for site surveys were again too small to permit examination of any interaction between seismic activity and presence of juveniles.

8.4.4 Volume of airguns

Where precise details of airgun parameters were provided in observers' reports or in notifications of surveys, data could be analysed to ascertain whether the degree of response to seismic activity varied in relation to the total volume of the airgun array. Sighting rates were compared during periods of shooting with arrays of differing total volume, controlling for bias due to location, season or weather conditions by using only those watches conducted during good weather conditions in months and areas of peak marine mammal occurrence. Sample sizes were only sufficient to compare sighting rates for all small odontocetes combined; during periods of shooting sighting rates were significantly higher when larger airgun volumes were used (Figure 36) ($\chi^2 = 47.069$, d.f. = 2, $p < 0.001$). (Periods when the airguns were silent were excluded from this analysis, but previous analysis (section 8.1) showed that sighting rates for all small odontocetes combined were highest during periods of airgun silence.)

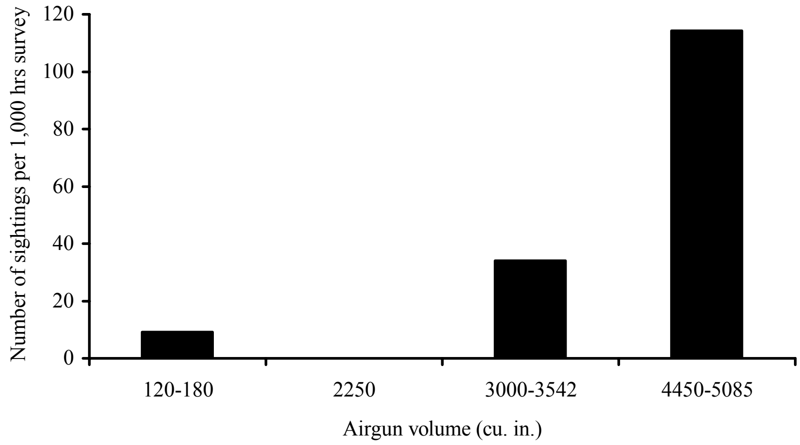


Figure 36. Sighting rate of all small odontocetes combined in relation to total array volume of airguns

The closest distance of approach of marine mammals to the airguns during periods of shooting was also compared for arrays of different total volume. All species/ species groups tested were further away from the airguns when the total array volume was largest (Figure 37). The extension of the median test established that the observed differences in distance were significant for minke whale, all small odontocetes combined and *Lagenorhynchus* spp. (Table 29).

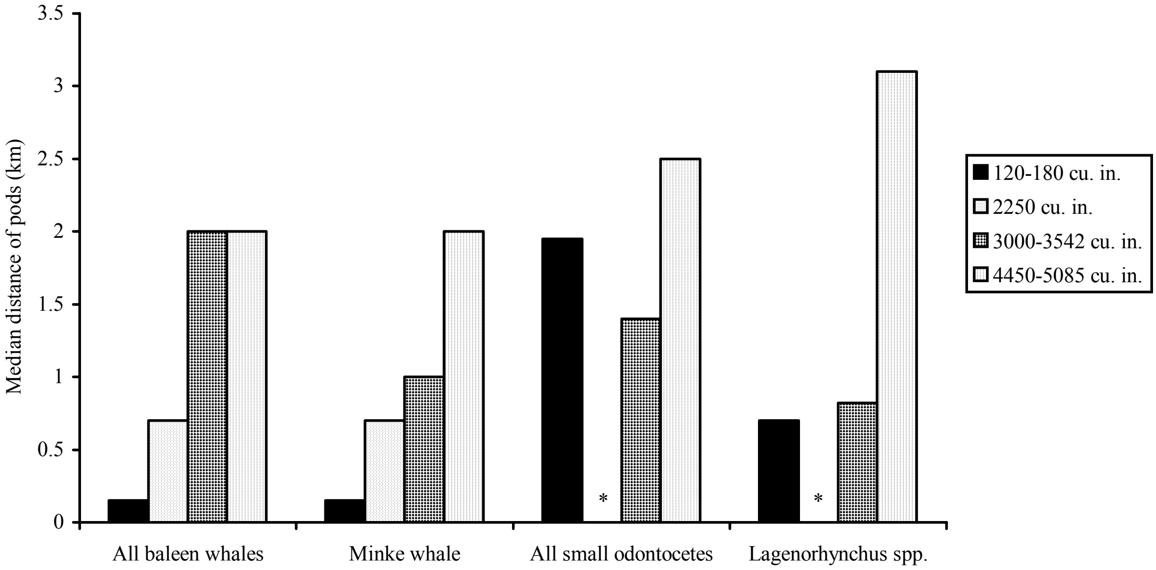


Figure 37. Median distance of marine mammals from the airguns during periods of shooting with different total array volumes (* = no sightings during shooting with array of this volume).

Table 29. Statistical significance of difference in closest distance of marine mammals from the airguns in relation to total array volume (extension of the median test; n = sample size; P = probability; n.s. = not significant; - = insufficient data).

Species	χ^2	***n***	***P***
All baleen whales combined	0.089	50	n.s.
Minke whale	5.466	39	<0.05
All small odontocetes combined	12.987	117	<0.001
Lagenorhynchus spp.	8.889	48	<0.01

The behaviours observed during periods of shooting at different total array volumes were also compared. Due to small sample sizes some categories of array volumes were combined. No significant differences in behaviour during periods of shooting at different total array volumes were found (Table 30).

Table 30. Behaviour of marine mammals in relation to total array volume (- = not encountered during shooting at that array volume; n = sample size; P = probability; n.s. = not significant).

Behaviour	*Species*	*% of encounters when behaviour was exhibited*			χ^2	*n*	*P*
		10-180 cu .in.	*2250-3542 cu. in.*	*4450-5085 cu. in.*			
Feeding	All small odontocetes	44.44	16.22	13.33	0.600	30	n.s.
	Lagenorhynchus spp.	42.86	17.78	20.59	0.003	18	n.s.
Breaching, jumping or somersaulting	All small odontocetes	22.22	25.23	36.67	1.887	52	n.s.
	Lagenorhynchus spp.	28.57	51.11	61.76	0.718	46	n.s.
	White-beaked dolphin	-	63.64	60.00	0.017	22	n.s.
Fast swimming	All small odontocetes	22.22	49.55	53.33	0.274	89	n.s.
	Lagenorhynchus spp.	28.57	64.44	50.00	0.342	48	n.s.
	White-beaked dolphin	-	45.45	48.00	0.010	17	n.s.
Slow swimming	Minke whale	50.00	25.00	31.58	0.098	14	n.s.
	All small odontocetes	0.00	12.61	6.67	1.000	18	n.s.
Surfacing infrequently	Minke whale	0.00	32.14	21.05	0.350	13	n.s.

8.5 Sightings during the soft-start

There were 53 sightings of marine mammals during the soft-start in 2001-02. Three of these occurred during site surveys, with the remainder occurring during surveys with large airgun arrays. 37 sightings were first detected during the soft-start, while 16 were seen initially when the airguns were silent, but were still present after the soft-start had commenced.

Of those animals that were present both prior to and during the soft-start, three pods showed a possible reaction to the commencement of the soft-start. A pod of killer whales that were 1.6 km away from the airguns when the soft-start commenced demonstrated avoidance by altering course and swimming rapidly away from the airguns; when full power was reached they were observed surfacing more often. A pod of *Lagenorhynchus* spp. moved away when the soft-start commenced but then re-approached whereupon some were observed spy-hopping, some leaping and one animal raised its tail flukes; these dolphins were at 400 m from the airguns when the soft-start commenced (shooting should have been delayed in order to comply with the guidelines). Another large mixed pod of common dolphins and *Lagenorhynchus* spp. altered course to avoid the vessel when the soft-start commenced; this pod was more than 500 m from the airguns when the soft-start commenced but had previously been swimming alongside the doors and had approached to a distance of 50 m from the airguns when they were silent. For the remaining 13 sightings that were present both prior to and during the soft-start there was no apparent reaction to the commencement of the soft-start (or observers did not differentiate between behaviours at different seismic activities).

Sightings occurring only during the soft-start were compared with those occurring only when the airguns were not firing or only when the airguns were firing at full power levels during surveys with large airgun arrays. As sample sizes for individual species were small, all cetaceans were combined. It was not possible to compare sighting rates, as no distinction was made between effort at full power and effort during the soft-start.

The median closest distance of approach of cetaceans to the airguns differed significantly according to the power level of the airguns (Kruskal-Wallis one-way analysis of variance; KW = 19.869, d.f. = 2, $p < 0.001$). The median distance during the soft-start was between that found during shooting at full power or during periods of silence (Figure 38; the influence of weather conditions on the ability to detect marine mammals at distance was controlled by using only sightings occurring during good weather conditions). Multiple comparisons showed that while there were significant differences between the distance of cetaceans when the airguns were not firing and their distance during shooting at full power levels, the distance of cetaceans during the soft-start did not differ significantly from either shooting at full power or not shooting.

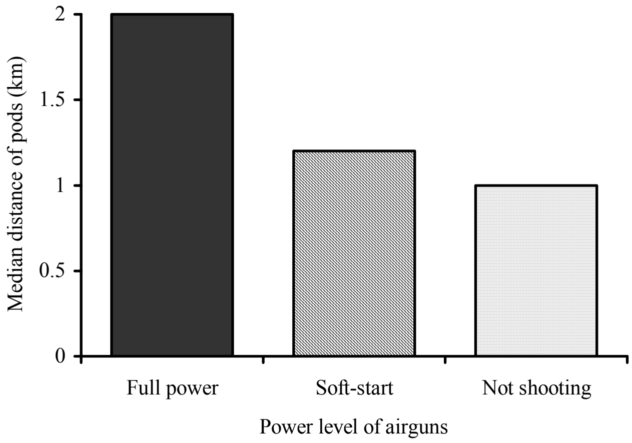


Figure 38. Median distance of cetaceans (all species combined) in relation to the power level of the airguns.

The median distance of cetaceans was greater at the commencement of the soft-start than in the early stages, but then increased until approximately two-thirds of the way through the soft-start. The distance from the airguns then decreased again towards the end (Figure 39). However, sample sizes were very small in each category, so this result should be treated with caution.

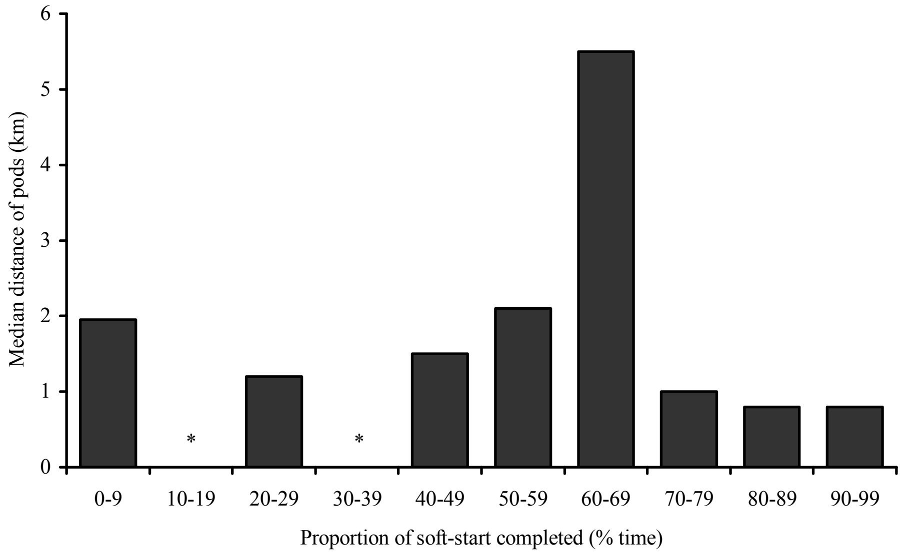


Figure 39. Median distance of cetaceans (all species combined) throughout the soft-start (* = no data).

Where sample size permitted, the behaviours exhibited by cetaceans were compared between shooting during the soft-start, shooting at full power and periods of silence. There was a significant difference in the proportion of pods swimming at speed, with more swimming fast when the airguns were shooting at full power than during the soft-start, and likewise more swimming fast during the soft-start than during periods of airgun silence (Table 31).

Table 31. Behaviour of cetaceans (all species combined) in relation to the power level of the airguns (n = sample size; P = probability; n.s. = not significant).

Behaviour	***% of encounters while shooting at full power when behaviour was exhibited***	***% of encounters during soft-start when behaviour was exhibited***	***% of encounters while not shooting when behaviour was exhibited***	χ^2	***n***	***P***
Breaching, jumping or somersaulting	27.78	34.38	25.03	1.556	306	n.s.
Fast swimming	35.38	31.25	25.66	7.984	336	<0.05
Slow swimming	19.01	6.25	21.90	3.998	242	n.s.

The direction of travel of cetaceans relative to the vessel differed significantly according to the power level of the airguns (Table 32). The proportion of animals heading towards the vessel during the soft-start was between that found during periods of shooting at full power and periods of silence. However, the proportion of animals heading away from the vessel was greatest during the soft-start.

Table 32. Direction of travel of cetaceans (all species combined) relative to the survey vessel in relation to the power level of the airguns (n = sample size; P = probability).

