6. Cetacean distribution

Between June 1979 and March 1999, surveys by SAST and European colleagues within ESAS have recorded a total of fifteen species (12,482 individuals) of cetacean within the study area (Table 8). A further 1,011 individuals were not identified to species level.

Table 8. Total number of each cetacean species recorded in the study area since 1979

Cetacean Species	Total number of animals recorded	Total number of sightings	Average group size
Fin whale *Balaenoptera physalus*	29	17	1.7
Sei whale *Balaenoptera borealis*	42	19	2.2
Minke whale *Balaenoptera acutorostrata*	158	143	1.1
Humpback whale *Megaptera novaeangliae*	5	4	1.3
Sperm whale *Physeter macrocephalus*	80	68	1.2
Northern bottlenose whale *Hyperoodon ampullatus*	17	7	2.4
Sowerby's beaked whale *Mesoplodon bidens*	1	1	1.0
Killer whale *Orcinus orca*	241	52	4.6
Long-finned pilot whale *Globicephala melas*	2,018	175	11.5
Atlantic white-sided dolphin *Lagenorhynchus acutus*	4,925	341	14.4
White-beaked dolphin *Lagenorhynchus albirostris*	1,859	531	3.5
Risso's dolphin *Grampus griseus*	292	78	3.7
Bottlenose dolphin *Tursiops truncatus*	131	21	6.2
Common dolphin *Delphinus delphis*	1,210	101	12.0
Harbour porpoise *Phocoena phocoena*	1,474	754	2.0
Unidentified Cetaceans			
Cetacean sp.	66	30	2.2
Whale sp.	192	104	1.8
Beaked whale sp.	62	21	3.0
Dolphin sp.	691	252	2.7

6.1 Fin whale *Balaenoptera physalus*

A total of 29 fin whales was recorded between May and October, with a peak number of 11 animals occurring during August. A single immature was recorded during August in the Faroe-Shetland Channel. Although average group size for this species was 1.7 animals, one sighting at the Anton Dohrn Seamount in July 1995 involved five animals. A single fin whale was also observed associating with six white-sided dolphins in the Faroe Bank Channel. The distribution of fin whales was centred north of 60°N to the south and south-east of the Faroe Islands, and all sightings occurred near or beyond the 1,000 m isobath (Figure 46). It is possible that fin whales utilise the shelf edge as a migration channel (Evans 1987), spending the summer months at high latitudes before returning to the southern wintering grounds. Most sightings of fin whales in UK waters occur between May and October (Evans 1992; Pollock *et al.* 1997), suggesting that whales utilise the area during the summer. However, acoustic detection of fin whales to the north and west of Scotland suggests that at least some animals may be resident in Atlantic Frontier waters throughout the year (Clark & Charif 1998). Also sightings of adults with calves off south-west England and Ireland during the winter may indicate that some animals remain within UK waters to breed (Evans 1992) or use the region as a nursery ground.

6.2 Sei whale *Balaenoptera borealis*

Sei whales are generally considered to be pelagic animals, and none had been recorded prior to the commencement of dedicated deep-water surveys. Seventy-four percent of the 42 animals recorded were observed in August. Sightings were concentrated in deep water to the south-east of the Faroe Islands (Figure 46). Sei whales tended to form slightly larger groups than fin whales, with aggregations occurring particularly in the Faroe-Shetland Channel. Whaling records suggest that numbers of sei whales in the north-east Atlantic fluctuate between years, with peak numbers occurring during 'invasion years' (Christensen *et al.* 1992). Compared with fin or minke whales, sei whales are specialist feeders (Sigurjónsson 1995) and the variation in their annual occurrence may result from fluctuations in food supply, particularly of the copepod *Calanus finmarchicus* (Ingebrigtsen 1929; Jonsgård & Darling 1977). However, in the North Atlantic, sei whales will also feed on euphausiids and small schooling fish (Mizroch *et al.* 1984). Sei whales migrate between high latitude summer feeding areas and low latitude wintering

areas, and they are thought to reach Scottish waters between April and July, leaving during late August and September (Jonsgård & Darling 1977). Within the study area, sei whales were sighted only between May and October, despite coverage in suitable waters at other times of year. Sei whale records occurred south of 59°N during June and July and north of 60°N during all other months. Although small groups of animals may remain at high latitudes over the winter (Evans 1992), none were recorded there during this study.

6.3 Minke whale *Balaenoptera acutorostrata*

Minke whales were the most common baleen whale species recorded in the study area, with a total of 158 individuals (Figure 47). Only 12 sightings occurred in water deeper than 200 m, indicating the inshore nature of this species. Sightings were most frequent along the east coast of Lewis in the north Minch, and to the south of the Isle of Skye. Minke whales were recorded only between May and October, with over 74% of the total number of animals recorded between June and August. The seasonal pattern in minke whale sightings suggests migration of animals into British waters to feed during the summer months, before movement south to breed during the winter (Evans 1980). Juvenile minke whales were recorded on the east and west coasts of Lewis during June and July, with two immature animals south of Skye in August and October. Minke whales have twice been recorded in association with harbour porpoises; it is possible that the two species occur in the same area to exploit similar food supplies (Camphuysen & Webb in press).

6.4 Humpback whale *Megaptera novaeangliae*

The humpback whale is uncommon in Atlantic Frontier waters, with only four records since 1979. Sightings occurred in the summer months between May and September, corresponding with seasonal migration to high latitude feeding areas in the north-west Atlantic (Martin *et al.* 1984). Three sightings were of single animals, while one sighting of two animals was made in the Faroe-Shetland Channel during July 1988. A single humpback whale was recorded with three white-sided dolphins in less than 200 m depth of water to the west of Lewis during September 1996. All other sightings have occurred in over 1,000 m depth of water (Figure 46). Five sightings from seismic vessels during 1996 and 1997 also occurred near the 1,000 m isobath (Stone 1997, 1998). Although records of humpbacks from both SAST and seismic observations occurred during the summer months only, acoustic surveys to the north and west of Scotland have detected humpbacks between November and March (Clark & Charif 1998), indicating that some animals may utilise the Atlantic Frontier during the winter months. The north-east Atlantic humpback whale population is only slowly recovering from heavy exploitation, although the species may never have been particularly numerous in the area (Winn & Reichley 1985). All four of the SAST sightings within the study area have occurred since 1988, suggesting a potential return of some animals to the region. This is also indicated by the annual return of up to three humpback whales to the inshore waters around the Shetland Islands between March and September since 1992 (P. Fisher pers. comm.) and by other sightings around the coast of Scotland (Gibson 1995).

6.5 Sperm whale *Physeter macrocephalus*

Sperm whales are the most frequently encountered species of large whale within the study area, with a total of 80 animals recorded. Sightings occurred in all months of the year except for February and March, and peaked in June. Low effort during February and March may explain the lack of records, though other months with low effort (November and December) did produce sperm whale sightings. Almost all sperm whale sightings occurred along the 1,000 m isobath, with animals either on or beyond the continental slope. Acoustic detection rates have also been found to be highest in offshore waters (Lewis *et al.* 1998). Concentrations of sperm whales occur particularly along the Ymir Ridge and north of Shetland in the Faroe-Shetland Channel (Figure 48). Sperm whales feed on squid, octopus and fish, particularly cephalopod populations that occur in intermediate and deep waters (Clarke 1980; Gaskin 1982). An increased primary productivity and subsequent increase in prey species where water currents converge along the continental slope may therefore explain the relationship of sperm whales with the shelf edge (Waring *et al.* 1993; Jaquet 1996). All aged animals were adults and the average group size of 1.2 animals suggests that most animals were adult males, since females tend to form gregarious breeding pods (Best 1979). In the North Atlantic, adult females were not taken by whaling stations in the British Isles (Rice 1989), and the majority of sighted or stranded sperm whales around Britain and Ireland are sub-adult or mature males (Berrow *et al.* 1993).

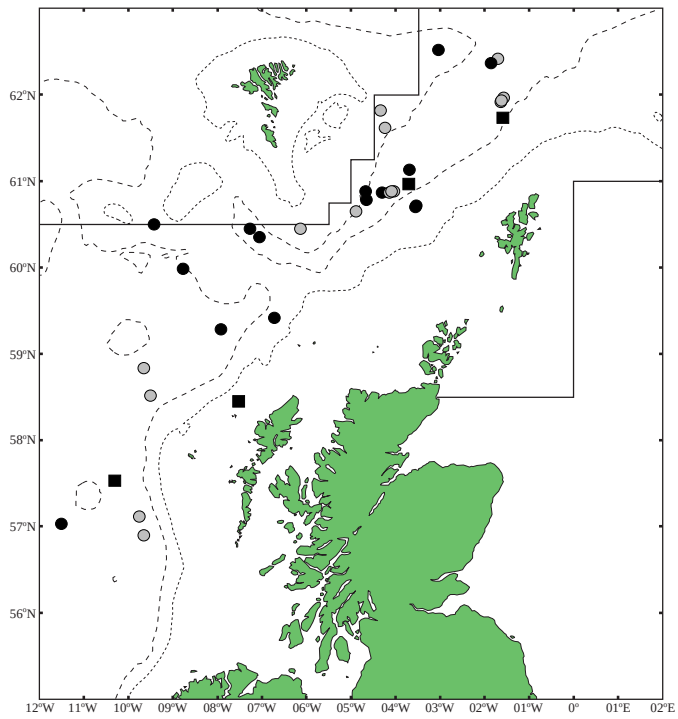


Figure 46. Distribution of fin, sei and humpback whale sightings throughout the year

