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Local declines in the abundance of harbour seals: implications for the designation and monitoring of protected areas

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Summary

1. Information on the abundance of European pinnipeds is required to assess interactions with fisheries and to meet new conservation obligations under the European Community (EC) Habitats Directive. A detailed time-series of data has documented increases in grey seal populations, but there remains considerable uncertainty over the current status of UK harbour seal populations.
2. We present data on changes in the abundance of harbour seals in a study area within Orkney, Scotland, UK, previously considered a stronghold for this species. In 1998, intensive shore-based counts of both adults and pups were only 16–36% of similar counts made between 1984 and 1987. Furthermore, a significant reduction in the proportion of yearlings present in haul-out groups indicated a reduction in local recruitment.
3. Current monitoring of UK harbour seals, using wider-scale aerial survey techniques, has provided important estimates of site distribution and relative abundance at regional and national scales. However, these larger-scale surveys lack associated data on within-year variation in counts at particular sites. Consequently, they cannot currently be used to explore the spatial scale of the changes in seal numbers that we report here. Similarly, current data from wider-scale monitoring cannot be used to determine whether observed local changes in abundance result from redistribution or a change in survival or reproduction.
4. Management and monitoring plans are currently being developed for special areas of conservation (SAC) for harbour seals in response to the EC Habitats Directive. We suggest that more intensive research is required to assess whether or not similar changes in the abundance and age structure of seals have occurred in these areas. Without a better understanding of the current status of harbour seals both within and outside proposed SAC, future efforts to monitor the effectiveness of management initiatives will be constrained.

Key-words: fisheries interactions, marine mammals, *Phoca vitulina*, population status, special areas of conservation

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Introduction

Pinnipeds include some of the most abundant as well as some of the rarest mammals in the world. Both extremes raise concerns over the need for management or conservation action, and require reliable data on abundance and status. However, while intensive studies of a few species have resulted in a good understanding of their population dynamics (Cooper & Stewart 1983; Testa *et al.* 1991; Gentry 1998) the status of many populations remains unclear (Reijnders *et al.* 1993; Forcada 2000).

Information on the abundance and status of UK seals is required to assess the extent of interactions between seals and fisheries (Harwood & Greenwood 1985; Harwood & Croxall 1988) and to meet new conservation obligations under the European Community (EC) Habitats Directive. Under this directive, member states are required to designate special areas of conservation (SAC) to protect the habitats of listed species, which include both harbour (common) seals *Phoca*

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vitulina L. and grey seals *Halichoerus grypus* Fabricus. As well as needing information on distribution and abundance to identify the most suitable areas for SAC, monitoring programmes must be developed for each so that the status of animals within these protected areas can be reported to the European Parliament. Information on current status is also important prior to designation to inform the development of management plans. However, the availability of such data for these two species in UK waters differs markedly. Replicated annual surveys have been carried out at all major grey seal breeding sites since the early 1960s, and the resulting data on changes in pup numbers have been modelled to produce annual estimates of total population size (Ward, Thompson & Hiby 1987). These data have shown a steady increase in abundance throughout the UK since monitoring began (Hiby *et al.* 1996). In contrast, annual surveys of harbour seals have been carried out in just a few areas, while synoptic surveys over all key UK harbour seal habitats are made on only a single day every few years (Hiby *et al.* 1996).

In the absence of a detailed time-series of data on harbour seal abundance, it is commonly perceived that UK populations are expanding, like grey seals. Annual surveys in the Wash (East Anglia) have indicated that, as in other parts of the southern North Sea (Reijnders *et al.* 1997), harbour seal populations are recovering from the 1988 morbillivirus outbreak (Hiby *et al.* 1996; Sea Mammal Research Unit, unpublished data). Throughout the rest of the UK, however, there remains considerable uncertainty over their current status. In contrast to findings in the southern North Sea, this paper presents data indicating that there has been a marked reduction in numbers of harbour seals in an area considered a stronghold for this species in the 1980s (McConnell 1985; Thompson & Harwood 1990). We discuss the implications of these findings for our understanding of harbour seal population dynamics and status in other areas, and for current efforts to designate and monitor SAC under the EC Habitats Directive.