Power level of airguns	***Towards ship***	***Away from ship***	***Crossing path of ship***	***Parallel to ship in same direction***	***Parallel to ship in opposite direction***	***Milling or variable***	χ^2	***n***	***P***
Full power	7.72%	25.40%	28.62%	9.00%	26.05%	3.22%	37.840	1,093	<0.001
Soft-start	10.71%	32.14%	28.57%	14.29%	14.29%	0.00%			
Not firing	14.85%	14.85%	22.15%	13.79%	28.38%	5.97%			

9. 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 use of appropriate personnel as marine mammal observers; 3) the maintenance of an adequate watch for marine mammals prior to shooting commencing; 4) the delay in commencing shooting if marine mammals were close by; and 5) the use of a soft-start procedure. The use of acoustic monitoring, as recommended by the guidelines, was also considered. Since *The offshore petroleum activities (conservation of habitats) regulations 2001* came into force on 31st May 2001, anyone wishing to conduct a seismic survey on the UK continental shelf has to obtain consent from the DTI; application of the guidelines is routinely made a condition of consent for all seismic surveys (including high resolution site surveys) taking place on the UK continental shelf. Prior to this application of the guidelines was required under licence conditions in blocks licensed in the 16th and subsequent rounds of offshore licensing (13 reported surveys in 2001 were completed prior to 31st May in other UK blocks), although all companies had agreed through their trade associations (UKOOA, IAGC) to adopt the guidelines throughout UK waters. It is therefore assumed that all seismic surveys throughout 2001-02 should have been conducted in accordance with the guidelines, thus compliance with the guidelines was monitored for all surveys from which reports were received.

9.1 Notification and reporting of surveys

JNCC received notification of and/ or reports from 130 seismic surveys during 2001 and 83 during 2002 taking place in UK waters (excluding those surveys without airguns that were notified but not reported, and also excluding vertical seismic profiling for which consent is not required at present). There were many surveys for which reports were not received; however, surveys with large airgun arrays were reported more often than site surveys or similar surveys where the volume of airguns was low (Table 33). The level of notification of surveys was better than the level of reporting; in 2001 a number of surveys, particularly site surveys, were not notified, but in 2002 it appeared that notification was received for nearly all surveys.

Table 33. Notification and reporting of seismic surveys in UK waters

Notification and/ or report received	*2001*		*2002*	
	Site surveys	*Surveys with large airgun arrays*	*Site surveys*	*Surveys with large airgun arrays*
Notification and report	50%	69%	28%	63%
Notification only (no report)	37%	22%	68%	33%
Report only (no notification)	13%	8%	4%	3%

Although there were apparently many surveys for which reports were not received, some caution should be applied. Some surveys in 2001-02 where consent was applied for are known to have been postponed or cancelled, but it is also possible that some others for which no report was received did not go ahead; sometimes more than one survey was notified using the same ship with planned start dates and estimated durations that overlapped, making it unlikely that all these surveys would have been possible. Furthermore, some operators had multiple surveys of short duration (often just one day) using the same ship either concurrently or consecutively. Such surveys were not always reported separately, and as the reference numbers provided were rarely used on reports it was often difficult to establish exactly which of these surveys were included in a report, so it is possible that some notified surveys recorded as unreported were in fact included in reports of other notified surveys.

It is not possible to make a direct comparison of the level of notification and reporting in 2001-02 with that of previous years, due to the introduction of the consent process in 2001. Prior to 2001 only surveys in blocks subject to the guidelines (i.e. in blocks licensed in the 16th and subsequent rounds of offshore licensing) were considered when assessing the level of notification and reporting. As all surveys on the UK continental shelf are now required to follow the guidelines as a condition of consent, the figures in Table 33 for 2001-02 include all UK surveys. DTI forwards applications for consent for seismic surveys to JNCC and other organisations for consultation; as a result of this it is likely that JNCC receives a greater level of notification of surveys than in the years prior to 2001. Indeed, in 2002 there were only three surveys that were known to have taken place for which no notification was received. If the level of notification of surveys in previous years was lower, this may have falsely inflated the proportion of notified surveys for which a report was received in these years, preventing a true comparison of the level of reporting.

In addition to reports from UK waters, JNCC received some reports from surveys that took place in adjacent waters; there were reports from at least ten such surveys in 2001 (in Irish, Norwegian and French waters) and five in 2002 (in Norwegian and Dutch waters).

9.2 The use of appropriate personnel

The proportion of surveys where dedicated marine mammal observers were used had increased only slightly to around 24% of known surveys in UK waters in 2002 (including those where notification but no report was received, except where no airguns were used) (Figure 40). However, figures from previous years may be falsely inflated due to less efficient notification of surveys prior to 2001, and this effect would be exacerbated if there were unknown cancellations of notified surveys during 2001-02. The use of dedicated marine mammal observers was much more common on surveys with large airgun arrays than on site surveys in 2001-02; most reported surveys with large airgun arrays used dedicated marine mammal observers (82% in 2001, 90% in 2002) whereas few reported site surveys did so (12% in 2001, 15% in 2002) (it was not possible to calculate a proportion of all known surveys of different types using dedicated marine mammal observers as some unreported surveys did not include sufficient detail in the notification of the type of survey or source used).

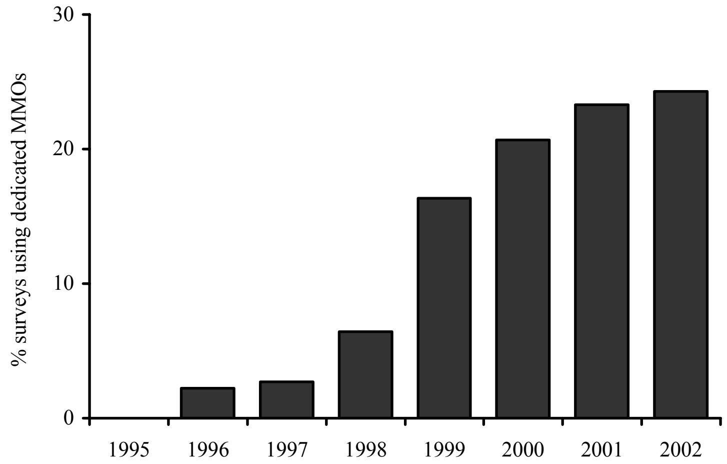


Figure 40. The proportion of seismic surveys in UK waters for which dedicated marine mammal observers were used

The 1998 version of the guidelines, operative throughout 2001-02, states 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. In 2001 there were 30 surveys in areas of importance for marine mammals but only nine used dedicated marine mammal observers. In 2002 there were 16 surveys in areas of importance for marine mammals, of which 9.5 used dedicated marine mammal observers. For the majority of those surveys in areas of importance for marine mammals that did not use dedicated marine mammal observers there were no reports, so it is assumed that no observations were undertaken. Some surveys used members of ships' crews to undertake the additional role of marine mammal observer, while a minority used fishery liaison officers in a dual role.

JNCC sometimes made specific requests for marine mammal observers as part of the consent process. These requests could include the number of observers and whether they were to be dedicated to the task of marine mammal observations; sometimes it was also specified that observers should be trained. In 2001-02 there were 46 surveys (17 in 2001, 29 in 2002) where specific requests for personnel to be used were made; these were fully complied with more often in 2002 than in 2001 (Table 34). Where the requirements were not met the most common failing was that no observers at all were used (assumed from the absence of reports). Other cases where requests were often not met included surveys where a dedicated observer was not present (fishery liaison officers performing a dual role instead) and where one observer rather than two were used.

Table 34. Compliance with specific requests for type of observer (- = specific requests of this type not made; some surveys where requirements were not met are included in more than one category).

Year	*Observer met requirements*	*Observer not dedicated when requested*	*Only one observer used when two requested*	*Observer not trained when requested*	*Observer not assisted by fishery liaison officer when requested*	*No observer used (one or two requested)*
2001	7 (41%)	3 (18%)	2 (12%)	1 (6%)	2 (12%)	3 (18%)
2002	17 (59%)	1 (3%)	1 (3%)	-	-	10 (34%)

A specific request that observers should be trained is only occasionally made during the consent process, but the guidelines state that as a minimum, observers should have attended an appropriate training course. 31% of observers used during 2001 had undergone training; these observers worked on 50% of surveys from which reports were received. In 2002 90% of observers used had received training, but as some untrained observers frequently worked on a number of surveys the proportion of reported surveys with trained observers was only 70%. There is a small minority of individuals repeatedly working as marine mammal observers who have not attended an appropriate training course but who nevertheless imply in their reports to clients that they are trained – these observers sometimes conducted inadequate pre-shooting searches, were present on surveys where shooting continued between lines (without consultation with JNCC), and were involved in several delay situations where incorrect procedures were followed (although these instances occurred in Irish waters the survey report states that the client intended to follow the guidelines).

9.3 The use of acoustic monitoring

Acoustic monitoring is encouraged in the guidelines, and JNCC is keen to see this technique being used to complement visual observations particularly in areas where deep-diving mammals such as sperm whales and beaked whales occur. No surveys during 2001 used acoustic monitoring, and there were no specific requests for acoustic monitoring to be conducted on any surveys. In 2002 there was an agreement between JNCC and the operator of one survey for acoustic monitoring to be carried out, and four other surveys also undertook acoustic monitoring – on some surveys acoustic detections outnumbered visual detections, while on others visual detections were more frequent.

9.4 Watches for marine mammals

The guidelines require that a watch for marine mammals is carried out for at least 30 minutes prior to any use of the airguns. Where 'Record of Operations' forms were completed correctly the duration of the pre-shooting search could be monitored. Throughout the two years the airguns were used on 5,388 recorded occasions in UK waters, of which 3,770 occurred during daylight hours when visual monitoring prior to shooting was possible. The proportion of occasions when an adequate pre-shooting search was conducted was higher in 2002 than 2001 (Table 35). Inadequate pre-shooting searches occurred most often during site surveys in 2001, when searches of less than ten minutes duration were commonplace.

Table 35. Duration of pre-shooting searches for marine mammals in UK waters

Duration of search	*2001*		*2002*	
	Not site surveys	*Site surveys*	*Not site surveys*	*Site surveys*
No search	55 (3.90%)	37 (4.02%)	15 (1.35%)	6 (1.85%)
Search stopped before firing commenced	6 (0.43%)	8 (0.87%)	6 (0.54%)	0 (0.00%)
1-9 minutes	13 (0.92%)	150 (16.30%)	2 (0.18%)	1 (0.31%)
10-19 minutes	26 (1.84%)	65 (7.07%)	7 (0.63%)	6 (1.85%)
20-29 minutes	46 (3.26%)	12 (1.30%)	15 (1.35%)	3 (0.92%)
30 minutes or more	1,265 (89.65%)	648 (70.43%)	1,069 (95.96%)	309 (95.08%)

Short or prematurely terminated searches were most common when fishery liaison officers were fulfilling the role of marine mammal observer, particularly in 2001 (Table 36). The standard of pre-shooting searches by fishery liaison officers had improved considerably in 2002. Members of ships' crews had the highest proportion of pre-shooting searches of adequate duration, reflecting the fact that a ship's officer is always present on the bridge of ships. However, it is not only the duration of the pre-shooting search that is important, but also the skill of the observer in detecting marine mammals. Although members of ships' crews were almost always available during the pre-shooting search period, their detection rates were very low (section 10). Dedicated marine mammal observers maintained a high standard of pre-shooting searches in both years, and also had the highest detection rate of all types of observer (section 10) – it is worth noting that all instances where animals were detected requiring a delay in shooting occurred when dedicated marine mammal observers were being used, reflecting the higher quality of pre-shooting searches by such personnel. Trained observers had a higher standard of pre-shooting searches than untrained observers in 2001, but there was little difference between the pre-shooting searches of trained and untrained observers in 2002 (members of ships' crews were excluded from the comparison of trained and untrained observers as these personnel are usually anonymous so it is not known whether they are trained or untrained individuals, and they are usually constantly on the ship's bridge, resulting in an adequate duration of watch regardless of training). Most detections of animals requiring a delay in shooting occurred when trained observers were used.

Table 36. Proportion of pre-shooting searches for marine mammals of acceptable duration (30 minutes or more) in relation to type of observer (UK waters only)

Type of observer	*2001*		*2002*	
	Proportion of adequate pre-shooting searches	*n*	*Proportion of adequate pre-shooting searches*	*n*
Dedicated MMO	90.15%	1,584	96.07%	1,195
Fishery liaison officer	42.63%	448	92.96%	199
Ship's crew	99.32%	296	100.00%	45
Trained	80.43%	1,681	95.03%	1,067
Untrained	73.80%	332	97.55%	327

9.5 Delays in shooting

The guidelines require that if marine mammals are detected within 500 m of the airguns when they are due to commence firing, then shooting should be delayed until at least 20 minutes after the animals are last seen. On the 'Record of Operations' form observers recorded whether marine mammals were present before each use of the airguns and what action was taken if necessary. As an additional check, for all instances where marine mammals were recorded on the 'Record of Sighting' form as being within 500 m of the airguns when they were not firing, the 'Record of Operations' form was examined to ascertain when the airguns next began firing. In each year one delay situation was found using this additional check that had apparently escaped the attention of the marine mammal observers.

The proportion of occasions when a delay in shooting was required in UK waters was low. In 2001 delays were required for 12 (0.36%) of 3,315 recorded occasions when airguns were used, while in 2002 delays were required for 12 (0.58%) of 2,073 recorded occasions when airguns were used. In each delay situation, the time between the last sighting of the animals and firing commencing should have been at least 20 minutes, and once firing commenced the subsequent soft-start should have been at least 20 minutes long. Correct procedures were followed more often in 2002 than in 2001 (Table 37). There were three further occasions (one in 2001 and two in 2002) when correct procedures may have been followed, but the duration of the soft-start was not recorded. In 2001 there were five occasions when the delay in shooting was less than the required 20 minutes, but two of these were due to unfortunate circumstances; on one occasion the soft-start began as the marine mammal observer was moving from the observation platform to the bridge to inform the crew of the presence of marine mammals (the airguns were shut down after a few shots had been fired but the subsequent soft-start was too short), while on the other occasion when the marine mammal observer enquired when the soft-start was due to begin the wrong information was given. There was only one occasion in 2002 when the delay in shooting was too short. All occasions where the subsequent soft-start was too short in 2001-02 occurred during site surveys.