Fin whale Sei whale Humpback whale

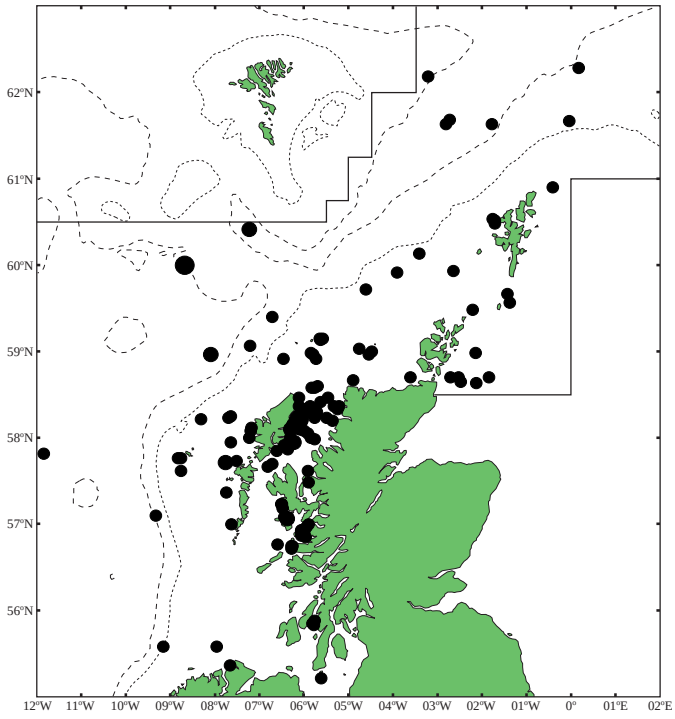


Figure 47. Distribution of minke whale sightings throughout the year

Number of individuals: 1 2 3+

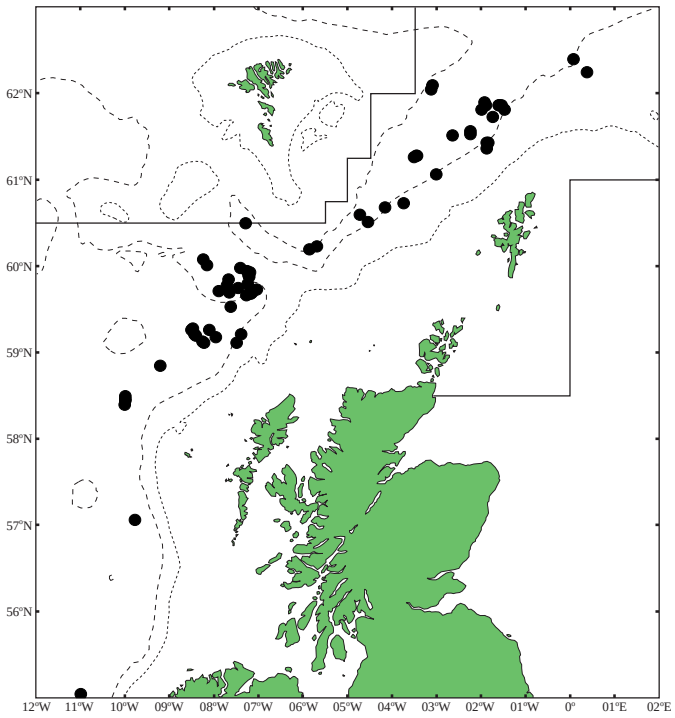


Figure 48. Distribution of sperm whale sightings throughout the year

Number of individuals: 1 2 3+

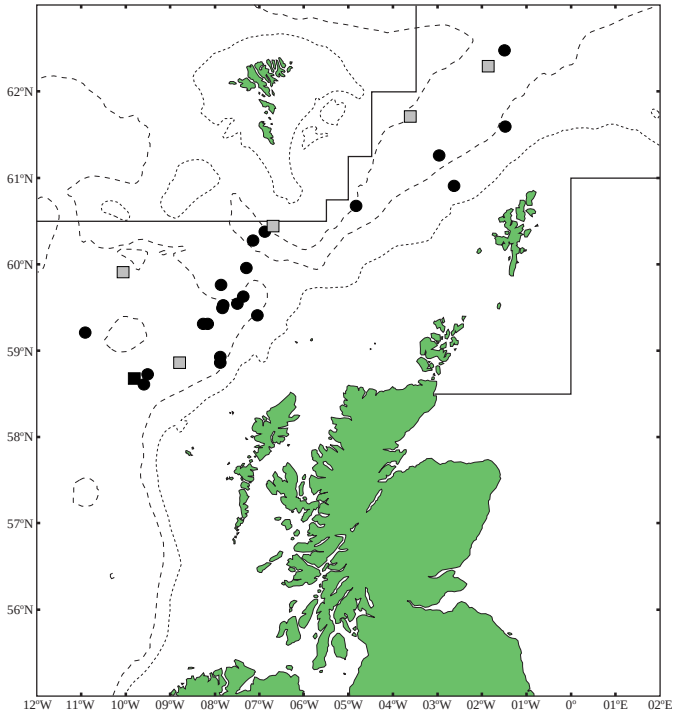


Figure 49. Distribution of beaked whale sightings throughout the year

Northern bottlenose whale

Sowerby's beaked whale

Unidentified beaked whale

6.6 Unidentified beaked whales *Mesoplodon* spp.

The distribution and occurrence of beaked whales in the waters to the north and west of Scotland is poorly understood. Beaked whales tend to inhabit deep, offshore waters, and their long dive duration and inconspicuous surfacing behaviour may explain the limited number of sightings at sea. A total of 62 unidentified beaked whales have been recorded in the study area, with no sightings at all prior to the commencement of deep water surveys in 1995. The majority of animals observed were thought to belong to the genus *Mesoplodon*, which includes 14 species of small, taxonomically similar beaked whales. Beaked whales were observed throughout the year, but have not been recorded between February and April or during July. In February, there was no coverage in the waters in which beaked whales have been recorded in, but suitable survey coverage was achieved during April and July. A distinct peak in the number of whales recorded occurred during August (68% of all individuals sighted). Their distribution is similar, but slightly more southerly than that of the sperm whale, with almost all sightings occurring in water deeper than 1,000 m, particularly south of the Ymir Ridge (Figure 49). The diet of beaked whales is mostly squid and pelagic fish, which explains their occurrence in deep-water areas, although this is largely based on the stomach contents of stranded animals (Mead 1989). Whereas the average group size over the year was 2.95 animals, sightings were most frequently of single animals, and groups of up to ten have been recorded in the study area. A sighting of three juvenile animals occurred during August.

6.7 Northern bottlenose whale *Hyperoodon ampullatus*

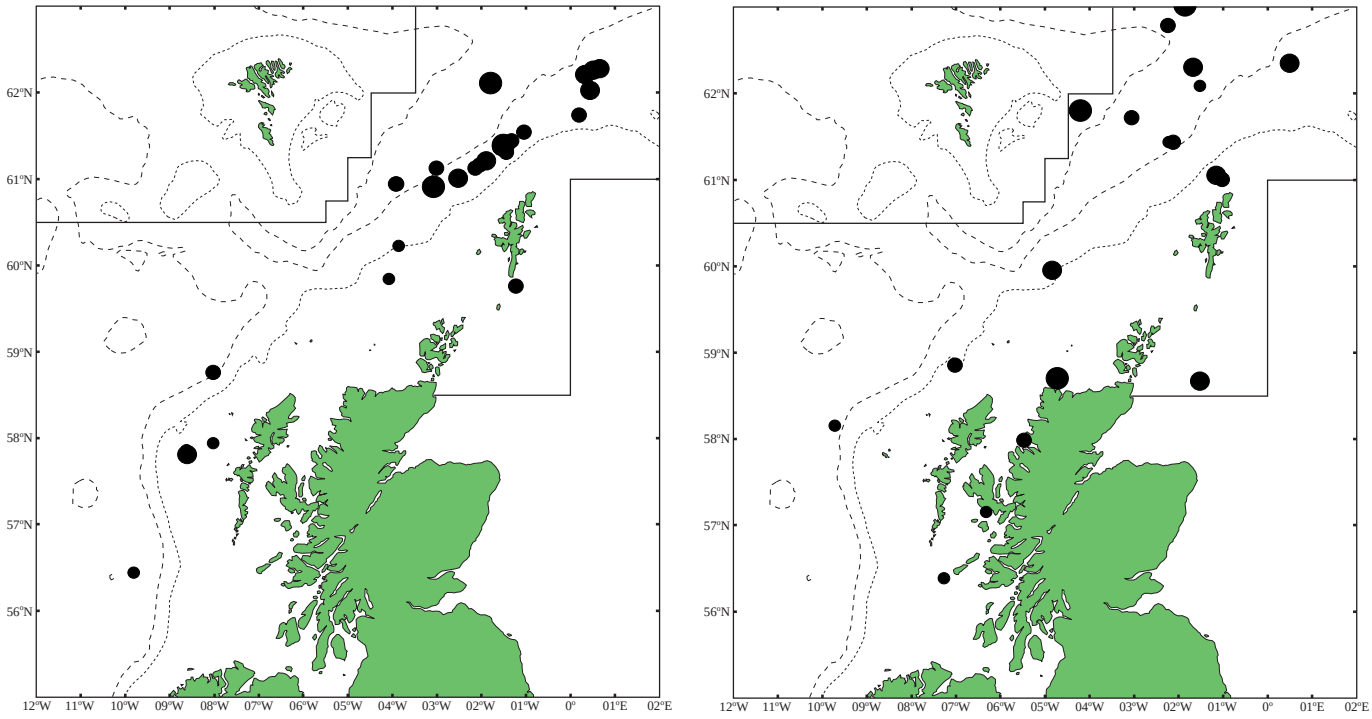
There have been seven sightings of northern bottlenose whales since 1979, involving a total of 17 animals. The distribution of northern bottlenose whales in the North Atlantic is centred in cold, deep waters near or seaward of the 1,000 m isobath (Reeves *et al.* 1993). This is definitely the case to the north and west of Scotland where all SAST records have occurred over deep water (Figure 49). Northern bottlenose whales are thought to migrate northwards from low latitudes in the spring, returning south from polar waters in the autumn (Benjaminsen & Christensen 1979). Peak numbers of animals during April and August, suggests that spring and autumn movements do occur within the region. Three northern bottlenose whales recorded to the north-west of Lewis during August 1998 appeared to be associating with large numbers of migrating long-finned pilot whales. Catches of bottlenose whales in the Faroe Islands peak during the autumn (Bloch *et al.* 1996), but they do occur throughout the year suggesting that some individuals within the study area may be non-migratory as has been found in the north-west Atlantic (Whitehead *et al.* 1997). There was only one winter record (in November). The average group size of bottlenose whales observed in the study area was 2.4 animals. Frequent sightings of two animals in both British (Evans 1980; Weir 1999) and Faroese waters (Bloch *et al.* 1996) suggests that animals may travel together in pairs.

6.8 Sowerby's beaked whale *Mesoplodon bidens*

Sowerby's beaked whale was positively identified once, when a single individual surfaced in deep water south of the Rosemary Bank in June 1998 (Figure 49). The close proximity of the animal to the vessel enabled identification to be made from the position of the teeth halfway along the lower jaw. It is likely that many of the unidentified *Mesoplodon* spp. were also of this species. Although Moore (1966) considered the centre of distribution of Sowerby's beaked whale to be the North Sea, stomach contents from stranded animals indicate an offshore pelagic distribution (Ostrom *et al.* 1993). This is also suggested by sightings at sea that occur in deep, offshore water (Carlström *et al.* 1997; Hooker & Baird 1999).

6.9 Killer whale *Orcinus orca*

Killer whales were distributed over both the continental shelf and in deep offshore waters, with the main concentration of sightings occurring over the slope to the north and north-west of Shetland. They were recorded on 52 occasions, and were observed in every month of the year except February and September. Of the total number of animals recorded, 43% were observed during June. Throughout May and June, sightings were distributed predominantly along the continental slope to the north of Shetland (Figure 50a). During the rest of the year sightings were widespread over the region (Figure 50b). Based on two sightings of an identifiable animal recorded over 100 km apart in the space of two weeks, Evans (1988) suggested that individual pods of this species may range over comparatively large distances in British waters. The average group size within the study area was 4.6 individuals, which accords with the mean group size recorded in the rest of British and Irish waters (Evans 1988). However, group size increased between June and August. Juvenile killer whales are generally sighted only in summer (Hammond & Lockyer 1988), and calves were observed in the study area in July and August.



a) May and June

b) July to April

Figure 50 a) - b). Distribution of killer whale sightings Number of individuals: • 1 ● 2-4 ● 5-8 ● 9+