Methods

STUDY AREA AND POPULATION

The study area was centred on Eynhallow, an uninhabited island in Orkney, UK, but it also included the adjacent coasts of mainland, Rousay, Egilsay, Wyre and other small islands in the vicinity (Fig. 1). The behaviour and ecology of harbour seals in this area were studied intensively between 1984 and 1987 (Thompson & Rothery 1987; Thompson 1988, 1989; Thompson *et al.* 1989; Thompson, Kovacs & McConnell 1994), when the study area held > 15% of the total Orkney population (Thompson & Harwood 1990) and 4% of the UK population (Hiby *et al.* 1996). These studies showed that seals were found in the study area throughout the year, but there were marked seasonal changes in site use. In Orkney, most harbour seal pups were born during June (Thompson & Harwood 1990), after

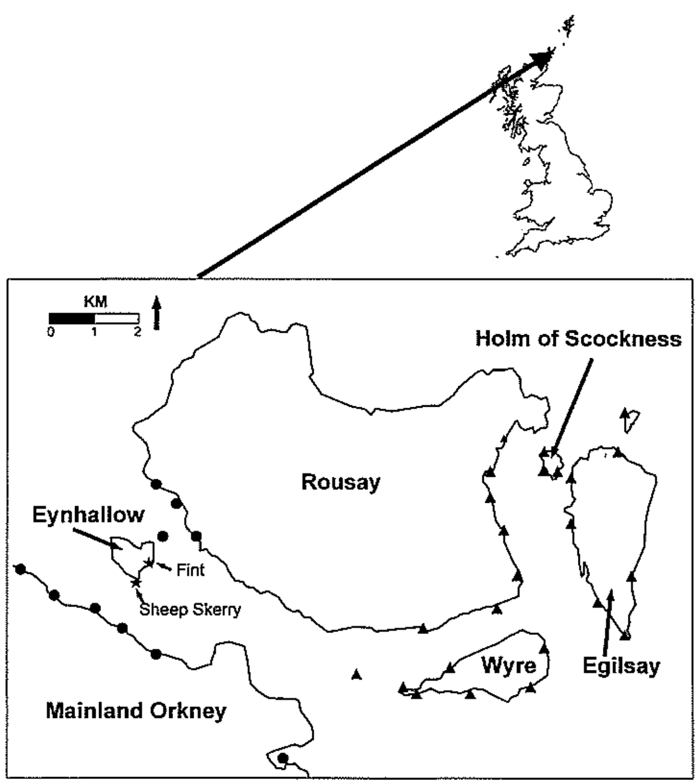

Fig. 1. A map of the study area showing the reference sites and the location of harbour seal haul-out sites. Haul-out sites that were covered by standard boat surveys in 1985 and 1998 are shown as triangles, those additional sites in Eynhallow sound that were surveyed in 1998 are shown as circles, and sites on Eynhallow are shown as stars.

Table 1. Dates when fieldwork was carried out in the pupping season of different years, together with the number of counts made at different sites on Eynhallow

Year	Start date	End date	Number of daily counts at Sheep Skerry	Number of daily counts at Fint
1984	3 June	6 July	23	3
1985	1 June	26 July	12	17
1986	3 June	25 July	43	0
1987	2 June	15 July	34	0
1998	13 June	22 July	38	41

which all seals of 1 year old or more underwent their annual moult (Thompson & Rothery 1987). The two haul-out sites on Eynhallow were used most intensively during the summer months, whereas seals moved to more sheltered mainland Orkney sites during the winter months (Thompson 1989). There were sex differences in the composition of groups at these two sites, with almost all mothers and pups being found at Sheep Skerry, at the southern tip of the island. Fint, a site on the east side of the island, was dominated by males early in the summer, although females were found to move to this site after the pupping season to moult (Thompson 1989).

CHANGES IN ABUNDANCE AND GROUP STRUCTURE ON EYNHALLOW DURING THE PUPPING SEASON

Eynhallow was visited regularly through June and July of 1984–87 and 1998 to count seals at the haul-out sites on Sheep Skerry and Fint. Sampling effort did, however, vary between years and sites (Table 1). In all years except 1985, fieldworkers were living on the island throughout much of June and July and, unless prevented by bad weather, daily counts were made at Sheep Skerry as part of more detailed behavioural studies. Counts at Fint were made less frequently because these studies focused on mothers and pups. In contrast, intensive studies were made at Fint in 1985 to study patterns of moult (Thompson & Rothery 1987), and less regular counts were made at Sheep Skerry. Finally, in 1998, counts were generally made at least once per day at both sites.

Seals were observed at distances of between 10 and 250 m using 8 × 30 binoculars and a 30 × 75 telescope. Observations were made either from hides or from behind dry stone dykes. Sampling protocol varied between years but, in all cases, we aimed to obtain the maximum daily count of seals at each haul-out site. In 1984, 1986 and 1987 regular counts were made throughout the day at Sheep Skerry, and only the maximum daily count was used in these analyses. In 1985, counts at Fint were timed to match the afternoon peak in numbers (Thompson & Harwood 1990). In 1998, counts were generally made twice a day at both sites, once in the morning and once in the late afternoon. Both haul-out sites were available on all but the most extreme of high tides; related studies indicated that the tidal cycle had little influence on behaviour and group size (Thompson *et al.* 1989).