Table 37. Action taken in delay situations in UK waters

Year	*Number of delay situations*	*Correct procedures followed*	*Delay too short, soft-start adequate*	*Delay adequate, soft-start too short*	*Both delay and soft-start too short*
2001	12	4 (33.33%)	3 (25.00%)	2 (16.67%)	2 (16.67%)
2002	12	8 (66.67%)	0 (0.00%)	1 (8.33%)	1 (8.33%)

There were four additional occasions in Irish waters (all occurring on one survey) when a delay would have been required if the guidelines were being followed. Surveys in Irish waters are not subject to the guidelines, but the report states that the intention was to comply with the guidelines on this survey; however, in all four cases the delay was too short and in two of the cases the subsequent soft-start was also too short. In one case shooting commenced as the marine mammal observer was informing the client of the presence of marine mammals, while in another case shooting commenced due to "a breakdown in communications" (after which procedures on board were changed).

In all delay situations occurring in 2001-02 dedicated marine mammal observers (mostly trained) were used, so a comparison of compliance with delay procedures in relation to type of observer was not possible – however, this does reflect the higher quality of pre-shooting searches by dedicated and trained marine mammal observers.

9.6 Soft-starts

The guidelines state that 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. The time of commencement of the soft-start and the time when full power was reached was recorded on the 'Record of Operations' form. Occasions when the airguns never reached full power (e.g. if shooting was aborted during the soft-start) were disregarded in the analysis. Soft-starts during test firing of the airguns were analysed separately, as the soft-start could be unusually protracted at these times.

The duration of soft-starts for site surveys was analysed separately from surveys with large airgun arrays. The 1998 version of the guidelines recognised that on some site surveys the seismic sources always remain at low power levels, but guidance issued by JNCC in March 2000 (*Guidance note on the implementation of the guidelines for minimising acoustic disturbance to marine mammals from seismic surveys*) stated that site surveys should use a full soft-start unless a prior waiver has been agreed with JNCC. There was one site survey in 2001 when JNCC permitted shorter soft-starts for part of the survey; these soft-starts were excluded from the analysis.

The majority of soft-starts on surveys with large arrays of airguns met the required minimum of 20 minutes duration in 2001-02, with a slight increase in standards in 2002 (Table 38). However, very few site surveys had soft-starts of adequate duration, and a high proportion of these surveys had no soft-start at all, especially in 2001. For a number of site surveys the report stated that a full soft-start was deemed impractical and it was decided to have either no soft-start or a short soft-start, but in all except one survey there was no record of any consultation with JNCC. On the one site survey where JNCC agreed that soft-starts could be shorter than 20 minutes full power was permitted after just ten minutes, but at a longer shot point interval that would then be decreased over a further ten minutes until the desired interval was reached; of 11 uses of the airguns on this survey there were two occasions when full power was reached in less than the permitted ten minutes. Some reports cited short line turns as a reason for shortening or omitting the soft-start, but in all cases 'Record of Operations' forms showed that there was sufficient time for a full soft-start on most lines.

Table 38. Soft-starts used during seismic surveys in UK waters

Parameter	***2001***		***2002***	
	Surveys with large airgun arrays	***Site surveys***	***Surveys with large airgun arrays***	***Site surveys***
Minimum duration (minutes)	0	0	0	0
Maximum duration (minutes)	90	33	270	26
Mean duration (minutes)	22	2	24	7
Sample size	1,818	1,167	1,468	395
Number of occasions with:				
no soft-start	4 (0.22%)	929 (79.61%)	2 (0.13%)	155 (39.24%)
soft-start < 20 minutes	176 (9.68%)	1,097 (94.00%)	81 (5.45%)	374 (94.68%)
soft-start > 40 minutes	19 (1.05%)	0 (0.00%)	42 (2.83%)	0 (0.00%)
soft-start ≥ 20 minutes	1,642 (90.32%)	70 (6.00%)	1,405 (94.55%)	21 (5.32%)

The guidelines have recently (April 2004) been revised, and one of the changes is that the soft-start should have a maximum duration of 40 minutes to minimise the overall acoustic input to the marine environment. The proportion of soft-starts that were longer than 40 minutes during 2001-02 was small (Table 38). However, during testing of the airguns firing at low power was often protracted; 24% of tests during the two year period included firing at low power for more than 40 minutes, with a maximum duration of 285 minutes.

On surveys with large airgun arrays the standard of soft-starts in 2001 was higher when dedicated marine mammal observers were used than fishery liaison officers, but the standard of soft-starts when fishery liaison officers were responsible for observations improved in 2002 (Table 39). Sample sizes for fishery liaison officers were relatively low, as these personnel were not often used as marine mammal observers on surveys with large airgun arrays. In 2001 the standard of soft-starts on surveys with large airgun arrays was better when trained observers were used, but in 2002 there was little difference in the standards between trained and untrained observers. There were no cases when members of ships' crews were responsible for marine mammal observations on surveys with large airgun arrays. However, members of ships' crews were often used on site surveys, and when this was the case very few soft-starts were of adequate duration (Table 40). There were also few soft-starts of adequate duration when fishery liaison officers were used on site surveys. The highest standard of soft-starts on site surveys occurred when dedicated marine mammal observers were used, but even then few soft-starts were of adequate duration; however, site surveys with dedicated marine mammal observers on board were more likely at least to have a short soft-start rather than none at all, which was common when fishery liaison officers or members of ships' crews were used. Soft-starts on site surveys were of a higher standard when observers were trained. In 2002 soft-starts of an acceptable standard on site surveys occurred only when trained dedicated marine mammal observers were used, but even then only rarely.

Table 39. Proportion of soft-starts of acceptable duration (20 minutes or more) on surveys with large airgun arrays in relation to type of observer (UK waters only)

Type of observer	*2001*		*2002*	
	Proportion of adequate soft-starts	*n*	*Proportion of adequate soft-starts*	*n*
Dedicated MMO	90.56%	1,800	93.98%	1,328
Fishery liaison officer	73.33%	15	99.37%	158
Trained	92.11%	1,330	94.58%	1,088
Untrained	85.45%	488	94.47%	398

Table 40. Proportion of soft-starts of acceptable duration (20 minutes or more) on site surveys in relation to type of observer (UK waters only)

Type of observer	*2001*		*2002*	
	Proportion of adequate soft-starts	*n*	*Proportion of adequate soft-starts*	*n*
Dedicated MMO	13.14%	137	9.38%	224
Fishery liaison officer	9.01%	566	0.00%	95
Ship's crew	0.22%	464	0.00%	76
Trained	9.52%	672	6.58%	319
Untrained	0.00%	434	0.00%	76

There were 42 occasions when full power was reached during testing of the airguns (32 in 2001, ten in 2002). On 17 of these occasions in 2001 the soft-start was less than 20 minutes long. There were additionally 74 occasions when the airguns were tested without full power being reached (50 in 2001, 24 in 2002).

9.7 Other issues

In March 2000 JNCC produced guidance on the application of the guidelines in certain situations commonly encountered on seismic surveys. One issue addressed was that of continuous shooting between lines. It was stated that continual shooting between lines was not encouraged and that shooting should stop at the end of each line. The recent (April 2004) revision of the guidelines permits continual shooting between lines where the line change time is less than that required for a soft-start, but during 2001-02 this practice was not permissible. Nevertheless there were some surveys in 2001-02 where continual shooting was practised. In 2001 there were at least seven site surveys where shooting continued between lines, all in cases where fishery liaison officers or members of ships' crews were responsible for marine mammal observations. In no cases was there any consultation with JNCC. Continual shooting during short line turns was also practised on seven (of nine) 4C/ OBC surveys taking place in 2001-02, reducing the volume at the end of the line and then building up to full power again by the start of the next line. In all these cases dedicated marine mammal observers were used, but in only one case was JNCC consulted and permission gained for doing this. There was one further case where dedicated marine mammal observers on an OBC survey consulted JNCC regarding short line turns, but the report contained no record of what was agreed or what practice was adopted.

In addition to continual shooting during short line turns on some site or 4C/ OBC surveys, there were also two 4C/ OBC surveys in 2002 where the airguns continued to fire at low power levels during periods of standby as the seismic crew were reluctant to shut the airguns down in case they were suddenly ready to resume seismic data acquisition. On one occasion the airguns were firing on standby for 293 minutes. In both surveys where firing continued during periods of standby dedicated marine mammal observers were used, but there was no consultation with JNCC regarding this practice. The recent (April 2004) revision of the guidelines states that protracted shooting that is not part of a survey line is discouraged.

One further problem that arose on two 4C/ OBC surveys in 2001 was that the observer was on board the receiving vessel rather than the source vessel. As the receiving vessel and source vessel can be several kilometres apart at times on 4C/ OBC surveys, a visual check of the area within 500 m of the airguns can only be effectively undertaken from the source vessel. For this reason it has been recommended in the past that marine mammal observers on dual/ multi-vessel surveys should be placed on the source vessel (Stone 2001, 2003a), and this is included in the recent (April 2004) revision of the guidelines. In one instance that occurred in 2001, it had been intended to transfer the dedicated marine mammal observer from the receiving vessel to the source vessel by small boat at the start of the survey, but poor weather conditions prevented the transfer taking place for several days. During this period every effort was made to ensure an effective search was made within a 500 m radius of the airguns prior to shooting commencing – the source vessel circled around the receiving vessel at a close distance for 30 minutes prior to commencing each soft-start, enabling the marine mammal observer to conduct a satisfactory search from the receiving vessel. During the other survey where the observer was stationed on the receiving vessel, observations were being carried out by the fishery liaison officer, who remained on the receiving vessel for the entire survey; there was no record of any procedures being adopted to ensure an effective pre-shooting search.

Undershooting also involves two vessels, with a second vessel usually becoming the source vessel for the duration of the undershoot. This requires that in order to enable an effective pre-shooting search marine mammal observers are either stationed on both vessels or change vessels for a period. During 2001-02 undershooting took place on 16 surveys; on ten of these there was no observer on board the source vessel during the period of the undershoot. During 2001 the only occasions when marine mammal observers were stationed on the undershoot vessel involved transferring observers; in one case there was only one observer who transferred to the undershoot vessel, while in the other case there were two observers, one of whom transferred while the other remained on the main vessel in case poor weather prevented transfer back after the undershoot was completed. In this latter case, problems setting up the equipment for the undershoot resulted in several days where lines continued to be shot by the main vessel, while the undershoot vessel fired test shots during line turns; in these circumstances it proved beneficial to have a marine mammal observer on each vessel as each was shooting in turn. For four surveys in 2002 separate marine mammal observer(s) arrived with the undershoot vessel, enabling the original marine mammal observer(s) to remain on the main vessel.

Time-sharing is an area where there is sometimes pressure to reduce or omit the soft-start. The guidance note issued in 2000 stated that a full soft-start of minimum 20 minutes duration should be carried out when time-sharing. It is not known how many surveys were involved in time-sharing in 2001-02, but there was one survey in 2001 where the marine mammal observer wrongly believed that the soft-start could be reduced when time-sharing.

9.8 Comparison with compliance in previous years

The level of compliance with the guidelines was assessed for each year since 1998 (when the 'Record of Operations' form was introduced to allow monitoring of compliance). Standards of pre-shooting searches were higher in 2002 than in all previous years, and there was also a high standard of compliance with the requirements for the soft-start on surveys with large airgun arrays in 2002 (Table 41). However, standards of soft-starts on site surveys had declined from a peak in 2000, when JNCC issued guidance stating that a soft-start should be followed for all site surveys unless prior exemption had been granted by JNCC. The proportion of delay situations where correct procedures were followed also peaked in 2000; in 2001 there was a marked drop in the number of occasions when correct procedures were followed, and although standards improved again in 2002 they did not reach the previous level attained in 2000.

Table 41. Compliance with the *Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys* in UK waters, 1998-2002 (information not available prior to 1998).

Requirement	*1998*	*1999*	*2000*	*2001*	*2002*
Pre-shooting searches of adequate duration	86%	85%	79%	82%	96%
Soft-starts of adequate duration (not site surveys)	87%	87%	95%	90%	95%
Soft-starts of adequate duration (site surveys)	3%	3%	37%	6%	5%
Delays in shooting when necessary	20%	57%	86%	33%	67%

10. Quality of observations

'Location and Effort' forms should have been completed for all surveys. The standard of 'Location and Effort' forms had increased in 2001-02 from previous years (Table 42). Where errors were still made the most frequent was that the duration of shooting during the watch exceeded the duration of the watch. Errors on this form were mostly made by fishery liaison officers. There was only a small proportion of surveys where 'Location and Effort' forms were missing, these being mostly when untrained observers were used, usually members of ships' crews. 'Record of Operations' forms should have been completed for all surveys where airguns were used. The standard of the 'Record of Operations' form declined in 2001 from previous years, but then in 2002 returned to a level approaching that of earlier years. Nearly all incorrect 'Record of Operations' forms were from observers who were untrained or trained prior to the introduction of this form, and nearly all were either fishery liaison officers or members of ships' crews. Where 'Record of Operations' forms were missing it was almost always untrained members of ships' crews that were responsible for marine mammal observations. Both 'Location and Effort' forms and 'Record of Operations' forms were missing or incorrect most often on site surveys. Most 'Record of Sighting' forms were of an acceptable standard for entry into the database, although there was considerable variation in the quality and level of detail included on the form. The proportion of sightings where the species identification had to be downgraded due to a description that was insufficient to confirm identification had increased from 2000 to be similar to levels in 1998 and 1999. However, as in 2000, there were few 'Record of Sighting' forms with no description and very few definitely wrong identifications.

Table 42. Standard of recording forms on surveys from which reports were received (* = information not available).

	1996	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*
'Location and Effort' form completed correctly	60%	72%	78%	53%	69%	88%	86%
'Record of Operations' form completed correctly	n/a	n/a	81%	82%	84%	65%	79%
Downgraded sightings on 'Record of Sighting' form	*	35%	25%	23%	13%	20%	21%
No description on 'Record of Sighting' form	*	12%	3%	10%	2%	2%	3%
Identification wrong	*	5%	2%	<1%	<1%	<1%	0%

The type of observer had a number of effects on the quality of observations (Table 43). Dedicated marine mammal observers were generally better than other types of observer at completing the recording forms correctly, had better identification skills (more identified to species level and fewer as broad identification categories such as "whale", "large whale", "dolphin" etc.) and described a wider range of behaviours. They were also better able to detect animals at distance and, of particular importance, had much higher detection rates of marine mammals than other types of observer (sighting rates were compared using only periods of good weather in months and areas of peak marine mammal occurrence). The ability to detect marine mammals efficiently is of crucial importance to the effective operation of the guidelines.