6.10 Long-finned pilot whale *Globicephala melaena*

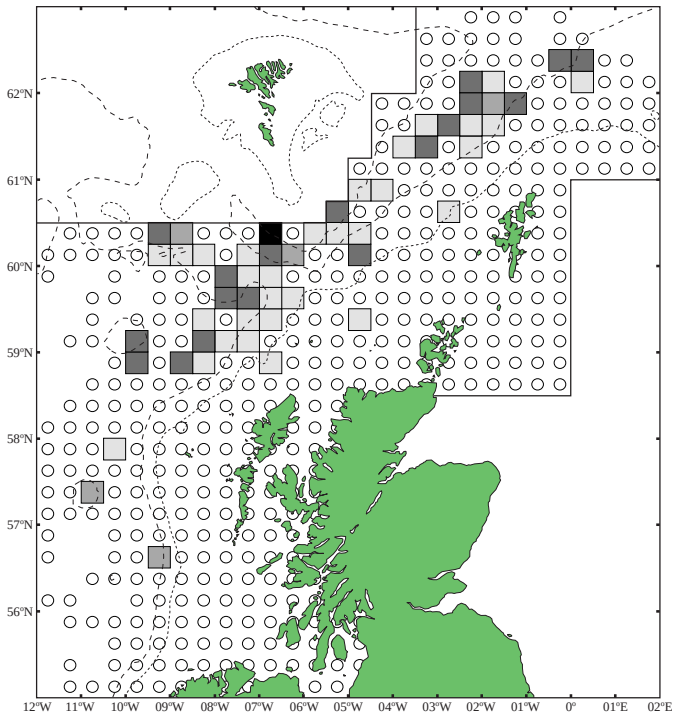


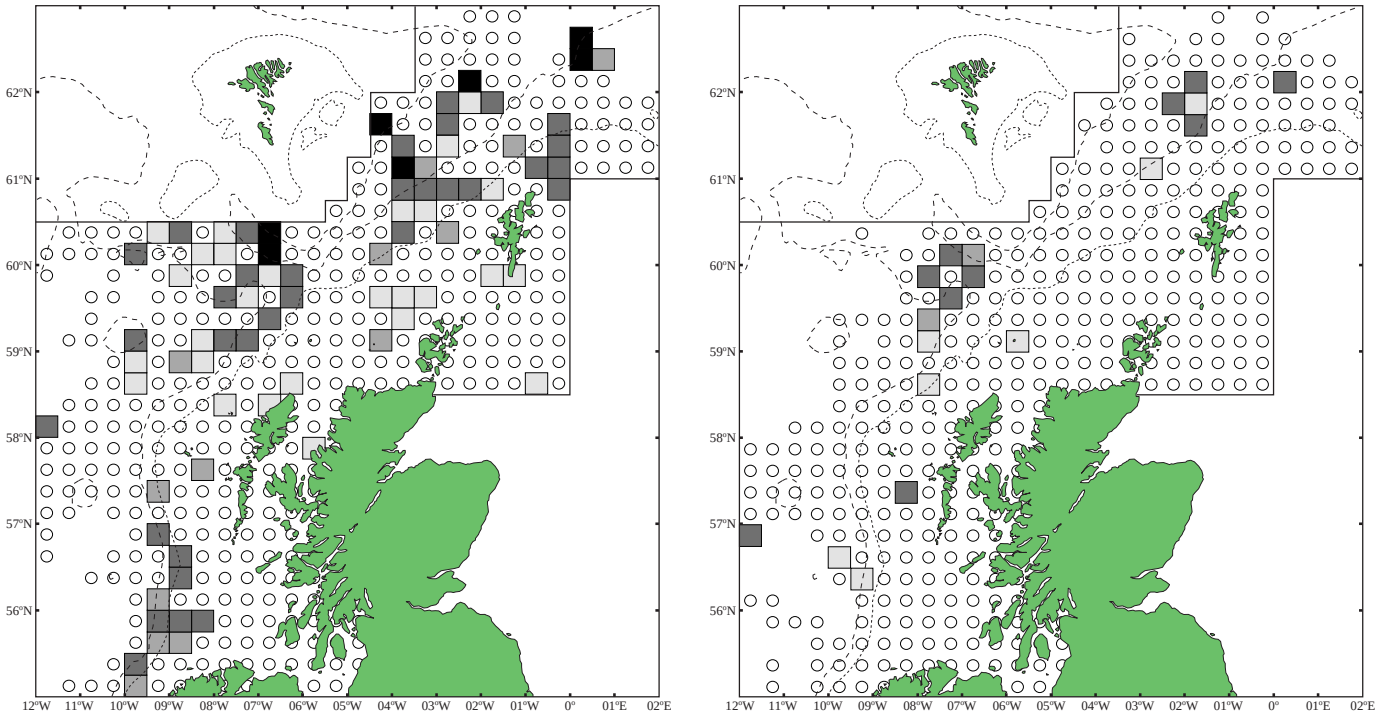
Figure 51. Abundance of long-finned pilot whales throughout the year

Abundance (individuals/km): ○ No whales ▢ 0.01-0.03 ▢ 0.04-0.06 ▢ 0.07-0.99 ■ 1.00+

Long-finned pilot whales were the second most abundant species of cetacean with 2,018 animals recorded (Table 8). Their distribution was concentrated along the continental slope north of Scotland, particularly in waters around 1,000 m deep (Figure 51). The highest abundance occurred in the Faroe-Shetland Channel and the Faroe Bank Channel. Within the study area, long-finned pilot whales feed principally on deep water squid (Desportes & Mouritsen 1993), and their occurrence in deep water channels appears to be related to the distribution of squid (Bloch *et al.* 1993). Concentrations of long-finned pilot whales along the United States shelf edge have also been related to the presence of squid (Payne & Heinemann 1993). Long-finned pilot whales are a gregarious species, the average group size recorded was 11.5 animals, although a pod of 400 individuals was encountered in the Faroe Bank Channel in August 1997. The average group size peaked between June and September, and 67 % of recorded calves occurred in August. Associations were recorded with white-sided dolphins on 37 occasions, bottlenose dolphins twice, and once each with common dolphins and northern bottlenose whales.

6.11 Atlantic white-sided dolphin *Lagenorhynchus acutus*

The Atlantic white-sided dolphin was the most abundant species observed in the study area, with a total of 4,925 animals recorded (Table 8). The distribution of this species is centred mostly in deep water along the shelf edge and in water deeper than 1,000 m. Atlantic white-sided dolphins were recorded in all months of the year, but were more widespread and abundant between June and November (Figure 52a), when animals occurred in high abundance over the Faroe-Shetland Channel and the Faroe Bank Channel. Groups were more frequently recorded in continental shelf waters (<200 m depth) during the summer, particularly in July. This may correspond with the calving period (Evans 1992) although other data suggests an extended breeding period (Reeves *et al.* 1999a). Juvenile animals were recorded between June and August, and peaked in July. An inshore movement of this species during the summer has also been recorded in areas of the western Atlantic (Northridge *et al.* 1997). During August there was a large increase in numbers of white-sided dolphins. The average group size of 14.4 animals indicates that the white-sided dolphin was the most gregarious species of those recorded. Groups of dolphins were often split into several sub-groups when both feeding and travelling, as has been found elsewhere in the North Atlantic (Leopold & Couperus 1995). Groups of over 100 animals were recorded on six occasions. Between December and May, there was a reduction in the number of animals, and most sightings occurred in deep, offshore water (Figure 52b). The distribution of white-sided dolphins in the north-west Atlantic is centred on areas of high seabed relief (Selzer & Payne 1988), which seems also to be the case in the Atlantic Frontier where dolphins were concentrated over the shelf edge and deep water channels. Atlantic white-sided dolphins are regularly recorded in association with long-finned pilot whales, and have also been observed with fin and humpback whales, and bottlenose, white-beaked and common dolphins.



a) June to November

b) December to May

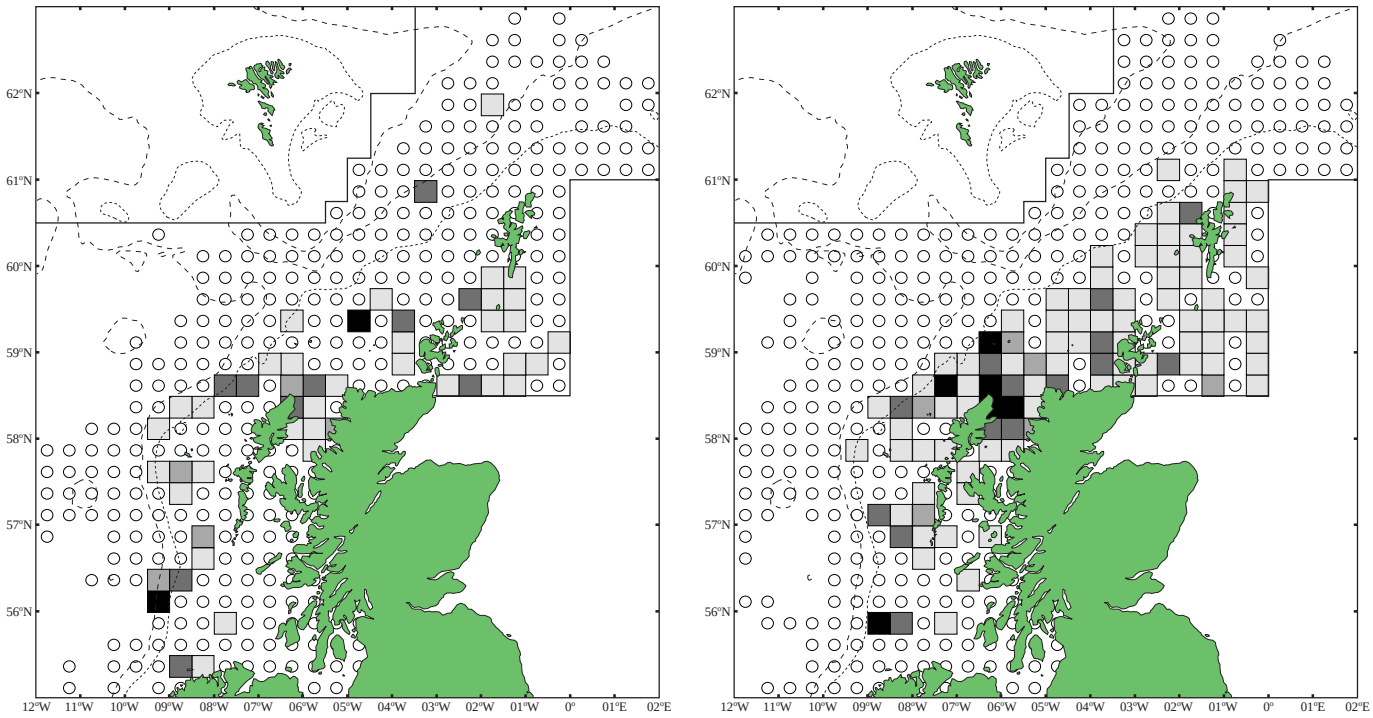
Figure 52 a) - b). Abundance of Atlantic white-sided dolphins

Abundance (individuals/km): ○ No animals ▢ 0.01-0.03 ▢ 0.04-0.06 ▢ 0.07-0.99 ■ 1.00+

6.12 White-beaked dolphin *Lagenorhynchus albirostris*

The white-beaked dolphin was the most commonly recorded species in shelf waters to the north and west of Scotland, to where its distribution was almost entirely confined. White-beaked dolphins were recorded in every month of the year, with an increase in number between May and October, peaking during July. Between November and April, white-beaked dolphins were distributed at low abundance in the Minch, south of Shetland and along slope waters (Figure 53a). White-beaked dolphins showed a much more widespread pattern of distribution between May and October, with low abundance throughout most of the shelf waters, and high abundance in the northern portion of the Minch (Figure 53b). The white-beaked dolphin generally feeds on clupeids (e.g. herring), gadids (e.g. cod, haddock and whiting) and hake (Reeves *et al.* 1999b). It has been suggested that the peak in the number of white-beaked dolphins during July may be related to concentrations of

herring, which spawn during the spring and autumn off north-west Scotland and in the autumn off north Scotland (Coull *et al.* 1998; Evans 1980). The white-beaked dolphin was the only cetacean to be recorded in every year since 1979, indicating its common occurrence. Although white-beaked dolphin schools comprised an average of only 3.5 animals, the high frequency with which they were observed rendered this species the third most numerous cetacean recorded. Juvenile white-beaked dolphins were seen in January, March and between July and October, with August providing the highest numbers of juvenile and immature animals. White-beaked dolphins have been recorded in association with white-sided dolphins and harbour porpoises.



a) November to April

b) May to October

Figure 53 a) - b). Abundance of white-beaked dolphins

Abundance (individuals/km): ○ No animals □ 0.01-0.02 □ 0.03-0.04 ■ 0.05-0.09 ■ 0.10+

6.13 Risso's dolphin *Grampus griseus*

Risso's dolphin is not as abundant as many other dolphin species in the study area, but is widely distributed throughout the shelf waters of north Scotland, the Orkney and Shetland Islands, and particularly around the Western Isles (Figure 54). Although they are generally considered to be a species found beyond the continental slope (Kruse *et al.* 1999), most sightings occurred in shelf waters shallower than 200 m, with records along the shelf edge between July and December. Numbers show a clear peak in August and September, when animals were particularly concentrated around the north-east coast of Lewis. Juvenile Risso's dolphins were sighted between March and November. Risso's dolphins are probably resident in certain areas of the study area, in particular the waters east of Lewis where recognisable individuals are seen repeatedly (Atkinson *et al.* 1997).