Data on group structure were also collected during counts at both sites on Eynhallow. While it is not possible to determine the age of most harbour seals accurately, pups can be distinguished until nursing ends, and yearling seals can be recognized until the end of their first postnatal moult (at 1 year old) by their pale unpatterned pelage (Thompson & Rothery 1987). Prior to the moult in June and July, we therefore counted all pups, yearlings or adults, although this broad category of 'adults' includes both reproductive and non-reproductive individuals. A number of different personnel were involved in the study, but one of us was involved in identification, data collection and training in all years. When several estimates of group structure were made at a site on a single day, we selected the estimate with the largest sample size for comparisons of group structure in different years.

CHANGES IN ABUNDANCE AT OTHER SITES IN THE STUDY AREA DURING THE PUPPING SEASON

In addition to regular counts on Eynhallow, we carried out a series of standardized boat surveys (Thompson & Harwood 1990) of neighbouring haul-out sites through June and July of 1985 and 1998 (Fig. 1). Surveys in 1998 also covered other haul-out sites on the mainland Orkney and Rousay coasts overlooking Eynhallow. Each survey was made from an inflatable boat with at least two observers. Haul-out sites were approached cautiously and seals were counted using 8 × 30 binoculars. When large groups were encountered, the boat was landed > 1 km from the site and an observer went ashore to count seals using a telescope.

ABUNDANCE OF SEALS FOLLOWING THE 1988 EPIZOOTIC

To explore any direct effects of the 1988 epizootic (Heide-Jørgensen *et al.* 1992) in this study area, we present data from wider-scale surveys that were conducted before and after this mass mortality event. In 1985 and 1989, systematic helicopter surveys (Thompson & Harwood 1990) were flown at an altitude of 100 m around the whole coast of Orkney, excluding areas of exposed cliff. The surveys used two observers and were flown between

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the hours of 08:30 and 18:30 BST, over a period of 2–3 days in the first 2 weeks of August. The size of all groups of harbour seals was estimated visually and their position was recorded to within 500 m on 1 : 50000 maps. Where possible, large groups (> 25) were also photographed using a 35-mm camera with an 80–210 zoom lens. Counts were later made directly from transparencies using a binocular microscope.

STATISTICAL ANALYSES

Data from Sheep Skerry were divided into two classes: pups and all other age classes. The number of seals in each class was compared in different years using an ANOVA on peak daily counts from the pupping season. A *t*-test was used for comparisons at Fint because data were available for only 2 years. Because births were occurring throughout the season, we also compared mean counts obtained from Sheep Skerry in each week. Sample sizes in the earlier years were small and variable, so data were pooled for all years between 1984 and 1987 for comparison with the larger data set from 1998. The age structure of groups was compared by calculating the percentage of yearlings in each group, after pups were excluded, for data from 1985 and 1998. These data sets were compared using a Mann–Whitney *U*-test. All analyses were carried out using SYSTAT version 7.0 (Wilkinson *et al.* 1992).

Results

CHANGES IN ABUNDANCE AND GROUP STRUCTURE ON EYNHALLOW DURING THE PUPPING SEASON

The numbers of harbour seal adults present on Eynhallow in June and July 1998 were markedly lower than those observed in comparable seasons during the 1980s (Fig. 2). The most detailed time-series was for the pupping site on Sheep Skerry. Here, there were significant differences in abundance between years (ANOVA $F_{4,147} = 32{\cdot}45$, $P < 0{\cdot}001$) and the 1998 mean count of 45·7 seals was only 22–27% of annual mean counts obtained between 1984 and 1987 (Fig. 2). Data from the non-breeding haul-out site at Fint in 1985 and 1998 showed that, here too, numbers were significantly lower in 1998 ($t = 5{\cdot}443$, $P < 0{\cdot}001$; Fig. 2).

The numbers of pups observed on Sheep Skerry were significantly lower in 1998 (ANOVA $F_{4,145} = 16{\cdot}51$, $P < 0{\cdot}001$), with the mean of 6·3 pups representing only 16–36% of means for 1984–87 (Fig. 2b). Compared with the numbers of adults, annual mean pup counts showed more between-year variability during the earlier time period. This variability appeared to be related to differences in sampling effort, as annual mean counts of pups increased in relation to the number of counts used in each year (Pearson's $r = 0{\cdot}99$, $P < 0{\cdot}05$, $n = 4$). The number of counts in 1998 was comparable to those in the more intensively sampled years in the period 1984–87 (Table 1).