Table 43. Information supplied in relation to type of observer, and ability of observer

	2001			2002		
	Dedicated marine mammal observer	*Fishery liaison officer*	*Ship's crew*	*Dedicated marine mammal observer*	*Fishery liaison officer*	*Ship's crew*
All recording forms completed correctly	80.3%	55.6%	44.8%	87.6%	80.0%	30.8%
'Location and Effort' form completed correctly	91.8%	85.2%	86.2%	92.6%	100.0%	46.2%
'Record of Operations' form completed correctly	93.6%	50.0%	40.9%	92.6%	77.8%	0.0%
Mean sighting rate per 1,000 hours survey	113.8	42.4	4.8	63.9	11.8	0.0
Distance of sighting:						
Median	1,800 m	400 m	1,000 m	1,000 m	1,225 m	550 m
Mean maximum	3,900 m	2,250 m	1,057 m	2,445 m	1,667 m	890 m
Species identification:						
Proportion of sightings downgraded	19.4%	26.8%	20.0%	18.5%	45.5%	50.0%
Proportion of sightings wrong	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%
Proportion of records with no description	0.9%	0.0%	10.8%	1.1%	0.0%	25.0%
Identified to species level	62.7%	57.1%	40.0%	65.6%	45.5%	25.0%
Identified as one of a narrow group of similar species	13.7%	17.9%	9.2%	4.5%	9.1%	3.6%
Identified as one of a broad group of species	23.6%	25.0%	50.8%	29.9%	45.5%	71.4%
Behaviour:						
Mean range of behaviours used per observer	11.2	3.2	3.0	9.2	4.6	1.9
Mean number of behaviours recorded per sighting	1.8	1.3	1.3	1.9	1.6	1.0

Training also had an effect on the quality of observations. Trained observers were usually better at completing the recording forms than untrained observers, and generally had better identification skills and described a slightly greater range of behaviours (Table 44).

Table 44. Information supplied in relation to training of observer

	2001		2002	
	Trained	*Untrained*	*Trained*	*Untrained*
All recording forms completed correctly	65.9%	56.5%	84.4%	60.0%
'Location and Effort' form completed correctly	86.4%	87.0%	94.2%	75.0%
'Record of Operations' form completed correctly	68.7%	64.9%	87.8%	50.0%
Species identification:				
Proportion of sightings downgraded	12.9%	26.2%	20.1%	22.8%
Proportion of sightings wrong	0.3%	0.3%	0.0%	0.0%
Proportion of records with no description	1.4%	0.3%	0.9%	3.7%
Identified to species level	71.0%	52.9%	68.2%	53.7%
Identified as one of a narrow group of similar species	12.1%	15.8%	5.0%	4.3%
Identified as one of a broad group of species	17.0%	31.4%	26.7%	42.0%
Behaviour:				
Mean range of behaviours used per observer	7.2	5.3	7.4	4.4
Mean number of behaviours recorded per sighting	1.7	1.8	1.9	1.9

Very few reports included a reference number, with only 6% of reports in each year using the correct reference number. A smaller proportion included the wrong reference number, but on most reports the reference number was missing.

There were a number of errors in the printing of reports. The recording forms are usually included in the appendices of reports, but in a small number of cases some pages of the appendices were missing, resulting in missing data. There were also some instances where the information that had been typed into boxes on the forms did not fit on the page when printed. On the 'Record of Sighting' forms, where observers are asked to draw an arrow representing the direction of travel of animals relative to the ship, on some occasions this arrow appeared elsewhere on the form and thus this information was unable to be correctly interpreted.

11. Discussion

11.1 Distribution of marine mammals

Maps of marine mammal distribution as observed from seismic surveys should be interpreted with a degree of caution, as the distribution presented will to a large extent reflect the location and timing of the surveys. Nevertheless, some patterns of occurrence were apparent in 2001-02, that in general concurred with previous knowledge of marine mammal distribution.

Many of the large whales, including fin whale, blue whale, humpback whale and sperm whale were found exclusively in deep waters to the north of Scotland, as was Sowerby's beaked whale. A preference for these deep waters by these species has been found previously (Clark and Charif 1998; Evans 1990; JNCC 1995; NERC 1998; Pollock *et al.* 2000; Reid *et al.* 2003; Skov *et al.* 1995). There were only three sightings of sei whales from seismic survey vessels in 2001-02, but of these two occurred to the east of Shetland, although most records of sei whales around the UK have been from deeper waters between the Northern Isles and the Faroes (Reid *et al.* 2003).

Pilot whales also occurred in deep waters, both to the north of Scotland and to the west of Ireland, concurring with their known distribution (Bloor *et al.* 1996; JNCC 1995; NERC 1998; Pollock *et al.* 1997, 2000; Reid *et al.* 2003; Skov *et al.* 1995). There was an additional cluster of sightings that occurred in the northern North Sea; Reid *et al.* (2003) noted some sightings along the western edge of the Rinne at depths of around 200 m, but most sightings in the northern North Sea from seismic survey vessels in 2001-02 were further west than the Rinne, in shallower waters of depths of 100-150 m.

White-beaked dolphins were seen predominantly in the northern North Sea, where concentrations are known to occur (Evans 1992; NERC 1998; Northridge *et al.* 1995; Reid *et al.* 2003). White-sided dolphins, however, whilst also relatively common in the northern North Sea, were also abundant in deep waters to the north of Scotland and were also seen to the west of Ireland, following known patterns of distribution (Evans 1990, 1992; JNCC 1995; NERC 1998; Pollock *et al.* 1997, 2000; Reid *et al.* 2003; Skov *et al.* 1995).

Killer whales were more common in northern areas; Evans (1992) notes that this species is most abundant in colder waters. Both common dolphins and striped dolphins are more prevalent in south-west waters (NERC 1998; Reid *et al.* 2003), but due to lower survey effort in these areas this was not apparent from sightings during seismic surveys in 2001-02. Reid *et al.* (2003) note that common dolphins mostly occur south of 60°N; while common dolphins were seen during seismic surveys in the St. George's Channel, some were also seen further north as far as 61°N.

Risso's dolphins are mainly found off western Scotland, south-west Ireland and in the southern Irish Sea (Reid *et al.* 2003). Survey effort was low to the west of Scotland, but some Risso's dolphins were seen to the north of Scotland and to the west of Ireland, as well as some in the Irish Sea. Reid *et al.* (2003) found that there were a few Risso's dolphins recorded immediately over the continental shelf edge, but none in deeper waters; sightings from seismic survey vessels in 2001-02 found this species in waters up to 620 m depth.

Bottlenose dolphins have been mostly recorded from near-shore waters; further offshore around the UK the main concentrations occur along the continental shelf edge to the south-west of Ireland, although some other offshore occurrences have been recorded (Reid *et al.* 2003). Seismic survey effort in near-shore waters was limited, although some bottlenose dolphins were seen in the St. George's Channel; others occurred further offshore in the northern North Sea.

Minke whales were more widespread around the UK. Concentrations close to land have been noted for this species (Northridge *et al.* 1995; Reid *et al.* 2003), but as seismic surveys mostly took place further from land this trend was not apparent in data from seismic survey vessels. Sightings of harbour porpoises were also fairly widespread, again reflecting their known distribution (JNCC 1995; NERC 1998; Northridge *et al.* 1995; Reid *et al.* 2003). Sightings of harbour porpoises from seismic survey vessels were more common in 2001-02 than in previous years, probably reflecting the greater proportion of reports that came from dedicated marine mammal observers, whose detection ability is greater than that of other types of personnel. However, harbour porpoise numbers were still low relative to other surveys.

There were relatively few sightings of seals during seismic surveys. Common seals were seen off the Moray Firth, where there are breeding sites for this species. Grey seals were also seen off the Moray Firth where they forage and haul-out in the summer, but they also occurred further offshore than common seals; long distance trips to the Faroes have been recorded for grey seals (McConnell *et al.* 1999) and Pollock *et al.* (2000) also found this species further offshore than common seals. Previous studies have suggested that grey seals make longer foraging trips from their haul-out sites than common seals (Thompson *et al.* 1996), but recent work has shown that common seals travel further offshore than was previously known (Hammond, pers. comm.).

11.2 The effects of seismic activity on marine mammals

Cetaceans are considered to be vulnerable to acoustic disturbance as hearing provides their primary source of information about their environment, playing a role in feeding, breeding, navigation and communication. Although audiograms are only available for a few species, it is usually assumed that cetaceans have good hearing at the frequencies at which they communicate. Seismic surveys usually utilise frequencies up to around 220 Hz; the species likely to have good hearing in this frequency range include the baleen whales, while small odontocetes are likely to hear at much higher frequencies. Therefore it has often been assumed that baleen whales would be more vulnerable to disturbance from seismic surveys than odontocetes (e.g. Lawson *et al.* 2000), but both the present and previous results (Goold 1996; Stone 1997, 1998, 2000, 2001, 2003a,b) from UK waters indicate that there are some effects of seismic activity on small odontocetes as well as on baleen whales.

Baleen whales have been recorded in a number of studies as showing avoidance of seismic activity (e.g. Ljungblad *et al.* 1988; McCauley *et al.* 1998; Richardson and Greene 1993; Richardson *et al.* 1986). In UK waters baleen whales have at times been shown to remain at greater distances from the airguns and/ or orient away from the vessel during periods of shooting (Stone 1998, 2000, 2001, 2003a,b). Although these effects of seismic activity have been observed in the past, baleen whales in UK waters have never before shown a reduction in sighting rates at times when airguns were firing. However, sighting rates were reduced during periods of shooting in 2001-02 for minke whales and all baleen whales combined, although no other effects were observed for baleen whales in these years.

Similarly, sperm whales in UK waters have never in the past shown a reduction in sighting rate in response to seismic activity, or indeed any other reaction (Stone 1998, 2000, 2001, 2003a,b). In 2001-02 the first instance of an effect of seismic activity on sperm whales in UK waters was noticed, with a reduction in sighting rates during periods of shooting. Elsewhere, reactions of sperm whales to seismic activity have been noticed previously; in the Gulf of Mexico effects on abundance, communication and orientation of sperm whales have been recorded (Mate *et al.* 1994; Rankin and Evans 1998).

Medium-sized odontocetes showed no response to seismic activity in 2001-02. In a previous analysis of data pooled over three years (1998-2000) killer whales were observed to remain further from the airguns when they were firing (Stone 2003b), but this result was not repeated in 2001-02. In most years in the past there have been insufficient data to assess the effects of seismic activity on killer whales, but as sightings of killer whales have increased in recent years knowledge of the effects on this species is beginning to appear. In contrast, sighting rates of pilot whales have decreased since 1998. This decrease was first noticed when sighting rates over the three years to 2000 were compared (Stone 2003b), and sighting rates remained low in 2001-02. The reasons for the reduction in sightings of this species are not known. In earlier years pilot whales were amongst the most frequently seen species during seismic surveys in UK waters, although few effects of seismic activity were observed other than sometimes an effect on their orientation (Stone 1998, 2003b).

As in previous years, smaller odontocetes showed a greater range of responses to seismic activity. Goold and Fish (1998) found that high frequency noise was incidentally emitted by seismic airguns; this could be responsible for the observed responses by small odontocetes. White-beaked dolphins were seen at reduced sighting rates during periods of shooting, and also remained further from the airguns, were oriented away from the vessel and were less likely to interact with the vessel or its equipment. Similar effects have been observed for white-beaked dolphins in some previous years (Stone 1997, 1998, 2001, 2003a,b). Previously white-sided dolphins have also in some years shown a reduction in sighting rates and/ or a tendency to remain at greater distances from the airguns during periods of shooting (Stone 1997, 1998, 2001, 2003a,b), but neither effect was apparent in 2001-02, nor was there any other significant reaction to seismic activity in this species. There has only been one other year previously (1998) where white-sided dolphins in UK waters have shown no reaction to seismic activity (Stone 2000). With repeated exposure to an acoustic source cetaceans may possibly habituate to the noise or alternatively become increasingly sensitive (Richardson *et al.* 1995). However, it would be premature to speculate that white-sided dolphins may be habituating to noise from seismic activity.

Sighting rates of harbour porpoises were reduced when the airguns were firing, the first time that this effect has been noted for this species. They were also further away than during periods of airgun silence. There have been few data for harbour porpoises in previous years, although pooling data over the three years from 1998 to 2000 also showed that harbour porpoises remained further from the airguns during periods of shooting and additionally that they oriented away from the vessel at these times (Stone 2003b).

Some other reactions to seismic activity were noticed when all small odontocetes were combined. For this group of species, swimming at speed was found to be more prevalent during periods of shooting, and alterations of course, mostly away from the vessel, were more common. Similarly, when all cetaceans were combined some other effects were noted, such as swimming at speed during periods of shooting, and an increased tendency to be logging at the water surface. Combining species has the advantage of increasing sample size, thus increasing the power of statistical tests.

It is possible that the response of marine mammals to seismic activity will vary in relation to other factors. Some possible factors that could conceivably exert an influence on the degree of response were examined for 2001-02 data. The only effect that depth of water had on the degree of response to seismic activity was that slow swimming was more prevalent in small odontocetes during periods of shooting in outer continental shelf waters, while in deeper or shallower waters the reverse was true. Swimming at speed may be indicative of disturbance, while slow swimming may indicate a lack of disturbance. It is difficult to speculate why there may be lower levels of disturbance on the outer continental shelf than in both deeper and shallower waters.