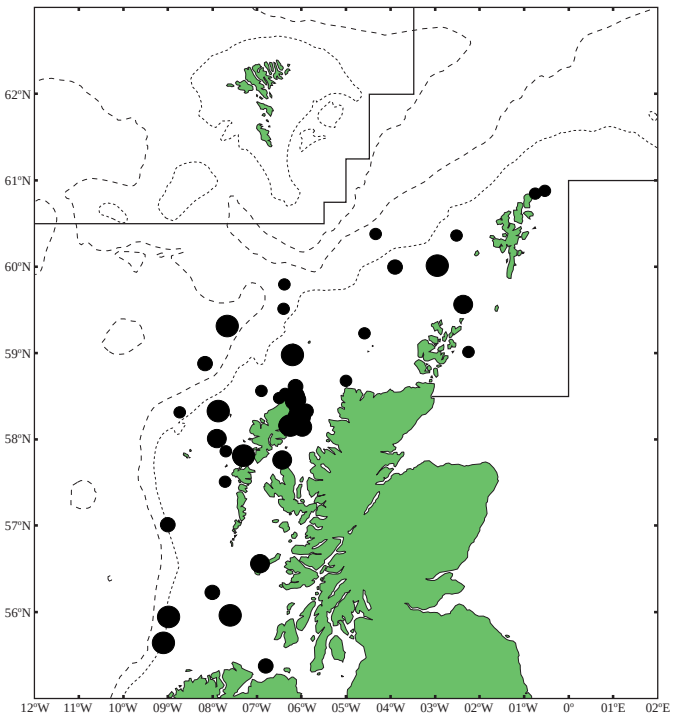
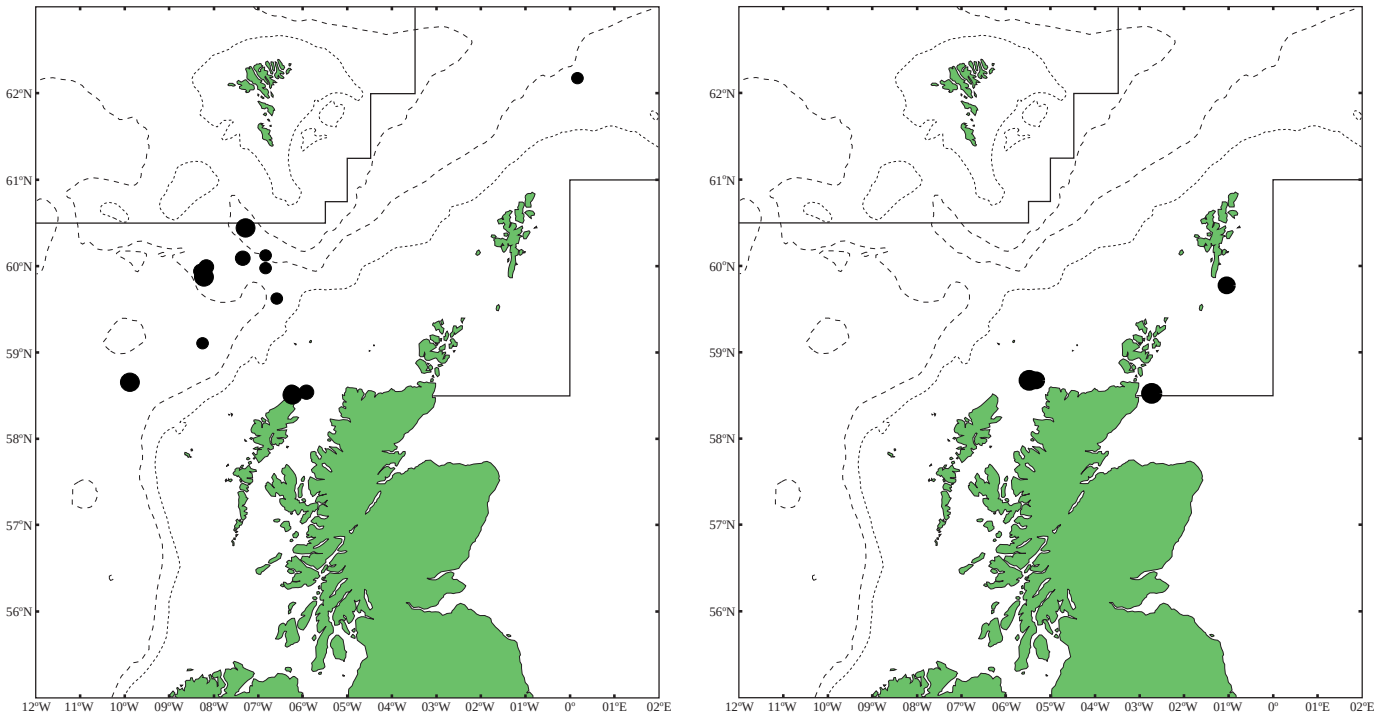


Figure 52. Distribution of Risso's dolphin sightings throughout the year

Number of individuals: • 1-2 • 3-4 • 5-7 • 8+

6.14 Bottlenose dolphin *Tursiops truncatus*

Bottlenose dolphins were infrequently recorded, with a total of 21 sightings (131 animals) since 1979. Between April and August, bottlenose dolphins were found in coastal shelf waters to the north-east of the Western Isles, south of Shetland and off north-east Scotland (Figure 55a). Bottlenose dolphins were generally uncommon during these months with only five sightings. The bottlenose dolphin also occurred in offshore groups that were recorded along the continental shelf edge close to the 1,000 m isobath. Bottlenose dolphins were sighted offshore between September and March (Figure 55b), with deep-water sightings concentrated along the Wyville-Thomson and Ymir Ridges. The water depth at these ridges is similar to the mean depth for offshore bottlenose dolphin sightings in the north-west Atlantic (Kenney 1990). School size ranged from one to 30 animals, with an average of 6.23 animals. School size increased to an average of 13.0 animals during September and October when animals were mostly offshore. Bottlenose dolphins in offshore waters have been recorded with pilot whales and white-sided dolphins. Sightings of bottlenose dolphins recorded on other UK surveys (Evans 1981), and in other areas of the world (Scott & Chivers 1990) indicate ecological separation into inshore and offshore populations, but the number of sightings is low in our data-set and more research and survey work would be required to establish this.



a) September to March

b) April to August

Figure 55 a) - b). Distribution of bottlenose dolphin sightings throughout the year Number of individuals ● 1-3 ● 4-8 ● 9+

6.15 Common dolphin *Delphinus delphis*

There have been 101 sightings of common dolphins in the Atlantic Frontier, where they occur towards the northern extremity of their distribution. There were only three records north of 60°N latitude, with most sightings concentrated at about 59°N on the shelf west of the Western Isles (Figure 56). The majority of common dolphin sightings were recorded in deep water over or beyond the 1,000 m isobath. Common dolphins were found in every month of the year, with numbers peaking in July, September and November. Notable concentrations of animals occurred on the shelf to the north-west of the Western Isles during October and November. Juvenile common dolphins were recorded between July and November, with a peak in August. Common dolphins were more gregarious than many species, with an average group size of 12.0 animals and five records of schools containing over fifty animals. Associations of common dolphins with long-finned pilot whales and white-sided dolphins were recorded, each on one occasion. Common dolphins occur more frequently over areas of high seabed relief and in warmer, more saline waters off the north-eastern United States (Selzer & Payne 1988). The seasonal variation in abundance and distribution of common dolphins may be related to prey distribution, with aggregations of dolphins occurring over upwellings (Hui 1979) and at frontal systems (Goold 1998) where prey species may concentrate.

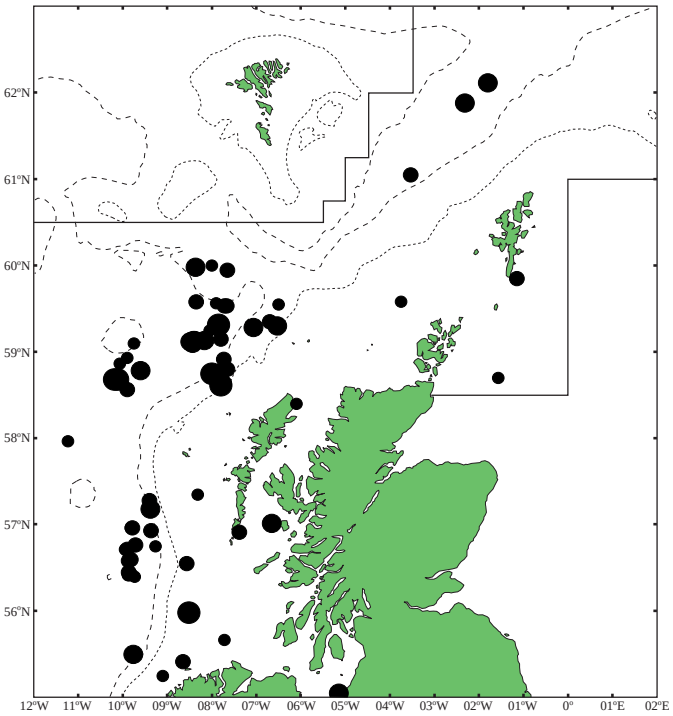
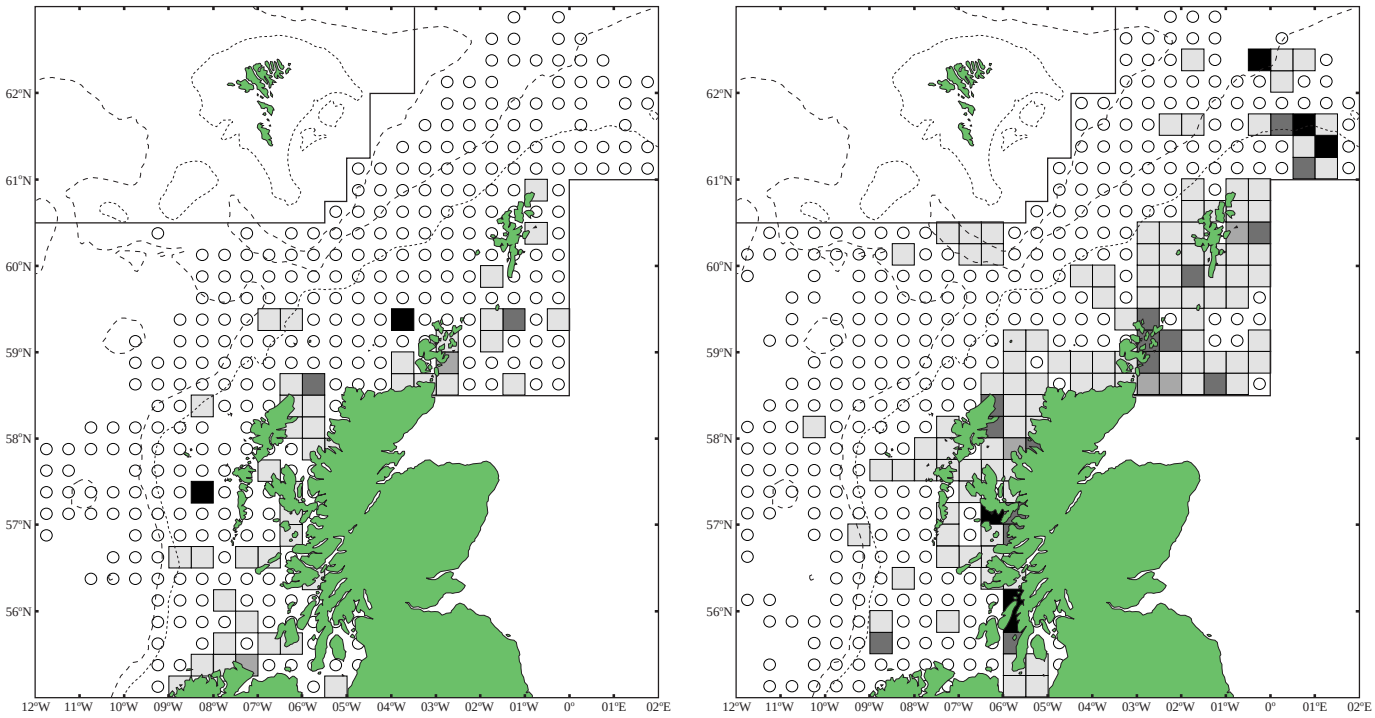


Figure 56. Distribution of common dolphin sightings throughout the year

Number of individuals: ● 1-3 ● 4-9 ● 10-39 ● 40+

6.16 Harbour porpoise *Phocoena phocoena*

The harbour porpoise was the most frequently sighted cetacean species (Table 8) and was widely distributed in shelf waters, shallower than the 200 m isobath. Acoustic monitoring techniques have also shown the harbour porpoise to be more frequent in inshore waters (Lewis *et al.* 1998). Between November and March, harbour porpoises were sighted at low abundance over the shelf, with higher concentrations to the north-west of the Orkney Islands and west of South Uist (Figure 57a). Over the summer months between April and October, they were much more widely sighted over the shelf with moderate concentrations on the north-east coast of Lewis, around



a) November to March

b) April to October

Figure 57 a) - b). Distribution of harbour porpoise throughout the year

Abundance (individuals/km): ○ No animals □ 0.01-0.02 ■ 0.03-0.04 ■ 0.05-0.09 ■ 0.10+

Orkney and Shetland, and on the west Scottish mainland (Figure 57b). Also during this period, a small number were found in deep water off the shelf edge, particularly within the Faroe Bank Channel. School size varied between one and 20 animals, but with an average of 2.0 individuals. The average observed group size increased from 1.9 during May to September, to 2.4 over the winter months from October to April. Sightings increased between June and September, and reached a marked peak during July and August. Calves were recorded in the study area between June and August. Harbour porpoises were recorded in the vicinity of minke whales and white-beaked dolphins in the Minch. The diet of harbour porpoises varies regionally but is dominated by clupeids supplemented with gadids and other demersal fish (Martin 1995; Read 1999).

7. Pinniped distribution

Three species of pinniped have been recorded during surveys (Table 9). The common (harbour) seal *Phoca vitulina* and the grey seal *Halichoerus grypus* both breed in the survey area, whereas the hooded seal *Crystophora cristata* has been recorded as a non-breeding visitor.

Table 9. Distribution by month of pinniped sightings (number of animals)

Species	J	F	M	A	M	J	J	A	S	O	N	D
Common (Harbour) seal	6	4	11	10	2	19	7	13	4	4	0	4
Grey seal	51	16	22	16	88	67	64	45	28	10	6	6
Hooded seal	1	0	0	0	1	1	2	0	1	1	0	0
Unidentified pinniped	19	8	12	3	18	23	32	26	4	1	5	4

7.1 Common (Harbour) seal *Phoca vitulina*

The common seal is a resident breeder within the survey area. It is distributed around all the coasts of north-west Scotland and the offshore islands. There are no common seals breeding in the Faroe Islands (Mikkelsen & Haug 1999). The total population in the UK is estimated to be 28,980, 85% of these within the survey area (Bleakley 1997; Duck 1996, 1997a-d).

Common seals were recorded in inshore waters throughout the survey area (Figure 58). There were few records further offshore and only one in waters deeper than 200 m, an animal on the edge of the Faroe-Shetland Channel in October.

Common seals were recorded during surveys in all months except November (Table 9). Peak numbers of common seals were recorded in the months of June to August. This may be a reflection of a larger proportion of the common seal population at sea in these months but it is probably also linked to the higher levels of survey effort in these months and/or better weather conditions. Low numbers of animals were recorded in May prior to the breeding season. Low numbers were also recorded during the winter months. This is more likely to be linked to low levels of survey effort at this time.

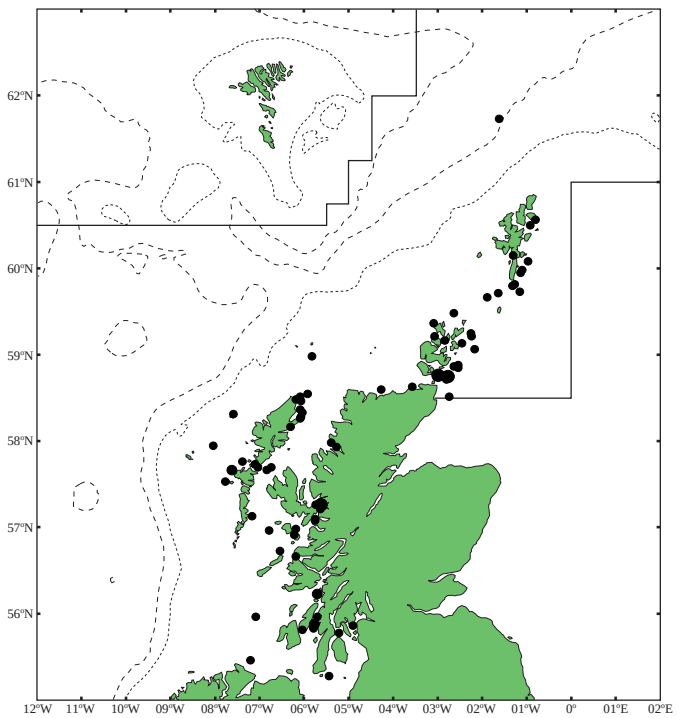


Figure 58. Common (harbour) seal sightings throughout the year

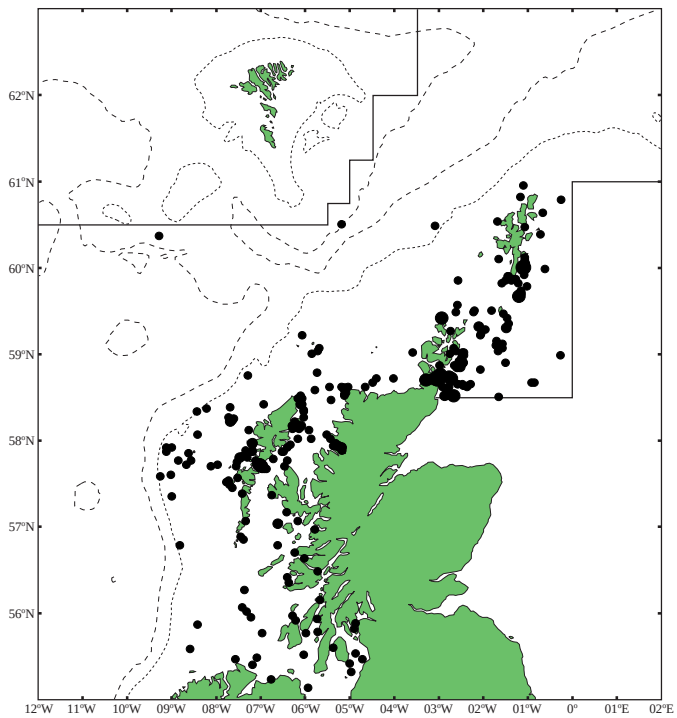


Figure 59. Grey seal sightings throughout the year

7.2 Grey seal *Halichoerus grypus*

The grey seal is a resident breeder within the survey area. It is widely distributed around the coasts of north-west Scotland and the offshore islands. The UK population of grey seals is of international importance; estimated to be about 40% of the world population (Thompson 1992). The survey area produces 86% of grey seal pups born in the UK and is therefore of national importance (Bleakley 1997; Duck 1996, 1997a-d). The Faroe Islands previously supported significant numbers of grey seals but there is no up-to-date information (Mikkelsen & Haug 1999).

Grey seals were recorded during surveys in all months (Table 9). Peak numbers of grey seals were recorded in the months of June to August, which may be partly a reflection on the high levels of survey effort in these months combined with better viewing conditions. Lowest numbers were recorded between October and December, which may be a factor of reduced levels of survey effort and is also due to the fact that animals are ashore to pup and mate at this time.

As with the common seal, grey seals were most frequently encountered in shelf waters (Figure 59). Grey seals were regularly encountered further offshore than common seals but they were only rarely recorded in waters deeper than 200 m. This corresponds with research showing that grey seals make longer distance foraging trips from haul-out sites than common seals (Bjørge 1995; Thompson *et al.* 1996). However, grey seals are also known to make long distance trips from the UK to the Faroes (McConnell *et al.* 1999).

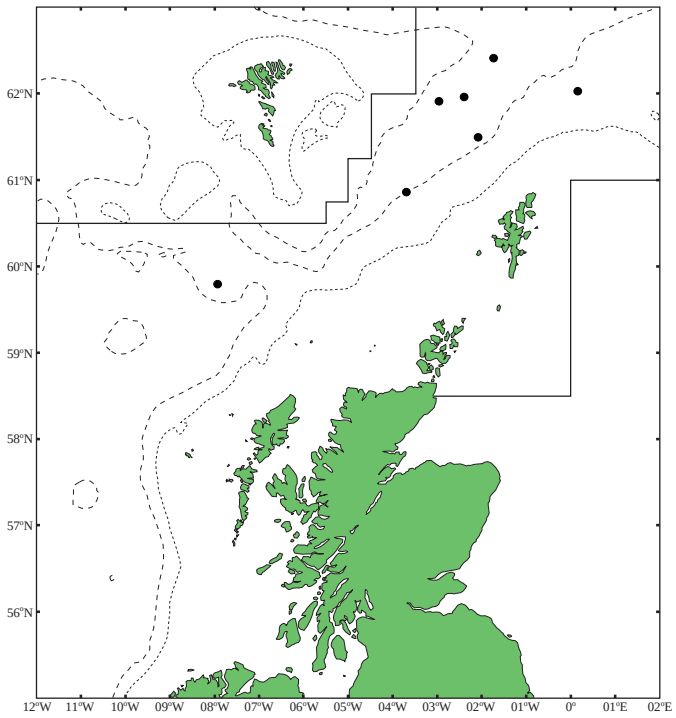


Figure 60. Hooded seal sightings throughout the year

Number of individuals: • 1 • 2 • 3-5 • 6+

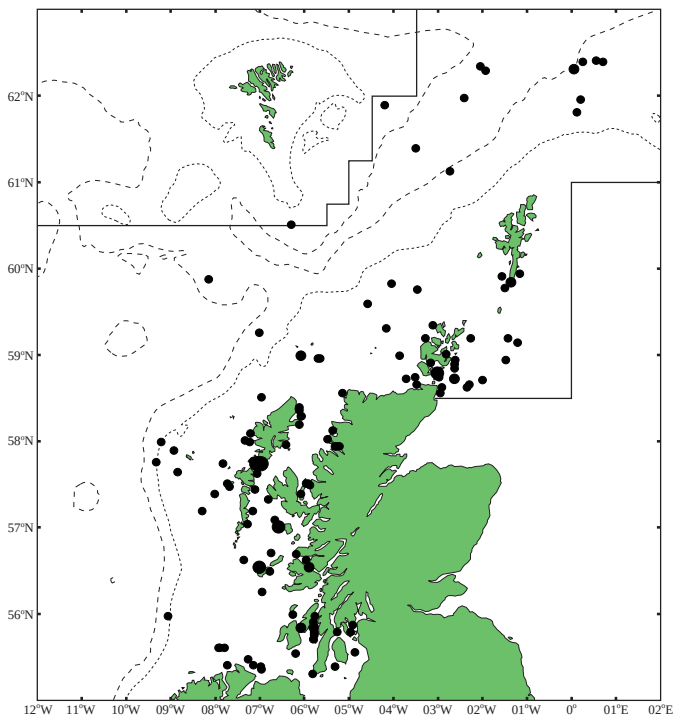


Figure 61. Unidentified seal sightings throughout the year

Number of individuals: • 1 • 2 • 3-5 • 6+

7.3 Hooded seal *Cystophora cristata*

Hooded seals do not breed in the survey area and have been observed only rarely on land in the region. The nearest breeding population of hooded seals is around Jan Mayen (71ºN, 8º30'W), where there is a population of perhaps 250,000 animals (Reeves *et al.* 1992).

Hooded seals were recorded only in deep waters and most sightings were in the Faroe-Shetland Channel (Figure 60). There were no records of hooded seal from SAST surveys until two were observed in deep water to the north of the Shetland Islands in May and June 1997 (White & Leaper 1997). In addition, five unidentified seals in the vicinity of the Shetland-Faroe Channel on the same survey were also likely to have been hooded seals. Following these observations there have been sightings in all seasons. Although it is tempting to speculate that the other unidentified seals in deep waters (Figure 61) may have been hooded, grey seals have been known to make long distance foraging trips from the North Sea to the Faroes (McConnell *et al.* 1999). Hooded seals were not recorded in waters shallower than 200 m.

These observations accord with the movements of satellite tagged hooded seals from Jan Mayen, which have been

recorded in waters around the Faroes in all months except May, June and July (Folkow *et al.* 1996). Movements of seals were not synchronised; different seals were recorded at different times of year. During their time at sea, most of their time was spent in deep waters along the shelf break, submarine ridges or sea mounts, where they made repeated dives of greater than 1,000 m.

The numbers of hooded seals using the survey area is undoubtedly small, but the at-sea observations and results of satellite tracking suggest that the area is used regularly by a small proportion of the hooded seal population, rather than by lost or vagrant individuals.

8. Discussion

The primary aims of this project were to gain information on seabird and marine mammal dispersion along the continental slope, particularly in the offshore blocks licensed in the 17th and earlier offshore oil licensing rounds and to census several important seabird colonies on islands nearest the licensed areas.

8.1 Survey coverage

Since dedicated surveys began, total survey coverage has increased from 36,381 km^2 before May 1997 to 48,220 km^2 in March 1999. Over deeper waters coverage has more than doubled from 7,629 km^2 to 15,773 km^2 (Table 6). Monthly survey effort is less intensive and extensive during September to April compared with the summer months (Table 5, Figures 5 and 6). Inadequate coverage during parts of the year could result in the yearly distribution of a species being misrepresented. Outwith summer, surveying is constrained by poor weather and decreased daylight hours, especially when surveying remote water.