Distance from land, however, did seem to influence the degree of response of marine mammals to seismic activity, with some reactions being greater closer to land. Sighting rates of white-beaked dolphins were lower during periods of shooting than during periods of airgun silence in all distance bands but the furthest from land. Small odontocetes approached closer to the airguns when they were silent than when they were shooting, but the difference was most extreme closest to land. All cetaceans combined, all small odontocetes combined, and *Lagenorhynchus* spp. were found to be breaching, jumping or somersaulting more often when the airguns were firing than when they were silent, with the greatest difference being apparent closer to land. When all cetaceans were combined, within 100 km of land fewer were observed to be surfacing infrequently (i.e. more were remaining at or near the surface) when the airguns were firing, but this was not the case at greater distances from land. It is perhaps surprising that there was no similar interaction of depth with the degree of response to seismic activity, as depth tends to correlate with distance from land. If the effects of seismic activity are greater closer to land, this could have management implications for seismic surveys taking place in nearshore areas that are important for marine mammals, such as the Moray Firth, St. George's Channel and Cardigan Bay.

It would seem logical that larger arrays of airguns would have a greater effect than small arrays. In 2001-02 no reactions to seismic activity were observed during site surveys that had small total volumes of airguns. However, sample sizes were low during periods of shooting on site surveys. When pooled data from 1998-2000 were analysed, some effects of shooting during site surveys were demonstrated, particularly amongst small odontocetes (Stone 2003b). In 2001-02, when data from all surveys of known airgun volume were analysed, ranging from some site surveys where miniguns only (10 or 20 cu. in.) were used to surveys with total airgun volume in excess of 5,000 cu. in., some differences in the reaction to seismic activity were found. Minke whales, all small odontocetes combined and *Lagenorhynchus* spp. remained relatively further from the airguns when total array volumes were largest. During periods of shooting, sighting rates of small odontocetes (all species combined) increased when airgun volumes were greater, although this should be interpreted in the light of the knowledge that sighting rates of this species group were greater during periods of airgun silence than during periods of shooting (with large airgun arrays of any volume). It is possible that there is some behavioural response to shooting that is elicited more with the largest airgun arrays, that also renders the animals more easily visible. Such behaviours could include remaining near the surface, where noise levels may be less (Richardson *et al.* 1995; Urick 1983). Results for all large airgun arrays combined (regardless of volume) found that during periods of shooting there was an increased tendency to be logging at the water surface when all cetaceans were combined. There have previously been indications that fin/ sei whales may remain nearer the surface during periods of shooting (Stone 2003b), and humpback whales have also been recorded as spending much time near the surface during periods of seismic activity (McCauley *et al.* 1998, 2000).

It might be expected that a greater reaction to seismic activity would be found amongst pods where juveniles are present, but no such effect was observed from these data. Were such differences to be found, this could have implications for mitigation strategies.

Sample sizes of sightings during the soft-start were relatively small, so caution should be exercised when interpreting the results. However, it appeared that more cetaceans were heading away from the vessel during the soft-start than at any other time, which could indicate that the soft-start may achieve its intended aim of reducing injury or disturbance by allowing animals time to move out of the way before full power levels are reached.

The distance from the airguns at which cetaceans were seen throughout the soft-start varied – although sample sizes were very small in each category, and too small to permit statistical testing, it is interesting to note that a similar pattern was observed in 1998-2000 (Stone 2003b). In both sets of data the closest distance of approach to the airguns increased to a maximum approximately two-thirds of the way through the soft-start (based on time elapsed), and then decreased again for the remainder of the soft-start; a secondary peak in the closest distance of approach was observed at the commencement of the soft-start. Most soft-starts operate by firing one or a few small airguns initially and then adding in more active airguns at roughly equal time intervals, often with a similar number of airguns added at each stage in the process. The output from an airgun array has a relationship with the number of airguns firing; with a similar number of airguns added in at each stage of the soft-start the output could therefore be expected approximately to double between the first and second stages of a soft-start, with subsequent relative increases in output becoming less with each successive stage. Therefore, the early stages of a soft-start would have the greatest relative increases in acoustic output, and consequently may have the greatest impact on marine mammals in the vicinity, which may explain the observed increase in the closest distance of approach to the airguns throughout the initial two-thirds of the soft-start. Thereafter, the decline in relative increases in acoustic output may be less disturbing to marine mammals, perhaps encouraging closer approaches once more. The increased distance immediately at the commencement of the soft-start could be due to a startle response as firing begins after a period of airgun silence. It has often been noted that marine mammals are more responsive to sounds with varying or increasing levels than to steady sounds (e.g. Richardson *et al.* 1995). It may be appropriate to operate soft-starts in such a way that the increases in acoustic output are more even throughout the process. However, in order to develop the most appropriate methodology for the soft-start, further data are needed to examine with more certainty the reaction of marine mammals to this procedure.

11.3 Quality of observations

The quality of observations can be assessed in terms of the ability of observers to detect marine mammals and their ability to provide high quality data. The ability to detect marine mammals is of crucial importance to the effective operation of the guidelines, enabling those animals present prior to shooting to be detected, and shooting to be delayed if necessary. Dedicated marine mammal observers had a much higher detection rate than other types of personnel, and were better at detecting animals at distance. Although delays in shooting are only required if animals are detected within 500 m of the airguns, the ability to detect animals while they are further from the vessel will enable observers to monitor and track their progress, resulting in more reliable detection should they enter within a 500 m radius of the airguns. Members of ships' crews had the poorest detection rates, as has also been found previously (Stone 2001, 2003a,b) – these personnel are fully occupied with their normal duties concerning the safe navigation of the vessel, which quite rightly have higher priority than watching for marine mammals. Expecting such personnel to perform a dual role effectively is unrealistic.

Dedicated marine mammal observers, in addition to having better detection abilities, also provided higher quality data. They were better at completing the recording forms correctly, had better identification skills and recorded a wider range of behaviours. Members of ships' crews again provided the poorest performance in this respect. Trained observers provided higher quality data than untrained observers, being better at completing the recording forms correctly and having better identification skills. The provision of high quality data, whilst not essential to the operation of the guidelines, enables better assessment of the level of compliance with the guidelines and any effects of seismic activity on marine mammals. Ascertaining those aspects of the guidelines that are working well and those where difficulties are encountered can be extremely useful during periodic reviews of the guidelines, as is knowledge of any observed effects of seismic activity on marine mammals.

Overall, the quality of information received had improved from previous years in a number of respects. The 'Location and Effort' recording form was completed correctly for a greater proportion of surveys where reports were received in 2001-02 when compared to previous years. The information contained on this form is important in a number of the analyses that are performed on the data, so the increase in standards for this form enabled more use to be made of the data. More reports provided details of airgun parameters than in previous years – although this information is requested in the guidelines there is no standard form for it and it has often been missing previously. Other aspects of reporting showed no notable increases in standards. The 'Record of Operations' form showed a decline in standards in 2001 but then in 2002 standards returned to a level approaching that of before. 'Record of Sighting' forms were generally completed to an acceptable standard, although approximately one-fifth of identifications overall had to be downgraded. Incorrectly completed recording forms were mostly by untrained or not recently trained fishery liaison officers or members of ships' crews, while most missing recording forms were from surveys where untrained members of ships' crews were responsible for observations. Most incorrect or missing forms were from site surveys. Sample sizes for site surveys are generally low, and as there is a need for more information on the effects of site surveys on marine mammals, it would be beneficial for accurate data to be collected on and returned from such surveys.

One area where a simple improvement could be made to the quality of data is if there was better proof-reading of reports before submission. Missing pages and the use of large font sizes in text boxes or other objects such that text/ drawings did not fit in the available space and thus had not printed were not uncommon. Observers should ensure that the information they provide is full and complete, and where agencies are responsible for final submission of reports they should likewise ensure that all the information contained in a report is provided. Thorough proof-reading before final submission could easily eliminate such mistakes. Proof-reading of electronic reports is equally important and should not be viewed as unnecessary; it is important that electronic reports are able to be printed correctly without adjustments having to be made.

Another simple improvement to the data would be for more observers to include the seismic survey reference number on the report. This would enable better matching of reports to notifications and thus better tracking of surveys and their adherence to any requirements specified as part of the consent process. Very few observers provided a reference number on their reports in 2001-02. When this reference number was introduced it was as the JNCC seismic survey reference number, but JNCC are now using the same reference number as DTI, so the DTI reference number should be used. The recording forms have been amended to reflect this.

11.4 Compliance with guidelines

With the introduction of consent procedures in 2001 it seems likely that JNCC is now getting a high level of notification of surveys. However, there were many surveys in 2001-02 for which reports were not received, particularly site surveys. Even allowing for the possibility that some surveys may have been cancelled, the number of surveys where reports were not submitted would still be high. Although many of the unreported surveys were of very short duration, a report should nevertheless have been submitted.

The proportion of known surveys where dedicated marine mammal observers were used appears to have increased only slightly since 2000. However, if the level of notification has increased compared to previous years then the proportion of known surveys using dedicated marine mammal observers would actually have increased more substantially compared to previous years. Of the reports that were received, a higher proportion were by dedicated marine mammal observers than in previous years, at least for surveys with large airgun arrays. This may be an indication that the level of use of dedicated marine mammal observers has actually increased more than is apparent.

The absence of dedicated marine mammal observers on some surveys in areas of importance for marine mammals is of some concern, especially given that standards of compliance with the guidelines are generally poorer for other types of personnel. In areas where there are known to be concentrations of marine mammals it is important that the highest standards are maintained, and this is best achieved by employing one or more dedicated marine mammal observer(s). Also of concern are those surveys where the observers employed did not meet the requirements specified by JNCC as part of the consent process, as this may indicate a level of disregard for the conditions of consent by some operators.

Although acoustic monitoring was not a condition of consent for most surveys in 2001-02, its relative lack of use is perhaps disappointing. Acoustic monitoring has been recommended since the original introduction of the guidelines in 1995, and although that recommendation has gained strength, as far as 2002 there has been little increase in the use of this technology. Acoustic monitoring would provide a useful complement to visual monitoring, especially in areas where deep-diving species regularly occur.

Most pre-shooting searches on surveys with large airgun arrays were of adequate duration. However, even though the majority were acceptable in 2001, one in ten pre-shooting searches were still shorter than the required minimum duration. On a typical 3D survey, this might mean that once in every two or three days a pre-shooting search is too short, which might seem rather too frequent. In 2002 only one in twenty pre-shooting searches on surveys with large airgun arrays was too short, and this might represent a more acceptable standard to aim for as a minimum. On site surveys most pre-shooting searches were of an acceptable duration in 2002 but in 2001 many were too short. In order for pre-shooting searches to be of an acceptable standard, the duration has to meet the required minimum and the observer has to be capable of detecting marine mammals. Members of ships' crews are always present on the bridge, therefore these personnel had a very high standard for the duration of the pre-shooting search. However, their ability to detect marine mammals was poor, rendering the pre-shooting search ineffective. Dedicated marine mammal observers had the best detection rates of marine mammals, which coupled with a generally acceptable duration meant that pre-shooting searches were of the highest standard when such personnel were used.

Although precise figures are not available, the impression gained from the reports was that crews were better at regularly providing advance warning of shooting than has often been the case in the past, and this certainly aids the marine mammal observer to maintain a high standard of pre-shooting searches. However, the marine mammal observer still has a responsibility to maintain awareness of events without total reliance on the crew. Training teaches observers how to estimate when a pre-shooting search will need to commence, using available information from on-board computer displays. This may have contributed to the higher standard of pre-shooting searches in 2001 when trained observers were used, compared to untrained observers.

The majority of soft-starts were of an acceptable duration on surveys with large airgun arrays. However, as with pre-shooting searches, approximately one in ten were too short in 2001, meaning that on a typical 3D survey there might be a short soft-start every two or three days. In 2002 approximately one in twenty soft-starts were too short, and again this might represent a more acceptable standard to aim for as a minimum. The standard of soft-starts on surveys with large airgun arrays was higher in 2001 when dedicated marine mammal observers rather than fishery liaison officers were used, and when trained rather than untrained observers were used. In 2002 the standard of soft-starts on surveys with large airgun arrays was generally high for all types of observers used.

Standards of soft-starts on site surveys were very poor, and had declined from 2000 when guidance was issued stating that soft-starts should be used on site surveys and that exemptions would only exist for a minority of site surveys where a waiver had been agreed with JNCC prior to the start of the survey. It appears that the publication of this guidance may have resulted in an improvement (albeit an insufficient improvement) in the standard of soft-starts on site surveys, but that this improvement was only temporary, lasting no more than one season. In February 2002 JNCC began consultation on a proposed revision of the guidelines and, recognising that soft-starts are difficult on some site surveys, invited suggestions for solutions. However, at the end of 2002 the revision of the guidelines had not been finalised, so the 1998 version of the guidelines, and any guidance relevant to this version, applied throughout 2001-02. Those operators facing genuine difficulties in performing a soft-start on site surveys in 2001-02 should have consulted JNCC, but this only happened in the case of one site survey. Standards of soft-starts on site surveys were higher when dedicated marine mammal observers were used, and when observers were trained, but even then standards were still poor.

The proportion of occasions when correct procedures were followed when a delay in the commencement of shooting was required had fallen since 2000. On site surveys, whether or not the delay was long enough the subsequent soft-start was always too short – had it not been for short soft-starts half of the delay situations on site surveys would have followed correct procedures. Some occasions when correct procedures were not followed were due to unfortunate circumstances, but lessons can be learned from these to avoid repetition. In one case the airguns started firing while the marine mammal observer was on the way to inform the crew. This has also happened in previous years, albeit rarely. The marine mammal observer has to balance being in a good observation position and being in a position for rapid communication with key members of the crew – if a good view cannot be obtained within easy access of the ship's intercom then use of a portable means of communication may be advisable. The speed of communication becomes increasingly important in the final minute before the airguns commence firing, and this also requires consideration of the order in which key personnel are informed. In 2001 there was one instance when firing commenced as the marine mammal observer was informing the client representative. Seismic observers usually initiate the soft-start, so in any delay situation it is important that they are informed first and advised of appropriate action. If further authority is needed to delay firing the party chief or client representative can then be contacted, but it is essential that those controlling the soft-start are already aware of the situation and can suspend the commencement of the soft-start while authority is being sought. Furthermore, party chiefs and client representatives can be anywhere on the vessel and it may take time to locate and contact them, whereas the duties of seismic observers demand that they are at their station when commencement of the soft-start is imminent, making it much more efficient to contact them first in a delay situation when rapid communication is vital.