8.2 Seabird distribution: Atlantic Frontier and continental shelf

The main focus of the study was seabird distribution in the deep waters of the Atlantic Frontier i.e. the continental slope and oceanic waters (depth 200-2,500 m). The study area also included shelf waters in order to place the offshore observations into context. More importantly, a pollution incident in the deep waters of the Atlantic Frontier could also affect seabirds in shelf waters. Oil spills can be very mobile; prevailing weather systems and water currents of the Atlantic could push an oil spill inshore where it may affect a larger number of seabirds. The deep water of the Atlantic Frontier generally had lower species diversity than shelf waters, and most species occurring there were found in lower abundance than over the shelf. The shelf was characterised mainly by diving fish-eating species e.g. auks and Manx shearwaters, some of which occurred in important numbers, whereas surface feeders e.g. fulmars and storm-petrels were mainly encountered over deep water.

8.2.1 Importance of Atlantic Frontier for seabirds

The most abundant species over deep water were fulmar, gannet, and kittiwake, with fulmar occurring in the highest average densities. These species are highly pelagic, and capable of travelling long distances to forage. Furthermore, they are adaptable, opportunistic feeders, so high densities of all three species along the shelf edge prior to the breeding season may be associated with scavenging around fishing vessels (Hudson & Furness 1989; Camphuysen *et al.* 1993). High densities of gannets were recorded over the shelf edge near St. Kilda during the breeding season, suggesting the area was being used by birds nesting on the large gannetries on the islands. The study area supports almost 50% of the gannets found in the north-east Atlantic, almost half of these nesting at St. Kilda (Murray & Wanless 1997).

The Atlantic Frontier was found to be especially important for summer visitors such as Leach's storm-petrel and European storm-petrel. Of the two, Leach's storm-petrel is a true Atlantic Frontier species and was found only beyond the continental shelf and at most times of year. Some 97% of Leach's storm-petrels recorded were over the deep waters along the Atlantic Frontier. The European storm-petrel frequents both offshore and shelf waters (Bourne 1986; Harrison *et al.* 1994). High numbers of European storm-petrels were also found, and occur at higher densities off south-west Ireland (Pollock *et al.* 1997). Both these species breed in the study area in internationally important numbers (>1% of biogeographic population, Table 1). The pelagic habits of Leach's storm-petrel probably restricts its breeding distribution to sites closest to the continental shelf edge, such as St. Kilda and North Rona.

Almost 65% of the world's great skuas breed in the study area and they also utilised the deep waters, particularly in April and May. Moderate to high densities of lesser black-backed gulls were recorded along the shelf edge before the breeding season. These may have been associating with fishing vessels in the area (Camphuysen *et al.* 1995). Great black-backed gulls and puffins were recorded throughout the year and were abundant at times. Great black-backed gulls also forage around fishing vessels for discards (Furness *et al.* 1992), and high numbers were recorded in late winter. Puffins were most abundant in offshore waters during the summer months as they disperse widely during the winter.

Although the shelf break is of importance for species such as fulmars, kittiwakes, gannets and great black-backed gulls, densities are reduced during the late spring and summer when birds move into shelf waters to return to their breeding colonies (Webb *et al.* 1990).

Few of the species deemed most vulnerable to oil pollution, such as divers, auks, Manx shearwater, cormorant and shag (Webb *et al.* 1995), were present in offshore waters. Guillemot, razorbill and herring gull were present in Atlantic Frontier waters throughout the year, but only at low densities. These species are primarily found in waters less than 200 m deep and lack the pelagic characteristics of the more abundant species in offshore waters.

8.2.2 Importance of shelf waters north and west of Scotland for seabirds

Shelf waters are important for Atlantic Frontier species at certain times of year, especially during the breeding season. During the summer, Manx shearwaters were most common in shelf waters and often formed large rafts on the water. The relative abundance of Manx shearwaters, when compared solely with the numbers of other species found on the shelf (Figure 11), was quite low. However, when one considers that the study area holds an estimated 22% of the biogeographic breeding population then it can be argued that inshore waters are very important for this species. The same argument applies to the shag, which was almost entirely confined to the shelf and was recorded only in low numbers, yet the study area supports 29% of the biogeographic breeding population.

The Orkney and Shetland Isles are the main north-west European stronghold for great and Arctic skuas; shelf waters are particularly important for them. Herring gull, lesser black-backed gull and great black-backed gull were other important members of the shelf seabird community.

Large concentrations of guillemots and razorbills occur in inshore waters, particularly in July and August when they moult and are flightless for several weeks. High densities of puffins occurred between April and September, the shelf waters around Scotland being among the most important for this species in north-west Europe (Stone *et al.* 1995b). The distribution of the black guillemot was found to be almost entirely inshore, although it was one of the least numerous of the auks to be recorded. This species occurs too close to land to be detected in SAST type surveys. With the study area holding an estimated 45% of the biogeographic breeding population of this species, it is clear that this is one of the most important species found in shelf waters.

Shelf waters were also important for divers, cormorant, seaduck, black-headed and common gulls, and common terns although all were recorded in low numbers. Inshore waters west of Scotland are especially important for great northern divers between November and April, and may hold a substantial proportion of those spending the winter in European waters (Webb *et al.* 1990).

8.3 Marine mammal distribution

The proximity of the shelf edge to the Scottish islands, and the influence of the Gulf Stream, results in a diversity of habitats and a particularly rich number of species. A total of 27 species of cetacean have been recorded in UK waters (Evans 1995), and we recorded 15 species in this study.

The distribution of cetacean species within an area may be related to oceanographical features such as sea temperature, salinity, sea-floor relief and depth (e.g. Selzer & Payne 1988; Evans 1990; Skov *et al.* 1995a). Certainly different species show a tendency towards shelf, slope or deep-water habitats (Evans 1990; Davis *et al.* 1998). Some cetaceans also favour areas of high seabed relief where varied water currents may increase food availability (Hui 1979; Selzer & Payne 1988). It is probable that the observed relationships are a feature of prey distribution and abundance rather than a direct relationship between cetaceans and environmental features (Gaskin 1982; Kenney & Winn 1986; Evans 1987; Selzer & Payne 1988; Gowans & Whitehead 1995). A strong correlation exists between the abundance of fin, humpback and minke whales with that of their prey species in the north-west Atlantic, and these species may segregate by depth to avoid competing directly with one another for food (Piatt *et al.* 1989).

Species of cetacean that feed on squid, such as sperm, beaked and long-finned pilot whales, tend to occur in deeper waters along and seaward of the shelf edge where their prey is more abundant (Kenney & Winn 1987). Shelf edge habitats have been shown to be important for individual cetacean species (e.g. Waring *et al.* 1993), diversity of species (Kenney & Winn 1986), and overall biomass of cetaceans (Kenney & Winn 1987). Some largely piscivorous species such as white-beaked dolphins and harbour porpoises take a wide range of prey species and have their centre of distribution on the shelf and oceanic banks (Skov *et al.* 1995a). Large baleen whales may also use the shelf edge as a migration channel between feeding and breeding grounds (Evans 1987).

As stated earlier, surveys are inherently restricted by weather conditions during the year. During the winter, high swell heights and rough seas result in reduced sighting rates particularly for inconspicuous species such as beaked and minke whales, and small species such as harbour porpoises (Palka 1996), though large whales may still be relatively detectable in choppy seas (Stone 1998).

Sightings of cetaceans were found to peak during summer months with areas to the west of Shetland, and west of the Western Isles being important. Although this may be an artefact of improved weather conditions, there were marked seasonal patterns for some species. Few large whales were seen outside the summer months, though they generally inhabit deep waters where coverage is difficult to achieve during the winter. However, sightings of other deep-water species such as sperm and long-finned pilot whales and white-sided dolphins occurred throughout the year, and beaked whales were sighted between August and January, when coverage in deep-water regions was reduced. Although it is not easy to correct for variations in observer ability, survey vessel, weather conditions, and uneven

levels of survey coverage, overall trends in species distribution and occurrence may still be revealed (Evans 1980).

8.3.1 Importance of Atlantic Frontier for marine mammals

Whereas previous cetacean surveys focused on several areas of the Scottish continental shelf (see section 1.2), the distribution and abundance of cetaceans in deep water along the slope and off the shelf edge was poorly known.

Eight species of cetacean (fin whale, sei whale, humpback whale, sperm whale, beaked whales, killer whale, pilot whale, and white-sided dolphin) were primarily recorded in the Atlantic Frontier waters, although inshore movements of some of these species appeared to occur during the summer.

Almost all sightings of fin, sei, humpback and sperm whale were beyond the 200 m isobath, either over the shelf break or in deep water. The increase in sperm whale sightings corresponds to increased survey work over deep water. Prior to 1997, nine animals had been recorded in the study area by JNCC surveys, but since then a further 71 animals have been seen, particularly around the 1,000 m isobath. Stone (1997, 1998), reporting on sightings of cetaceans from seismic vessels, found that large whales (fin, blue, sperm and humpback) were distributed along or beyond the 1,000 m isobath. This corresponds with whaling records that show that most catches of these species occurred in deep waters just off the edge of the continental shelf (Thompson 1928). A degree of seasonal migration has been reported previously for baleen whales species in the study area (Christensen *et al.* 1992), and would appear to be supported by this study as baleen whales were sighted only between May and October. However, the area in the southern Faroe-Shetland Channel where the majority of fin whales are sighted receives little survey coverage during winter, and although some seasonal migration may occur, inadequate survey coverage obscures this. Individual fin whales, tracked by hydrophone arrays, have shown no consistent direction of movement (Clark & Charif 1998). In the Atlantic Frontier region, some fin whales may remain in deep water at high latitudes throughout the year, as the species has been detected by hydrophone arrays in considerable numbers in all months (Clark & Charif 1998). Humpback whales were rarely sighted during our survey work. However, individual humpback whales tracked using passive acoustic arrays that detect vocalisations seem to exhibit a late winter/early spring southward migration into and through the study area (Clark & Charif 1998).

The beaked whales, a poorly known group of cetaceans that favour deep submarine canyons, have also been increasingly recorded as increased survey coverage has been achieved in suitable habitats. The waters of the Atlantic Frontier may be of particular significance for beaked whales, whose distribution in the North Atlantic is poorly understood. Northern bottlenose whales were the most frequently sighted species of beaked whale, although 62 unidentified beaked whale individuals were thought to belong to the genus *Mesoplodon*. Almost all of these have been seen in waters over 1,000 m deep. Sightings of *Mesoplodon* species at sea are rare, partly as a result of their behaviour and habitat requirements. *Mesoplodon* species are rarely sighted in some areas where northern bottlenose whales are frequently observed, such as the Gully off Nova Scotia (Hooker & Baird 1999), suggesting that species of *Mesoplodon* may be generally uncommon throughout much of their range. Only one individual was positively identified to species: a single Sowerby's beaked whale seen near the Rosemary Bank. The genus *Mesoplodon* includes 14 species of small, taxonomically similar beaked whales, which are difficult to identify at sea. It is probable that most of the unidentified beaked whale sightings also refer to Sowerby's beaked whale. Further work may help to clarify the specific identity of the animals seen in the Atlantic Frontier.

Killer whales, long-finned pilot whales and Atlantic white-sided dolphins occurred in high numbers in the Atlantic Frontier throughout the year, according with observations made by Stone (1997, 1998). Killer whales were also frequently found close inshore. Bottlenose and common dolphins were found in all water depths, although the latter was most abundant along the shelf edge. Common dolphins were replaced by white-sided dolphins at latitudes greater than 60°N, although both species inhabited deep pelagic waters. Selzer and Payne (1988) suggest that the differences in distribution between these two species may be related to environmental factors such as temperature, with common dolphins occurring in warmer waters and white-sided dolphins in colder waters further north. Occasional sightings of minke whales also occurred.

The few records of hooded seals also came from deep water areas. A study of satellite-tagged hooded seals at Jan Mayen (Folkow *et al.* 1996) has indicated that these animals undergo long distance migrations and appear to favour the deep waters of the Faroe-Shetland Channel. Since increased survey effort began in these waters, we have also recorded hooded seal sightings in this area and further survey work may record more.