In previous years there has been a problem with marine mammal observers being on board the receiving vessel rather than the source vessel during 4C/ OBC surveys. In 2001-02 this only happened on two occasions (one of these being unintentional, with measures taken to ensure an adequate pre-shooting search was conducted from the receiving vessel until the observer could be transferred). However, it was a problem during undershooting, when in the majority of cases there was no observer on board the source vessel for the duration of the undershoot. It is important that observers are on board the source vessel to ensure an effective search of the area surrounding the airguns prior to shooting commencing. Sometimes there are concerns that observers will not be able to return to the main vessel once the undershoot is complete if poor weather prevents transfer using a small boat. Sometimes shooting may alternate between the main vessel and the undershoot vessel while the equipment is being set up, and in these cases continual transfers may become impractical. If there are two marine mammal observers one solution may be to transfer one observer and leave one on the main vessel. However, the ideal solution would be for the undershoot vessel to carry its own separate marine mammal observers. Sometimes undershoot vessels travel around a number of surveys, doing the undershoot for each survey in turn, and in such a situation it would be sensible to have separate marine mammal observers travelling around with the undershoot vessel. One further advantage of this approach is that it eliminates the need for transfers of marine mammal observers by small boat, thus avoiding any risks associated with this procedure.

It is particularly disappointing that the guidelines continue to be ignored in some situations. In general when surveys are progressing smoothly pre-shooting searches and soft-starts are carried out, and delays in shooting are put in place on at least some of the occasions when they are required (although there is still much room for improvement in this aspect of compliance with the guidelines). However, in situations where there may be difficulties in applying the guidelines they are often ignored with no consultation with JNCC. Time-sharing resulted in short soft-starts on one survey, in spite of guidance from JNCC stating that full soft-starts should be used in time-share situations. On all but one site survey there was no consultation with JNCC regarding difficulties of performing soft-starts, and no application for a waiver, even though in many cases a soft-start was deemed impractical and a decision was made to reduce or omit the soft-start. Continual shooting was practised between lines on a number of site surveys and 4C/ OBC surveys, again in spite of guidance from JNCC stating that shooting should stop at the end of the line, with only one case where JNCC's permission was sought. Since the recent (April 2004) revision of the guidelines, continual shooting is now permitted where line turns are shorter than the duration of a soft-start, but during 2001-02 continual shooting should not have happened without JNCC's permission. It seems that where difficulties were encountered, even where those difficulties were known about in advance, decisions were made to disregard certain aspects of the guidelines without JNCC being included in that decision-making process. In many cases, particularly where soft-starts were short or absent on site surveys, or where continual shooting was practised between lines, the reports said that the guidelines were followed "as deemed appropriate". It has often been the case in the past that the guidelines were viewed as optional, and that the items contained in them could be followed or ignored as convenient. Unfortunately it seems that this attitude still prevails, even though adherence to the guidelines is now routinely made a condition of consent for all seismic surveys on the UK continental shelf.

11.5 Considerations for future revisions to guidelines

Each year when reports from marine mammal observers are examined and data analysed, consideration is given to items that might be revised in future versions of the guidelines, taking into account the experiences reported from each year's surveys. A number of points have been suggested for revision (Stone 2000, 2001, 2003a). In April 2004 a revised version of the guidelines was published following a consultation process with interested parties. This revised version includes most of the recommendations made since the 1998 version of the guidelines was published.

Many of the concerns arising in 2001-02 are addressed in the revised version of the guidelines. Some of the main concerns were short or absent soft-starts on site surveys, continual shooting between lines, and the absence of marine mammal observers on board source vessels during undershoot operations. The following considers the experience of the 2001-02 seasons, and whether issues raised during these seasons are adequately addressed in the new version of the guidelines or whether further amendments may be necessary in the future.

The revised guidelines state that marine mammal observers should always be on board the source vessel during undershoot operations in sensitive areas. In other areas, while the aim should be to ensure that the marine mammal observer is on the source vessel, a waiver can be applied for if logistical difficulties exist, although the mitigation procedures contained within the guidelines will still apply. The placing of marine mammal observers on undershoot vessels should be monitored in future years; if there are frequent problems associated with transferring personnel or if vessels regularly shoot alternately for any part of the undershoot operation or in preparation for it, it may be necessary for future revisions of the guidelines to recommend that separate marine mammal observers are supplied with any additional source vessel used.

One significant issue in 2001-02 was that soft-starts on site surveys were frequently reduced or omitted, almost always without consultation with JNCC. The revised version of the guidelines provides alternative ways of achieving a soft-start on high resolution site surveys (defined as those with an airgun array volume of 180 cu. in. or less) or for vertical seismic profiling – a standard soft-start could be used, or a gradual increase in pressure, or a gradual decrease in shot point interval. The revised guidelines also say that if an operator is unable to undertake a soft-start using these methods then a waiver must be applied for prior to operations commencing. There should be very few site surveys where a soft-start cannot be performed using one of these methods, so it is anticipated that this revision will adequately address the problems encountered in previous years.

During 2001-02 there were a number of 4C/ OBC surveys and site surveys where firing continued throughout short line turns; in the case of 4C/ OBC surveys, where airgun volumes were relatively large, firing continued at reduced power with a build up to full power over the time available. This often-used procedure did not comply with the guidelines in these years (although permission was readily granted by JNCC in the one instance where it was sought). JNCC recognise the difficulties posed by short line turns and the revised guidelines address this issue by now allowing continual firing, either at full power or by initially reducing the output to 160 dB (depending on the circumstances of the survey), during line turns shorter than the time required for a soft-start. There will need to be a way of assessing whether continual firing is justified – a change in the 'Record of Operations' form is required to gather the information needed (times of end of line and start of line).

There were some 4C/ OBC surveys where firing continued during periods of standby in 2001-02. Firing on standby was at times protracted, lasting several hours. Such firing is unnecessary, and increases the overall noise input to the marine environment. The revised version of the guidelines says that there should be no shooting that is not necessary for the normal operations of a seismic survey or for a soft-start and that protracted shooting which is not part of a survey line is discouraged. This should adequately address the problem of continual shooting when on standby.

The revised version of the guidelines, as well as stipulating a minimum 20 minute duration for the soft-start also provides a maximum duration, with the period from commencement of the soft-start to commencement of the line being no longer than 40 minutes. From the data gathered in 2001-02 it seems that this will not be a problem for normal soft-starts used as a precursor to a survey line. However, when testing the airguns firing at low power can occasionally be protracted. Whilst unnecessarily protracted testing should not be encouraged, there may be situations where testing needs to continue for a period. It would be worth monitoring the length of firing at low power during periods of testing to see whether test firing should be subject to the same maximum duration of 40 minutes or whether in future a longer maximum or exemption from a maximum duration should apply. For monitoring this a revision to the 'Record of Operations' form is required to provide space to specify on which occasions the airguns are being tested.

One point raised in 2001-02 was that of how long a break in firing could be before a soft-start was required when re-commencing firing. Some observers in 2001-02, through their reports, requested clarification from JNCC on this matter. The revised version of the guidelines states that if firing has stopped and not restarted for at least 5 minutes then a full soft-start is required, provided that no marine mammals are present within 500 m of the airguns (if marine mammals are present re-commencement of shooting should be delayed).

It is unfortunate that occasionally when a delay in commencing firing is required due to the close proximity of marine mammals, firing starts as the marine mammal observer is on the way to inform the crew of the need for a delay. Delay situations arise infrequently, thus even rare occurrences where shooting commences before the crew can be informed can represent a reasonable proportion of delay situations. The frequency of occurrence of such cases should be monitored, and if necessary future revisions of the guidelines could include advice to marine mammal observers to bear in mind the potential need for rapid communication with the crew when choosing a suitable observation platform.

Some observers commented on the difficulties of providing cover throughout daylight hours. The revised version of the guidelines emphasises that observers are not expected to observe throughout all daylight hours and also states that for surveys north of 57°N between 1st April and 30th September two marine mammal observers should be used. Observers should manage their time such that they are available and at the best of their ability during the crucial period (30 minutes) leading up to commencement of the seismic sources. Some observers during 2001-02 suggested that where there are two observers the guidelines should specify how often they should change over. However, the different suggestions that have been put forward in this respect testify to the fact that each individual observer is different, each has different preferences for length of watch, and each has different abilities to maintain concentration. It would be inappropriate for the guidelines to force observers to maintain a schedule that may not suit some individuals, and this would provide no benefit as observers are already free to choose a work schedule that suits themselves, providing that the critical pre-shooting search period is covered. Accordingly the revised guidelines encourage marine mammal observers (where there are two on board a vessel) to collaborate to ensure that there is always an observer available to undertake a pre-shooting search, but without specifying any particular schedule.

The use of acoustic monitoring has been recommended since the introduction of the guidelines in 1995, and the revised guidelines say that JNCC will advise the use of passive acoustic monitoring where sensitive species (e.g. those of particular conservation importance or those difficult to detect by visual observation alone) are likely to inhabit the proposed survey location. Voluntary use of acoustic monitoring has been infrequent up to and including 2002; the strengthening of this aspect of the guidelines may serve to increase its use. However, the use of passive acoustic monitoring should continue to be monitored to assess whether this aspect of the guidelines requires further strengthening in future.

11.6 Changes to the marine mammal recording forms

On all three of the recording forms, the JNCC seismic survey reference number has been changed to the DTI reference number, as JNCC are now using the same reference number as DTI. Aside from this, the only major change is to the 'Record of Operations' form. In the light of the changes to the guidelines, this form now asks for some additional information to enable assessment of compliance with the new aspects of the guidelines.

As the revised guidelines provide alternative options for performing a soft-start for high resolution site surveys (defined as those with an airgun array volume of 180 cu. in. or less) and vertical seismic profiling, observers are asked on the 'Record of Operations' form to state the type of survey and airgun volume and, for site surveys or vertical seismic profiling, which method of soft-start is being employed.

Firing is now allowed to continue (either using the full array or with a reduced output of 160 dB, depending on the circumstances of the survey) during line turns shorter than the time required to perform a soft-start. In order to ensure that this procedure is only used where it is justified, it is necessary to record the duration of line turns where firing continues. For this reason, the 'Record of Operations' form now includes the times of the start and end of lines, and the time when output was reduced to 160 dB (where applicable).

The inclusion of the time of the start of each line will also enable checks to be made to ensure that the duration from the commencement of the soft-start to the start of the line does not exceed the maximum duration permitted under the revised guidelines, i.e. does not exceed 40 minutes.

In order to better assess any problems encountered during testing of the airguns (including whether the 40 minute maximum duration from the commencement of the soft-start until the start of line presents difficulties during test firing) observers are now asked on the 'Record of Operations' form to state whether firing was for a test or for a survey line.

Current versions of the marine mammal recording forms, including the revised 'Record of Operations' form, are presented in Appendix 2.

12. Acknowledgements

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13. References

BLOOR, P.D., REID, J.B., WEBB, A., BEGG, G. & TASKER, M.L. 1996 The distribution of seabirds and cetaceans between the Shetland and Faroe Islands. *JNCC Report,* No. 226.

CLARK, C.W. & CHARIF, R.A. 1998 Acoustic monitoring of large whales to the west of Britain and Ireland using bottom-mounted hydrophone arrays, October 1996 - September 1997. *JNCC Report,* No. 281.

EVANS, P.G.H. 1990 European cetaceans and seabirds in an oceanographic context. *Lutra*, **33**, 95-125.

EVANS, P.G.H. 1992 *Status review of cetaceans in British and Irish waters.* Report of the UK Mammal Society Cetacean Group, University of Oxford.

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

GOOLD, J.C. & FISH, P.J. 1998 Broadband spectra of seismic survey air-gun emissions, with reference to dolphin auditory thresholds. *Journal of the Acoustical Society of America*, **103**, 2,177-2,184.

HMSO 1983 *Meteorological Office state of sea booklet.* HMSO, London.

JNCC 1995 *European seabirds at sea database: seabird and cetacean UKDMAP datasets version 2.1.* JNCC, Peterborough.

LAWSON, J.W., DAVIS, R.A., RICHARDSON, J. & MALME, C.I. 2000 *Assessment of noise issues relevant to key cetacean species (northern bottlenose and sperm whales) in the Sable Gully Area of Interest*. LGL Report TA2446-2, LGL Ltd, Ontario, Canada.

LJUNGBLAD, D.K., WÜRSIG, B., SWARTZ, S.L. & KEENE, J.M. 1988 Observations on the behavioral responses of bowhead whales (*Balaena mysticetus*) to active geophysical vessels in the Alaskan Beaufort Sea. *Arctic*, **41**, 183-194.

MATE, B.R., STAFFORD, K.M. & LJUNGBLAD, D.K. 1994 A change in sperm whale (*Physeter macrocephalus*) distribution correlated to seismic surveys in the Gulf of Mexico. *Journal of the Acoustical Society of America*, **96**, 3,268-3,269.

MCCAULEY, R.D., FEWTRELL, J., DUNCAN, A.J., JENNER, C., JENNER, M-N., PENROSE, J. D., PRINCE, R.I.T., ADHITYA, A., MURDOCH, J. & MCCABE, K. 2000 Marine seismic surveys - a study of environmental implications. *Appea Journal,* **2000**, 692-708.

MCCAULEY, R.D., JENNER, M-N., JENNER, C., MCCABE, K.A. & MURDOCH, J. 1998 The response of humpback whales (*Megaptera novaeangliae*) to offshore seismic survey noise: preliminary results of observations about a working seismic vessel and experimental exposures. *Appea Journal*, **1998**, 692-707.

MCCONNELL, B.J., FEDAK, M.A., LOVELL, P. & HAMMOND, P.S. 1999 Movements and foraging area of grey seals in the North Sea. *Journal of Applied Ecology*, **36**, 573-590.

NERC 1998 *United Kingdom Digital Marine Atlas (UKDMAP) - Version 3, July 1998.* National Environment Research Council/ British Oceanographic Data Centre, Bidston Observatory, Birkenhead, Merseyside.

NORTHRIDGE, S.P., TASKER, M.L., WEBB, A. & WILLIAMS, J.M. 1995 Distribution and relative abundance of harbour porpoises (*Phocoena phocoena* L.), white-beaked dolphins (*Lagenorhynchus albirostris* Gray), and minke whales (*Balaenoptera* *acutorostrata* Lacepède) around the British Isles. *ICES Journal of Marine Science*, **52**, 55-66.

POLLOCK, C.M., MAVOR, R., WEIR, C.R., REID, A., WHITE, R.W., TASKER, M.L., WEBB, A. & REID, J.B. 2000 *The distribution of seabirds and marine mammals in the Atlantic Frontier, north and west of Scotland*. JNCC, Peterborough.

POLLOCK, C.M., REID, J.B., WEBB, A. & TASKER, M.L. 1997 The distribution of seabirds and cetaceans in the waters around Ireland. *JNCC Report*, No. 267.

RANKIN, S. & EVANS, W.E. 1998 Effect of low frequency seismic exploration signals on the cetaceans of the Gulf of Mexico. In *The World Marine Mammal Science Conference, Monaco, 20-24 January 1998, Society for Marine Mammalogy and the European Cetacean Society, Centre de Recherche sur les Mammifères Marins, La Rochelle, France,* p. 110.

REID, J.B., EVANS, P.G.H. & NORTHRIDGE, S.P. 2003 *Atlas of cetacean distribution in north-west European waters.* JNCC, Peterborough.

RICHARDSON, W.J. & GREENE, C.R. Jr 1993 Variability in behavioural reaction thresholds of bowhead whales to man-made underwater sounds. *Journal of the Acoustical Society of America*, **94**, 1,848.

RICHARDSON, W.J., GREENE, C.R. Jr, MALME, C.I. & THOMSON, D.H. 1995 *Marine mammals and noise.* Academic Press, San Diego.

RICHARDSON, W.J., WÜRSIG, B. & GREENE, C.R. Jr 1986 Reactions of bowhead whales, *Balaena mysticetus*, to seismic exploration in the Canadian Beaufort Sea. *Journal of the Acoustical Society of America*, **79**, 1,117-1,128.

SIEGEL, S. & CASTELLAN, N.J. Jr 1988 *Nonparametric statistics for the behavioural sciences.* McGraw-Hill Book Co, Singapore.

SKOV, H., DURINCK, J., DANIELSEN, F. & BLOCH, D. 1995 Co-occurrence of cetaceans and seabirds in the northeast Atlantic. *Journal of Biogeography*, **22**, 71-88.

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

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

STONE, C. J. 2000 Cetacean observations during seismic surveys in 1998. *JNCC Report,* No. 301.

STONE, C. J. 2001 Marine mammal observations during seismic surveys in 1999. *JNCC Report,* No. 316.

STONE, C.J. 2003a Marine mammal observations during seismic surveys in 2000. *JNCC Report,* No. 322.

STONE, C. J. 2003b The effects of seismic activity on marine mammals in UK waters, 1998-2000. *JNCC Report,* No. 323.

THOMPSON, P.M., MCCONNELL, B.J., TOLLIT, D.J., MACKAY, A., HUNTER, C. & RACEY, P.A. 1996 Comparative distribution, movements and diet of harbour and grey seals from the Moray Firth, NE Scotland. *Journal of Applied Ecology*, **33**, 1,572-1,584.

URICK, R.J. 1983 *Principles of underwater sound, 3rd edition*. Peninsula Publishing, Los Altos.

14. Appendices

Appendix 1 *Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys (April 2004)*

Appendix 2 Marine mammal recording forms

Appendix 3 Additional reports received by JNCC during 2001-02

Appendix 4 Scientific names of species mentioned in the text

Appendix 1

JOINT NATURE CONSERVATION COMMITTEE
Marine Advice
Dunnet House
7 Thistle Place
ABERDEEN
AB10 1UZ

Tel: 01224 655716
E-mail: seismic@jncc.gov.uk
Website: www.jncc.gov.uk/marine

JOINT NATURE CONSERVATION COMMITTEE

GUIDELINES FOR MINIMISING ACOUSTIC DISTURBANCE TO MARINE MAMMALS FROM SEISMIC SURVEYS

April 2004

These guidelines are aimed at minimising the risk of acoustic disturbance to marine mammals including seals, whales, dolphins and porpoises from seismic surveys. In addition to keeping noise levels at lowest practicable levels the recommendations contained in the guidelines should assist in ensuring that marine mammals in areas of proposed airgun activity are protected against possible injury. These guidelines reflect a precautionary approach that should be used by anyone planning marine operations that could cause acoustic or physical disturbance to marine mammals.

The guidelines have been written for use in the United Kingdom Continental Shelf (UKCS). Whilst we do not object to these guidelines being used elsewhere we would encourage all operators to determine if any special or local circumstances pertain as we would not wish these guidelines to be used where a local management tool has already been adopted (for instance in the Gulf of Mexico OCS Region). We also note that other fauna, for example turtles, occur in waters where these guidelines may be used. We suggest that, whilst the appropriate mitigation may require further investigation, the soft start procedures similar to those followed for marine mammals should also be employed for other fauna.

In relation to oil and gas seismic surveys on the UKCS, it is a legal binding condition of the consent issued for seismic surveys under regulation 4 of the Petroleum Activities (Conservation of Habitats) Regulations 2001 by the Department of Trade and Industry (DTI) that the JNCC Guidelines must be followed at all times for all seismic surveys. It should be noted that it is the responsibility of the company issued consent by the DTI, referred to as ‘applicant’, to ensure that these guidelines are followed and the relevant marine mammal observer reports submitted to the JNCC. We recommend that a copy of the JNCC guidelines are available onboard all vessels undertaking seismic surveys on UKCS.

Index

The guidelines are broken down in the following sections:

Terminology

High Resolution Seismic Site Survey is defined as those using an airgun array of 180 cubic inches or less.

Seismic Survey includes 2D/3D/4D and OBC (Ocean Bottom Cabling) surveys and any similar techniques

Vertical Seismic Profiling or **Borehole Seismic** is defined as seismic used in connection with well operations typically with a source size of 500 cubic inches.

Consent is the consent issued by the DTI under regulation 4 of the Offshore Petroleum (Conservation of Habitats) Regulation 2001.

Applicant is defined as the company who has applied to the DTI for PON 14A consent. This could either be an oil and gas operator or a seismic survey company.

Section 1 – General precautions to reduce the disturbance caused by seismic surveys

1.1 The Planning Stage - When a seismic survey is being planned, operators should:

- Consult relevant literature and if necessary, contact the Joint Nature Conservation Committee (JNCC) to determine the likelihood that marine mammals will be encountered. For instance: (http://www.jncc.gov.uk/Publications/cetaceanatlas/)
- Plan surveys so that their timing will reduce the likelihood of encounters with marine mammals especially during the breeding and calving seasons. If an area is particularly sensitive due to the species present an assessment of this should be included within the PON 14 application
- Seek to provide the most appropriately qualified and experienced personnel to act as marine mammal observers (MMOs) on board the seismic survey vessel (see Section 4 for further information on MMOs).
- Plan to use the lowest practicable power levels throughout the survey.
- Seek methods to reduce and/or baffle unnecessary high frequency noise produced by airguns or other acoustic energy sources.

1.2 During the Seismic Survey - When conducting a seismic survey, operators should:

- Ensure that the correct 'soft start' procedure is followed. Soft starts are intended as a time period to allow marine mammals to move away from an area should they wish to do so. (See Section 2)
- There should be no shooting apart from that necessary for the normal operations of a seismic survey or for a 'soft start'. Protracted shooting which is not part of a survey line is discouraged.

1.3 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 helps to increase our knowledge and allow us to improve these guidelines. Reports should be sent to the JNCC ideally by e-mail to seismic@jncc.gov.uk or faxed/posted to the address at the face of these guidelines. Reports should include the following information:

- The Seismic Survey reference number provided to operators by the DTI
- Date and location of survey
- Number and volume of each airguns used also calculated as total volume.
- Nature of airgun array 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 airguns 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

Section 2 – Guidance when carrying out a soft start

If dedicated MMOs are requested to be on board a seismic vessel they should make certain that their efforts are concentrated on keeping a watch prior to the soft start. At no time are these guidelines meant to imply that MMOs should keep a watch during all daylight hours. JNCC strongly encourage all MMOs to manage their time to ensure that they are available and at the best of their ability when carrying out a watch during the crucial time – the 30 minutes before commencement of the use of a seismic source. However, JNCC does appreciate the efforts of MMOs to collect data at other times than prior to the soft start but this should be managed to ensure these observations are not detrimental to the ability of the MMO to watch prior to a soft start. The JNCC will request that two marine mammal observers be used when daylight hours exceed approximately 12 hours per day. Where two MMO's are onboard a seismic vessel we would encourage them to collaborate to ensure cetacean monitoring is undertaken during all daylight hours and to ensure that an observer is always available to undertake a pre-start up search for the required 30 minute.

2.1 <u>Look and Listen</u>

Beginning at least 30 minutes before commencement of any use of the seismic sources, the dedicated MMO or if a dedicated MMO has not been requested by the DTI, a nominated member of the ships company should carefully make a visual check from a suitable high observation platform to see if there are any marine mammals within 500 metres (measured from the centre of the array).

2.2 <u>Delay</u>

If marine mammals are seen within 500 metres of the centre of the array the start of the seismic sources should be delayed until they have moved away, allowing adequate time after the last sighting for the animals to move away (at least 20 minutes). In situations where seal(s) are congregating immediately around a drilling or production platform, it is recommended that commencement of the seismic sources begin at least 500 m from the platform.

2.3 <u>The Soft Start</u>

Power should be built up slowly from a low energy start-up (e.g. starting with the smallest airgun in the array and gradually adding in others) over at least 20 minutes to give adequate time for marine mammals to leave the vicinity. This build up of power should occur in uniform stages to provide a constant increase in output. There should be a 'soft start' every time the airguns are used, even if no marine mammals have been seen.

- We encourage all seismic survey operators to ensure that, as far as possible, soft starts occur during daylight hours when MMO's or the nominated crew member can carry out the required 30 minute watch. If visual observations can not be made we continue to encourage the use of PAM for acoustic monitoring during this time.
- To minimise additional noise in the marine environment, a 'soft start' (from commencement of soft start to commencement of the line) should take no longer than 40 minutes.
- The 'soft start' procedure should be followed at all times including before test firing of the airguns.
- If, for any reason, firing of the airguns has stopped and not restarted for at least 5 minutes a full 20 minute 'soft start' should be carried out. After any break in firing of any duration a visual check should be made for marine mammals within 500 metres of the centre of the array. If a marine mammal is present then re-commencement of shooting should be delayed as per the Look & Listen, Delay and Soft Start instructions above.
- When time-sharing, where two or more vessels operate in adjacent areas and take turns to shoot to avoid causing seismic interference to each other, all vessels shooting should follow the full 'soft start' procedure for each line start.

2.4 Site Survey / Vertical Seismic Profiling (VSP) and Soft Starts

Whilst we appreciate that high resolution site surveys / VSP operation may produce lower acoustic output than 2D or 3D surveys and that firing of individual airguns may not be possible for technical reasons, we believe it is still necessary to undertake some form of a soft start to allow time for marine mammals to move away from an airgun.

We understand there are a number of options as to how a soft start may be undertaken. For reasons of flexibility we are content for high resolution seismic site surveys and VSP operations to use any of the methods below for a soft start:

A. The standard method, where power is built up slowly from a low energy start-up (e.g. starting with the smallest airgun in the array and gradually adding in others) over at least 20 minutes to give adequate time for marine mammals to leave the vicinity.
B. As the relationship between acoustic output and pressure of the air contained in the airgun is close to linear and most site surveys / VSP operations use only a small number of airguns a soft start can be achieved by slowly increasing the air pressure in 500 psi steps. From our understanding the minimum air pressure which the airgun array can be set to will vary, as this is dependent on the make and model of the airgun being used. The time from initial airgun start up to full power should be at least 20 minutes.
C. If neither of the above techniques (A or B) can be used, over a minimum time period of 20 minutes the airguns should be fired with an increasing frequency until the desired firing frequency is reached.

If an operator of an airgun array is unable to undertake a soft start using the methods above a waiver must be granted in the DTI consent. This must be applied for with the JNCC prior to the actual operation occurring ideally as part of the PON 14A submission or for VSP the PON14A or PON15B. If a waiver has not been agreed by the JNCC, and consented to by the DTI and a soft start is not implemented applicants will be in breach of their consent.

When submitting the MMO report to the JNCC for high resolution seismic site surveys operators should indicated which of the above methods was used to achieve the soft start.

2.5 Line Change

Seismic data is usually collected in lines. Line change is the term used to describe the time it takes for a vessel to turn from the end of one line to the start of the next. Depending upon the type of seismic survey being undertaken, the time for a line change can vary between five and ten minutes for site surveys to two to three hours for 3D exploration surveys. In the past this has caused some confusion as to when a soft start will be required. In order to standardise approaches the following guidance is provided:

A. For line change times greater than the time required to undertake a soft start, airguns should cease firing at the end of each line and commence a full soft start at the appropriate time before commencing the next line (i.e. a soft start of at least 20 minutes prior to commencement of the next line).
B. For line change which take less time than that required to undertake a soft start, airguns should continue firing the full array during the line turn (i.e. for a site survey line turn of 5 minutes continue firing at full power).
C. For high resolution site surveys line changes it is also permissible to reduce airgun output at the end of each line to an output of 160dB. The increase from 160 dB to full power, prior to the start of the next line, should be undertaken in a stepped manner similar to a full soft start.