8.3.2 Importance of shelf waters north and west of Scotland for marine mammals

Minke whale, white-beaked dolphin and harbour porpoise were found widely distributed in shelf waters. Previous surveys have found the distributions of each entirely confined within the 200 m isobath (Northridge *et al.* 1995; Stone 1997, 1998). Numbers of all three species peaked in summer, and the minke whale was not sighted at all between November and April. This suggests that seasonal variation in sighting rates and numbers for some species is not necessarily a result of bias in survey effort. The harbour porpoise was the most frequently sighted species, although white-beaked dolphins were more numerous (Table 8). Minke whales were the commonest baleen whale within the study area, and also in shelf waters, the Minch being especially important for this species. The distribution of white-beaked and white-sided dolphins showed an allopatric pattern; white-beaked dolphins appear to replace white-sided

dolphins in waters less than 200 m deep. Although mixed schools have been reported (Evans 1980, 1987; Northridge *et al.* 1997), the pattern of distribution for these species suggests some degree of mutual exclusion. This may be related to prey type, or to another factor. Both the white-beaked dolphin and the Atlantic white-sided dolphin occur on both sides of the North Atlantic. Survey data from the European shelf and North American shelf indicate the former species to be more numerous in the east, and the latter more numerous in the west (Northridge *et al.* 1997). Though the white-beaked dolphin was more often sighted during our study, the white-sided dolphin was the more numerous species. However, differences in skull measurements indicate that the white-beaked dolphins found in Europe may be a separate population to those in North America, whereas the white-sided dolphins are similar (Mikkelsen & Lund 1994). Northridge *et al.* (1997), based on the observed distribution of white-beaked dolphins throughout the north-east Atlantic, has further suggested that the white-beaked dolphins in Scottish and north-east English waters may even be isolated to some extent from those further north or west in Norwegian and Icelandic waters. In this case the Atlantic Frontier may hold a very significant proportion of, and consequently may be very important for, this local population.

Risso's and bottlenose dolphins were found in moderate numbers throughout the study area. Risso's dolphins were widely dispersed in shelf waters, particularly around the Western Isles. Each inhabits both deep offshore waters and shallow shelf waters throughout their geographical range (Evans 1987).

Common and grey seals were found mostly in shelf waters. Grey seals were the most numerous species, and were occasionally found in offshore waters. It is possible that the few grey seals recorded in the Faroe-Shetland Channel and near to the Faroe Bank originate from the Faroe Islands. The grey seal was the most numerous species. As with seabirds that occur inshore, both species are probably under recorded due to constraints and objectives of the survey methodology.

8.4 The threat of surface and noise pollution to seabirds and marine mammals in the Atlantic Frontier

Seabirds are affected by oil pollution in several ways: oiling of their plumage results in waterlogging, whereas oil ingested during preening may result in liver and kidney damage (Furness & Monaghan 1987). The impact of surface pollution on seabirds varies considerably with the geographic location of the spill, the season during which it occurs, and the ecology of the species affected. Species that spend a lot of time on the water, with small biogeographic populations and low reproductive output, are most vulnerable (Williams *et al.* 1994). The vulnerability of a species to surface pollution may also change over the year. Auks become more vulnerable after the breeding season when they gather in concentrations to moult, rendering them flightless and restricting their mobility.

Clearly the offshore waters of the Atlantic Frontier are important for seabirds. Although they host lower species diversity and numbers of seabirds than shelf waters, it would be erroneous to suggest that a pollution incident occurring there would be of little importance. For instance, oil spills can be highly mobile and disperse over large distances, and an offshore spill could possibly move inshore where it would have a greater effect. Also, seabird distribution patterns change over the year. An oil spill offshore during summer, when more species and higher numbers of birds are present, would have a greater impact than during winter. Fulmar, gannet, and European and Leach's storm-petrels were all recorded in high densities offshore during the breeding season, and this area was also important for kittiwake and puffin, prior to, and after the breeding season respectively. Of these species, gannet and puffin are considered to be the most vulnerable to oil pollution due to their ecology (Webb *et al.* 1995). Both are heavily reliant on the marine environment, have low breeding output with a long period of immaturity before breeding, and the study area contains a large percentage of the biogeographic population of each. Puffins also spend much time on the water. Results from beached bird surveys show that over 47% of puffins and 29% of gannets washed up dead on beaches are contaminated with oil (Stowe 1982). The aerial habits of the fulmar, together with its large population and widespread distribution, reduce its vulnerability.

As inshore waters contain greater species diversity and a higher number of seabirds, a pollution event on the shelf would have a greater potential impact on seabirds. In contrast to offshore waters, shelf waters held important concentrations of seabirds throughout the year, and a high number of species utilised only this habitat. An oil spill over the shelf would be especially serious during summer. Most seabirds forage close to their colonies when breeding, so a pollution event near the major assemblages of seabirds, such as those found on Shetland, Orkney, North Rona or St. Kilda, could have important consequences for breeding populations. High adult mortality during the breeding season would reduce productivity, resulting in population declines in successive years. The main species with a significant shelf component to their distributions include fulmar, Manx shearwater, gannet, great skua, Arctic skua, lesser black-backed gull, herring gull, great black-backed gull, kittiwake, Arctic tern, common guillemot, razorbill and puffin. Of these the three auk species, Manx shearwater and great skua are rated most vulnerable to oil pollution (Webb *et al.* 1995). The study area contains a large proportion of the biogeographic population of each. Furthermore, as stated above, auks spend much time on the water, gather in concentrations at certain times of the year, and moult while at sea, which renders them less mobile. In

Britain, almost 60% of all auks recovered dead on beaches during the autumn and winter are contaminated with oil (Stowe 1982). When at sea the Manx shearwater also spends much time in flight although, because they are sub-surface feeders, they sometimes gather in large rafts on the sea when feeding rendering them more at risk. Great skuas also spend much time in flight and occasionally gather in rafts to feed, but less frequently than the shearwaters. Nevertheless, with such a high percentage of the biogeographic breeding population contained in the study area, the species must be considered as one of those most at risk from an oil spill, especially when occurring close to a colony. Of the gull species, kittiwake is the most vulnerable as it is the only one which relies on the marine environment throughout the year.

Of the remaining species, red-throated diver, great northern diver, cormorant, shag and black guillemot are considered the most vulnerable to oil pollution. All spend a large amount of time on the surface of the water and the study area holds large percentages of the biogeographic breeding populations of shag and black guillemot, and high numbers of great northern divers in winter. Divers especially are very susceptible to oiling; 64% of those recovered dead on beaches show signs of oil pollution compared with 16% of cormorants and shags (Stowe 1982).

Marine mammals are less directly affected by oil pollution than seabirds due to a combination of factors. Compared with seabirds they are (usually) more mobile, more sensitive to disturbance and less abundant, but the main reason that they are less affected by oil pollution is because they rely on blubber for insulation, rather than feathers. Feathers contaminated with oil lose their insulating properties and consequent seabird mortality results from hypothermia and/or oil ingested through preening. Marine mammals are not affected in this way though death through ingestion of oil may still occur. As with seabirds, the effects of oil pollution can only be measured directly if stranded or dead animals are found. However, dead cetaceans are rarely found after major oil spills have occurred (Kingston 1995; SEEEC 1998), so the immediate affects from a pollution event are difficult to ascertain. The cetacean populations of the Atlantic Frontier are obviously highly important. However, it is impossible to say just how vulnerable they are without further data on their susceptibility to oil pollution. The seal populations of the Atlantic Frontier may be more at risk, but again data from previous large oil spills indicates low mortality due to such events (Kingston 1995; SEEEC 1998). Inshore concentrations of grey and common seals would be most vulnerable, especially if an incident occurred during the pupping season.

The vulnerability of different seabird species to surface pollutants may be indicated by vulnerability indices (Seip *et al.* 1991; Williams *et al.* 1994). When combined with known densities of seabirds in an area at a given time of year, vulnerability scores for different sea areas may be computed (e.g. Carter *et al.* 1993; Webb *et al.* 1995). Subsequent vulnerability mapping is a useful tool that has been used when advising on offshore activities in the oil and gas industry. The strategic timing of activities can greatly reduce the threat of surface pollution to seabirds. Vulnerability atlases may be incorporated into oil spill contingency plans in addition to providing conservation advice in the event of spillage. For areas containing vulnerable concentrations of seabirds within the Atlantic Frontier study area, readers are advised to consult Webb *et al.* (1995) or the latest version of UKDMAP (NERC 1998) on CD-ROM. Development of the vulnerability index currently used by JNCC is underway, with the aim of rendering it globally applicable.

While it is accepted that oil spillage from production platforms is a rare event, an increase in oil production inevitably leads to increased shipping. This sector accounts for the majority of spillage events and consequent degradation of the marine environment, particularly with respect to seabirds. The oil spill off south Shetland in 1993 that resulted from the wreck of the '*Braer*' was responsible for the deaths of at least 1,542 seabirds, mostly from locally important inshore concentrations of wintering seabirds such as shags, black guillemots, kittiwakes and duck species (Ritchie & O'Sullivan 1994). This oil spill occurred in an area where several seabird species breed in large colonies during the summer, but the timing of the spill, in January, avoided large-scale reductions to summer auk populations.

In addition to the toxic effect of oil spills on cetaceans, acoustic disturbance from the airguns used during seismic exploration for hydrocarbon reserves may have an effect on marine mammal species. The gun arrays towed by seismic vessels operate at low frequencies, generally below 200 Hz, although some high frequency noise may also be emitted (Goold 1996). Low frequency noise may overlap directly with the sounds used by baleen whales (10 Hz–l kHz) for communication, and incidental, high frequency noise produced may affect porpoises, dolphins and toothed whales, whose frequency range is most sensitive at 10-150 kHz (Evans & Nice 1996). Seismic vessels operate throughout UK waters, and are present in Atlantic Frontier waters particularly during the summer months. Although JNCC Guidelines have been issued to minimise the potential disturbance to cetacean species from seismic exploration, neither the short- nor long-term effects of the emitted sound on cetaceans have been studied. Potential effects include direct physical damage, changes in behaviour and interference in communication. Avoidance of loud noise by cetaceans may result in a shift in distribution away from feeding and breeding grounds, and this may also result indirectly if potential prey species are displaced by seismic activity. Although clear evidence for a reaction of marine mammals to seismic activity is limited, behavioural responses to the firing of airguns have been recorded for a number of species (Richardson *et al.*, 1995; Stone 1997, 1998, 2000).

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Appendix I. Scientific names of seabirds, cetaceans, pinnipeds and fish mentioned in the text

Seabirds

Red-throated diver	*Gavia stellata*
Black-throated diver	*Gavia arctica*
Great northern diver	*Gavia immer*
Great crested grebe	*Podiceps cristatus*
Fulmar	*Fulmarus glacialis*
Soft-plumaged petrel sp.	*Pterodroma* sp.
Cory's shearwater	*Calonectris diomedea*
Great shearwater	*Puffinus gravis*
Sooty shearwater	*Puffinus griseus*
Manx shearwater	*Puffinus puffinus*
Mediterranean shearwater	*Puffinus mauretanicus*
European storm-petrel	*Hydrobates pelagicus*
Leach's storm-petrel	*Oceanodroma leucorhoa*
Wilson's storm-petrel	*Oceanites oceanicus*
Gannet	*Morus bassanus*
Cormorant	*Phalacrocorax carbo*
Shag	*Phalacrocorax aristotelis*
Common eider	*Somateria mollissima*
Long-tailed duck	*Clangula hyemalis*
Common scoter	*Melanitta nigra*
Velvet scoter	*Melanitta fusca*
Red-breasted merganser	*Mergus serrator*
Red-necked phalarope	*Phalaropus lobatus*
Grey phalarope	*Phalaropus fulicarius*
Pomarine skua	*Stercorarius pomarinus*
Arctic skua	*Stercorarius parasiticus*
Long-tailed skua	*Stercorarius longicaudus*
Great skua	*Stercorarius skua*
Little gull	*Larus minutus*
Sabine's gull	*Larus sabini*
Black-headed gull	*Larus ridibundus*
Common gull	*Larus canus*
Lesser black-backed gull	*Larus fuscus*
Herring gull	*Larus argentatus*
Iceland gull	*Larus glaucoides*
Glaucous gull	*Larus hyperboreus*
Great black-backed gull	*Larus marinus*
Kittiwake	*Rissa tridactyla*
Sandwich tern	*Sterna sandvicensis*
Common tern	*Sterna hirundo*
Arctic tern	*Sterna paradisaea*
Little tern	*Sterna albifrons*
Common guillemot	*Uria aalge*
Brünnich's guillemot	*Uria lomvia*
Razorbill	*Alca torda*
Black guillemot	*Cepphus grylle*
Little auk	*Alle alle*
Puffin	*Fratercula arctica*

Cetaceans

Fin whale	*Balaenoptera physalus*
Sei whale	*Balaenoptera borealis*
Minke whale	*Balaenoptera acutorostrata*
Humpback whale	*Megaptera novaeangliae*
Sperm whale	*Physeter macrocephalus*
Northern bottlenose whale	*Hyperoodon ampullatus*
Sowerby's beaked whale	*Mesoplodon bidens*
Killer whale	*Orcinus orca*
Long-finned pilot whale	*Globicephala melaena*
Atlantic white-sided dolphin	*Lagenorhynchus acutus*
White-beaked dolphin	*Lagenorhynchus albirostris*
Risso's dolphin	*Grampus griseus*
Bottlenose dolphin	*Tursiops truncatus*
Common dolphin	*Delphinus delphis*
Harbour porpoise	*Phocoena phocoena*

Pinnipeds

Common (harbour) seal	*Phoca vitulina*
Grey seal	*Halichoerus grypus*
Hooded seal	*Cystophora cristata*

Fish

Herring	*Clupea harengus*
Sprat	*Sprattus sprattus*
Greater silver smelt	*Argentina silus*
Cod	*Gadhus morhua*
Haddock	*Melanogrammus aeglifinus*
Whiting	*Merlangius merlangus*
Blue whiting	*Micromesistius poutassou*
Poor cod	*Trisopteris minutus*
Norway pout	*Trisopterus esmarkii*
Pollack	*Pollachius pollachius*
Saithe	*Pollachius virens*
Torsk	*Brosme brosme*
Ling	*Molva molva*
Blue ling	*Molva dypterygia*
Hake	*Merluccius merluccius*
Redfish spp.	*Sebastes* spp.
Sandeel spp.	*Ammodytes* spp.
Goby spp.	*Gobius* spp.
Mackerel	*Scomber scrombus*
Greenland halibut	*Reinhardtius hippoglossoides*

Appendix II. Survey coverage (km^2) obtained in licensed rectangles located in Atlantic Frontier (June1979-March 1999)

Licensed rectangle	1/4 ICES Rectangle (see Figure 4.)	Lat/ Long	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
West of Hebrides														
132 NW	1	5645 0930			6.41	10.10	21.49	22.31	11.05	24.17	22.91		7.60	
NE	2	5645 0900	14.43	6.99	3.95	27.02	11.15		11.43	21.04	12.04	8.25		
CNW	3	5630 0930			22.50	21.02	20.48	26.80		24.03	22.67		1.40	
CNE	4	5630 0900	10.88	2.15		16.54	1.15	4.88		12.67	8.66		8.70	
CSW	5	5615 0930			23.24	22.78	23.23	23.03	3.60			22.61	3.60	
CSE	6	5615 0900	14.73	6.00	11.25	0.82	10.25	22.76	9.25	7.50	8.40	21.57		
142 SW	7	5700 0930	9.45		5.05	6.65	10.61	7.65	14.76	32.28			2.85	
SE	8	5700 0900	18.29	16.60	9.25	14.60	2.20	6.97		23.80	23.04	4.60		1.90
152 NW	9	5845 0930		22.56	21.38	20.93	1.83	22.08	3.06	24.60	18.90		20.60	
CNW	10	5830 0930		21.89	28.03	3.76	23.42	23.27		23.40	34.00		19.57	
153 NW	11	5845 0830		12.57	22.64	21.59	2.36	11.78		23.35	3.21	12.57	0.88	
NE	12	5845 0800	22.48			25.03	13.40	8.40		23.42	4.08	11.82	26.19	22.22
CNW	13	5830 0830	5.40			17.10	20.40	4.15		12.27			23.40	
CNE	14	5830 0800		7.20	1.25	2.45	11.86	17.92	11.95	6.95	3.84	3.45		0.91

Appendix II. continued

Licensed rectangle	1/4 ICES Rectangle (see Figure 4.)	Lat/ Long	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
154 NW	15	5845 0730	20.59	20.05	9.60	6.10	15.22		22.65	3.60	2.55	11.20	25.40	25.19
CNW	16	5830 0730	25.81	30.63	3.60	2.50	12.16	16.86	18.90	26.80	6.17	13.95	24.58	20.93
163 CSE	17	5915 0800	32.59		5.25	8.86	22.40	18.05		22.69		15.83	25.47	23.64
SE	18	5900 0800	33.26			22.03	5.84	12.12		11.55	25.01	18.25	26.52	24.40
164 NW	19	5945 0730	22.63	18.34	23.52	23.21		23.15		35.90	3.17	26.01	25.13	12.81
NE	20	5945 0700	23.49		8.22	22.32	23.43	23.37	3.75	15.48	2.28	23.19	25.33	16.94
CNW	21	5930 0730	29.58	23.00		22.43	23.81	23.35		31.61	12.41	23.73	26.33	24.67
CNE	22	5930 0700	28.16		21.63	23.82	22.26	3.80		22.25	9.00	22.76	27.93	22.69
CSW	23	5915 0730	25.48		2.10	3.95	21.57	23.52		27.56	21.55	23.23	23.63	1.50
CSE	24	5915 0700	23.37	4.98	2.05	8.63	5.80	5.50		10.77	10.08	25.97	27.47	23.92
SW	25	5900 0730	24.42		4.35	6.65	22.22	6.42	1.05	7.50		19.69	25.39	19.94
SE	26	5900 0700	21.58	6.60	23.75	13.30	35.85	7.10	29.15	15.35	8.25	23.24	26.40	7.51
165 NW	27	5945 0630	15.27		22.33	6.86	21.70		17.08	12.77	16.50	22.83	23.23	1.92
CNW	28	5930 0630	12.77	5.25		19.17		1.37	12.53	5.20		22.14	24.25	
West of Shetland														
202 NW	29	5945 0430	9.94		6.65		20.25	7.14	10.05	3.30	21.90		20.91	2.10
NE	30	5945 0400	3.61			8.00	23.45	8.85	43.01				21.85	6.00
CNW	31	5930 0430		4.00	7.60	1.10	4.10	7.92	15.15	16.55	15.61	12.65		8.40
CNE	32	5930 0400	21.95	9.00		7.60	1.20	8.54	39.43	18.75		4.55		6.90
CSW	33	5915 0430	2.55		4.17	1.00	10.85	12.23	6.20	11.10	1.70	2.40	18.90	
204 CNE	34	6030 0400	21.80		8.05	1.00	22.55	24.62	2.10	21.68	10.85	8.85	0.78	
CSW	35	6015 0430	20.69		6.96	2.00	22.99	1.85			4.56		1.22	23.83
CSE	36	6015 0400	3.34	10.41	10.15	8.00	32.88	21.30	12.65	23.66	10.00	18.08	8.17	10.91
SW	37	6000 0430	21.32		6.45	7.00	20.63	9.18	1.30	9.90	36.07		8.51	
SE	38	6000 0400	10.74	7.44	4.75	5.19	12.02	5.37	18.06	4.00	4.28		2.10	
205 NW	39	6045 0330	23.37			4.20	6.68	22.88	28.30	29.18	3.89			2.14
NE	40	6045 0300				4.20	14.85	20.88	13.55	15.90	16.24	3.81		10.93
CNW	41	6030 0330			11.54	8.40	22.07	22.60	7.31	42.16	9.55		8.45	9.65
CNE	42	6030 0300	6.40	10.95	1.62		5.90	21.22	38.62	8.41	6.76	0.99	8.00	
CSW	43	6015 0330	10.74	1.05	2.73		17.88	14.59	38.84	0.89	1.31	8.60	1.04	1.07
CSE	44	6015 0300	3.31	9.45			1.15	9.02	35.90	8.28	10.31	8.11	8.52	1.15
SW	45	6000 0330	10.11	8.44	1.52	3.14	24.91	28.36	39.96	4.58	14.74		8.40	9.29
SE	46	6000 0300	12.73				14.90	14.32	31.77	3.00	7.28		2.69	10.87
206 NW	47	6045 0230		4.20	3.95	9.05	13.55	18.05	9.79	25.11	1.90	8.36		
NE	48	6045 0200		16.63	10.45	4.35	7.15	8.47	48.20	16.62	9.35	1.84		
CNW	49	6030 0230	6.18	5.25	10.65		9.21	8.04	37.63	6.95	7.60	7.91		
CNE	50	6030 0200	8.07		10.15	13.15	11.06	17.20	67.18	6.25	2.10	1.98	7.35	2.40
CSW	51	6015 0230	9.68		24.15	1.70	1.20	13.13	68.43	4.90	0.95		8.05	3.80
207 NW	52	6045 0130	3.60	17.43	19.50	18.00	18.93		53.87	4.75	4.53	7.20		
213 CSW	53	6115 0330					7.62	5.93	6.32	7.72	2.05		8.54	
CSE	54	6115 0300		1.40	8.36	3.15	15.31	11.69	18.25	9.00	22.59		5.93	
SW	55	6100 0330	5.69				7.18	7.81	7.41	13.17			8.79	
SE	56	6100 0300	24.81			4.20	16.25	11.28	15.06	13.04	22.62		7.73	
North of Shetland														
214 CSW	57	6115 0230	0.79	3.50	0.98	4.05	8.19	13.20	24.15	23.53	21.58	4.06	13.43	
CSE	58	6115 0200	21.42		0.93		16.75	13.55	19.71	20.27	7.70		15.28	0.62
SW	59	6100 0230	21.78				8.45	15.87	12.85	22.61	22.80	2.91	2.96	
SE	60	6100 0200	0.74	2.10	10.08		18.53	20.99	10.87	15.39	8.19	14.93	4.60	2.99
208 CNE	61	6130 0100			1.50	2.85	21.00	5.00	20.30		3.80	1.35		
CSW	62	6115 0130			3.05		17.12	22.93	13.55	11.10			11.93	16.22
CSE	63	6115 0100	3.30		13.90	2.85	2.40	22.65	28.43		6.00	10.35		6.56
SW	64	6100 0130		5.80	23.17	1.90	25.53	20.23	27.52		10.70	7.51	1.06	5.22
209 CNW	65	6130 0030	9.80		13.13		16.67	9.98	6.59	1.50	21.36			
CSW	66	6115 0030	1.10		3.30		10.50	9.47	19.20	4.50	22.94			
214 NW	67	6145 0230			9.10		8.14	18.34	20.14		22.60		16.47	9.24
NE	68	6145 0200	22.61	7.80	5.87		24.72	24.13	21.36		10.70	22.87	24.38	22.52
CNW	69	6130 0230	1.51	4.90	4.95	2.00	10.96	33.04	21.57	12.75	25.05		14.40	8.94
CNE	70	6130 0200		12.30		7.00	28.60	34.25	29.96	13.98	5.70	23.03	24.82	23.28
208 NW	71	6145 0130	22.87	6.15	9.13	8.40	53.98	26.63	24.52	12.18		23.69	21.65	22.95
CNW	72	6130 0130	21.86		7.51	4.10	47.08	43.56	23.65	3.75		21.63	23.22	20.91
217 CSW	73	6215 0130	1.10		21.18		23.05	8.27	14.08	1.60		21.53	22.59	12.91
SW	74	6200 0130	22.61		21.79		16.50	9.26	15.92	20.39	23.68	23.83	22.18	22.86
219 CSW	75	6215 0000E	22.59		27.74		24.57	23.75	23.01	47.53	10.47			
CSE	76	6215 0030E	21.93		21.86		17.90	26.09	22.64	5.48	1.45			
SW	77	6200 0000E	25.23		20.65		39.10	25.22	21.94	8.29	13.13			
SE	78	6200 0030E	1.44		20.76		25.60	25.03	24.52					

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- to provide advice and knowledge to anyone on nature conservation issues affecting Great Britain and internationally;
- to establish common standards throughout Great Britain for the monitoring of nature conservation and for research into nature conservation and the analysis of the results;
- to commission or support research which the Committee deems relevant to the special functions.

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COVER PHOTOGRAPHS
Long-finned pilot whale *Globicephala melaena*, Peter Hope Jones/JNCC
Gannet *Morus bassanus*, Andy Webb/JNCC

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