We understand that, depending on the length of line turns for some surveys such as OBC, soft start methods may need to vary from those described above. If an applicant believes that for any survey a line change may not achieved using the above methods please contact JNCC at the earliest possible opportunity.

2.6 Undershoot Operations

During an undershoot operation a second vessel is employed to tow the seismic source or airguns although the main vessel will still tow the hydrophone array. This is to allow shooting under platforms or around any other obstructions at sea. It has been noted that this operation can sometimes lead to difficulties when, as a term of the consent, a dedicated MMO has been requested. The following guidance is provided:

In sensitive areas, the MMO should always be onboard the source vessel. If, following the receipt of a PON 14A application and advice from JNCC, the consent states that dedicated MMO(s) should be placed on board the seismic source vessel this condition of consent applies to all vessels including any source vessel undertaking undershoot operations.

When a dedicated MMO(s) has been requested in other areas operators should aim to ensure that the dedicated MMO is on the source vessel. If, due to difficulties in logistics (usually the health and safety issues of moving a MMO from one vessel to another) this is not possible, the operator should apply for a waiver, ideally at the time of the PON14A submission. If a waiver is given (which will depend upon the sensitivities at the survey location, and duration of undershoot operations) the look, listen and delay procedure should still be followed prior to commencing a soft start of the airgun source on the vessel undertaking the undershoot operation.

We realise that this guidance may be difficult to implement and therefore strongly encourage those applicants who foresee a problem placing an MMO onboard a vessel undertaking an undershoot operation to consult with DTI and JNCC during the PON 14A application process.

Section 3 – Marine Mammal Observers or MMOs

- A prerequisite for an MMO is the attendance of a short course on implementing the guidelines and recording procedure. Further details of the courses can be obtained by contacting seismic@ jncc.gov.uk.
- For sensitive areas including West of Britain, Moray Firth and Cardigan Bay, the MMO must also be an experienced cetacean biologist or an experienced marine mammal observer (i.e. an observer with at least three seasons worth of experience).
- When a dedicated MMO is requested, the MMO should be employed solely for the purpose of monitoring the applicants implementation of the guidelines and visual observation of marine mammals during periods of active seismic survey.
- All surveys that require MMOs taking place between 1st April and 30th September north of 57° latitude will require two dedicated MMOs due to the longer daylight hours (more than 12 hours a day at 57° latitude).
- When two dedicated MMOs are requested, the use of a crewmember with other responsibilities as the second observer is not considered an adequate substitute for a dedicated MMO.
- The MMO should be onboard the source vessel. (i.e. the vessel towing the airguns). When time sharing, if an MMO is required by DTI, MMOs should be placed on all source vessels.
- Operators are advised to contact JNCC at the earliest opportunity to request information on the need for MMOs. Every application for consent to carry out a seismic survey will be treated on a case-by-case basis by the JNCC however the following is a guide to our probable advice to the DTI on the need for MMOs.

3. Likely requirements for Marine Mammal Observers

Area	Sensitivity / MMO Requirement
• **Southern North Sea** • **Irish Sea Basin**	**Cetacean sensitivities are generally low to moderate.** • Seismic surveys using large sources such as those for 2D or 3D seismic surveys may require a dedicated MMO. For all other surveys a dedicated MMO is usually not required however • A watch should be kept for marine mammals before airgun start up (See section 2) • A report should still be submitted to the JNCC containing location, effort and sighting forms (See Section 2).
• **Central and Northern North Sea** • **St Georges Channel** • **South West Approaches** • **English Channel**	**Cetacean sensitivities are highly variable.** Requirements for MMOs are varied according to the energy source volume, energy source pressure level, sound frequency and survey location however the following guidance is available. • Seismic surveys using large sources such as those for 2D or 3D seismic surveys will require a dedicated MMO. • All surveys requiring MMOs taking place between 1st April and 1st October north of 57° latitude will require two dedicated MMOs due to the longer daylight hours.
• **Moray Firth,** • **Cardigan Bay,** • **West of Britain (includes all areas to the north and west of Shetland and to the west of Orkney and the Western Isles)**	**Cetacean sensitivities are high** • Any seismic operation including site surveys will require dedicated experienced MMOs. • All surveys requiring MMOs taking place between 1st April and 1st October north of 57° latitude will require two dedicated MMOs due to the longer daylight hours.

Section 4 - Acoustic Monitoring

JNCC will advise the DTI that passive acoustic monitoring (PAM) should be used as a mitigation tool if sensitive species are likely to inhabit the proposed survey location. This additional measure is required where there are species of particular conservation importance or where a given species or group is difficult to detect by visual observation alone. Examples of areas where PAM may be required include deep-water areas west of Britain (for large baleen and sperm whales) and the Moray Firth (for bottlenose dolphins).

In all sea areas there is a concern that visual observation can be an ineffective measure, particularly during hours of darkness or poor visibility (such as fog), as marine mammals in the vicinity of airgun sources will not be detected. In line with the revised DTI position and other Government departments, JNCC view PAM as the only available mitigation technique that, at its current stage of development, will increase the detection of marine mammals prior to the soft start whilst having no possible adverse effect on marine mammals of its own. We would therefore encourage applicants to use PAM as it will increase the detection of marine mammals and we expect that as the technology matures over the next few years, PAM will become a requirement on seismic surveys.

4.1 Use of PAM as a mitigation tool

The following guidance is provided in regard to PON 14A applications where JNCC request PAM use as a mitigation tool. In many cases, PAM is not as accurate as visual observation when determining range. In practice this will mean that the exclusion zone must reflect the range accuracy of the system and will often be more than 500m. For example, if the range accuracy of a system is +/-300 metres, animals detected within 500 + 300 (800) metres of the source would lead to a delay in the soft start. It is therefore in the operators best interests to use the most accurate system available and to factor in the range inaccuracy. Where PAM is used the PON 14A application must contain an explanation of how the operator intends to deploy PAM to greatest effect.

Some PAM systems do not have accurate range determination facilities or can only calculate range for some species. In such cases, the detection of a confirmed cetacean vocalisation should be used to initiate postponement of soft start based on the expert judgment of the PAM operator who may be able to make a judgement about the range of the marine mammal (dependent on species) from the vessel by differentiating between distant and near-field vocalisations. In the absence of PAM systems capable of range determination this expert judgement may be used to ensure an area is free from cetaceans prior to the soft start.

Section 5 - Background Information

These 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 (SMRU). The guidelines have subsequently been reviewed three times by the Joint Nature Conservation Committee following consultation with interested parties and in the light of experience after their use since 1995.

5.1 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, The Conservation (Natural Habitats, etc.) Regulations Northern Ireland 1995 and The Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001.
- In addition, the UK is a signatory to the Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS) 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".

Section 6 - Further information, comments on these guidelines and contacts

Further information on the DTI's consent procedure is available at www.og.dti.gov.uk.

A copy of these guidelines, the standard forms (electronic and hard copy) and further background information is available from the above address or on the JNCC website: www.jncc.gov.uk/marine

If you have any comments or questions on these guidelines, or suggestions on how they may be improved please contact the JNCC Senior Offshore Advisor at the address shown above.

Appendix 2

MARINE MAMMAL RECORDING FORM - RECORD OF OPERATIONS

DTI ref. no. …………………….. Client ………………………………... Type of survey (site, 2D, 3D, 4C, OBC, VSP etc.) …………..……….
Ship ……………………… Seismic contractor ………….……… Total airgun volume (cu. in.) ……...……………………
Method of soft start (if site survey/ VSP) *Increase no. guns* *Increase pressure* *Decrease shotpoint interval*

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

	Airgun activity							**Pre-shooting search for marine mammals**					**Action necessary**		
Date	Reason for firing (line/ test, etc.)	Time soft start began	Time of full power	Time of start of line	Time of end of line	Time output reduced to 160 dB (if relevant)	Time airguns stopped	Who carried out search? (Job title)	Time pre-shooting search began	Time search ended	Reasons why animals may have been missed? (e.g. dark, fog, swell, etc.)	Were hydro-phones used?	Were animals present in the 30 mins before firing?	If yes, when were they last seen?	What action was taken? (e.g. delay shooting)

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

MARINE MAMMAL RECORDING FORM - LOCATION AND EFFORT DATA

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

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

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

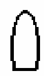
Return to: JNCC, Dunnet House, 7 Thistle Place, Aberdeen, AB10 1UZ (fax. 01224 621488; e-mail seismic@jncc.gov.uk).

MARINE MAMMAL RECORDING FORM - RECORD OF SIGHTING

Options in italics should be circled or underlined as appropriate

<table>
<tr><td>Date</td><td>Time (GMT)</td><td>DTI ref. no.</td><td>Sighting no.</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
(when animals first seen)

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

Please continue overleaf or on a separate sheet if necessary

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

GUIDE TO USING MARINE MAMMAL RECORDING FORMS

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

There are three forms to be completed:

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

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

Each form asks for a DTI reference number which should be obtained from the operator.

Record of Operations

This form asks for basic information on all uses of the airguns throughout the survey. JNCC will use this form to see how well your survey followed the *Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys*. You should complete one line on this form each time the airguns are used, whether for shooting a line, for testing, or for any other purpose (seismic crews do not routinely record test firing, so you will need to ask them to make a note of any times when they are testing the guns). The guidelines provide several alternative options for how to perform a soft start on high resolution site surveys and during vertical seismic profiling; the method used for these operations should be specified at the top of this form. The total volume of airguns firing at any one time should also be specified.

Airgun activity You should record all airgun activity at any time of day, including times when the airguns are firing overnight. You are asked to record the times of key stages of airgun activity: a) when the soft start began; b) when the airguns reached full power (this is not necessarily the same time as the start of line, as the airguns may reach full power before the start of line); c) the time of the start of line; d) the time of the end of line; e) the time when the output was reduced to 160 dB (this only applies where this procedure is permitted under the guidelines during short line turns on site surveys); and f) the time when the airguns stopped firing (this may or may not be the same as the time of the end of line). You should record this information for any uses of the guns, including testing - you may need to remind the seismic crew of the need for a soft start when testing the guns. If the guns stop before reaching full power, put "No full power" (or "NFP") in the column headed 'Time when the airguns reached full power' and record the time the airguns stopped as usual. If the airguns continue firing between lines (in cases where this is permitted under the guidelines during short line turns) the time when the airguns stopped should be left blank, but the start and end times of subsequent survey lines should be filled in on further lines of the form as appropriate (if firing continues at reduced output during short line turns, then the time when output began to increase again should be recorded as the beginning of the soft start and the time when full power was resumed should also be recorded).

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

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

Location and Effort Data

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

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

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

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

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

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

Record of Sighting

The sighting form need only be filled 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.

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

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

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

How did this sighting occur You should indicate whether you spotted the marine mammals while you were keeping a continuous lookout. Sometimes someone else may call your attention to a marine mammal that you would otherwise not have seen, in which case you should tick the second box ('spotted incidentally') - JNCC need to know this to make an accurate assessment of sighting rate. If you are not sure whether to tick the first or second box, then tick the third box ('other') and specify how you came to be aware of the marine mammals.

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

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

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

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

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

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

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

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

Behaviour If there is more than one sort of behaviour then record all behaviours seen. If airgun activity changes during an encounter with marine mammals then it should be made clear which behaviours were exhibited when the airguns were firing and which were exhibited when the airguns were not firing. Examples of behaviour are:

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

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

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

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

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

Completed forms should be returned to:

Joint Nature Conservation Committee,
Marine Advice,
Dunnet House,
7 Thistle Place,
Aberdeen,
AB10 1UZ.

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

Appendix 3

Additional reports received by JNCC during 2001-02

Seismic survey vessels and associated guard vessels operating outside Europe:

Geo Surveyor	Nigeria

Other vessels and platforms operating in UK and adjacent waters:

Arcana (guard vessel)	Northern North Sea
Faroe Connector (support vessel)	West of Shetland
Grampian Frontier (field support vessel)	West of Shetland
Highland Fortress (ROV survey vessel)	Southern North Sea
Highland Spirit (standby vessel)	West of Shetland
Jack Bates (drilling rig)	?
Kommander Subsea (survey vessel)	Southern North Sea
Long Sand (dredger)	Moray Firth
Regalia (construction vessel)	West of Shetland
Seaway Commander (survey vessel)	Southern North Sea
Tertnes (rockdumper)	Southern North Sea
West Navion (drillship)	West of Shetland

Appendix 4

Scientific names of species mentioned in the text

Common seal	*Phoca vitulina*
Grey seal	*Halichoerus grypus*
Humpback whale	*Megaptera novaeangliae*
Blue whale	*Balaenoptera musculus*
Fin whale	*Balaenoptera physalus*
Sei whale	*Balaenoptera borealis*
Minke whale	*Balaenoptera acutorostrata*
Sperm whale	*Physeter macrocephalus*
Beaked whale spp.	*Mesoplodon/ Ziphius/ Hyperoodon* spp.
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*

Joint Nature Conservation Committee
Report Distribution

Report number:	359
Date received:	June 2004
Report title:	Marine mammal observations during seismic surveys in 2001 and 2002.
Contractor:	C J S Barton
Comments:	Observations of marine mammals seen during seismic surveys carried out in accordance with the *Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys* were forwarded to JNCC. This report presents an analysis of the data gathered.

Restrictions: None   Number of copies: 250

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Peter Dyson	Total Exploration UK plc	1
Wendy Brown	Total Exploration UK plc	1
John Bruce	Total Exploration UK plc	1
Chris Stevenson	Total Exploration UK plc	1
Chris Sleap	TXU-Europe Upstream Limited	1
Mick Borwell	UKOOA	2
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Martin David	Veba Oil and Gas	1
Seismic contractors		
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Kirsty Clough	World Wide Fund for Nature	1
Nancy Nairn	World Wide Fund for Nature	1
Sîan Pullen	World Wide Fund for Nature	1