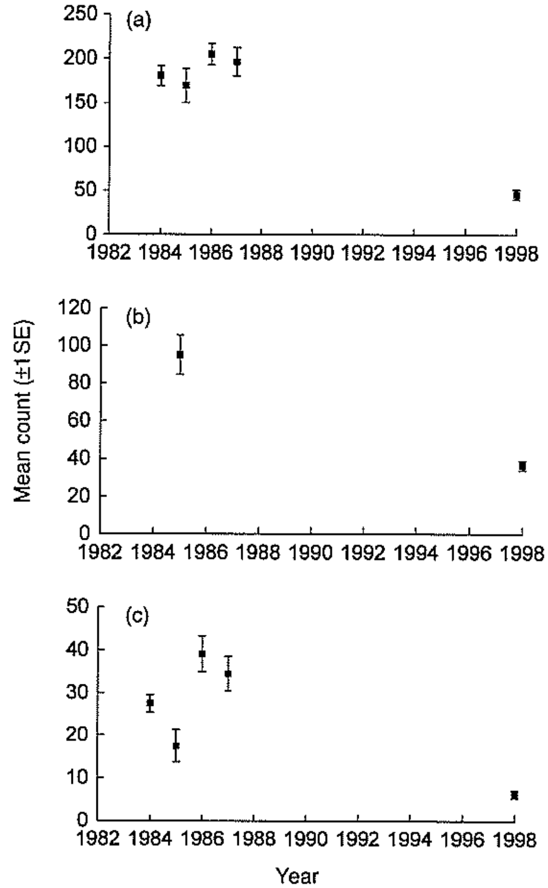

Fig. 2. Mean annual counts of harbour seals on Eynhallow. (a) All age classes except pups at Sheep Skerry; (b) all age classes except pups at Fint; (c) pups at Sheep Skerry. Data are annual means of the maximum daily counts recorded in June and July. Data from all years are based on shore counts.

Although the abundance of both pups and older age classes was lower in 1998 than between 1984 and 1987, the seasonal trend in abundance on Sheep Skerry seemed similar in both time periods (Fig. 3). All pups seen at the beginning of the 1998 study period were just a few days old. Although no detailed analyses were carried out, the timing of pupping therefore seemed similar to 1984–87.

In addition to the marked reduction in numbers of seals on Eynhallow in 1998, there was a notable absence of yearlings. The proportions of yearlings observed in haul-out groups in 1985 (median = 13·3, interquartile range = 7–24, $n = 22$) and 1998 (median = 0, interquartile range = 0–0, $n = 79$) were significantly different (Mann–Whitney $U = 1693$, $P < 0{\cdot}001$), and a maximum of two yearlings were seen in the whole of the 1998 season.

CHANGES IN ABUNDANCE AT OTHER SITES IN THE STUDY AREA DURING THE PUPPING SEASON

Boat surveys indicated that the decline in abundance of seals on Eynhallow was mirrored at neighbouring sites. Numbers of seals observed along the standard survey

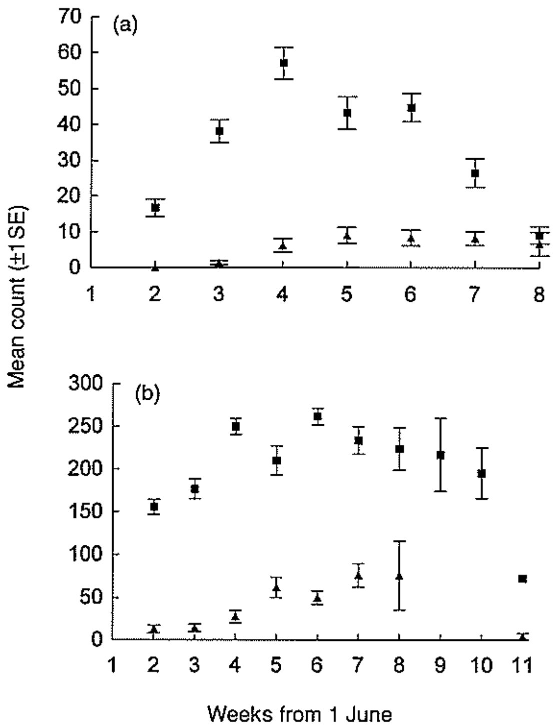

Fig. 3. Seasonal changes of (a) pups and (b) of all other age classes of harbour seals on Sheep Skerry, Eynhallow. Data are weekly means for pooled daily maxima from 1984 to 1987 (squares) and for daily maxima from 1998 (triangles). Data from all years are based on shore counts.

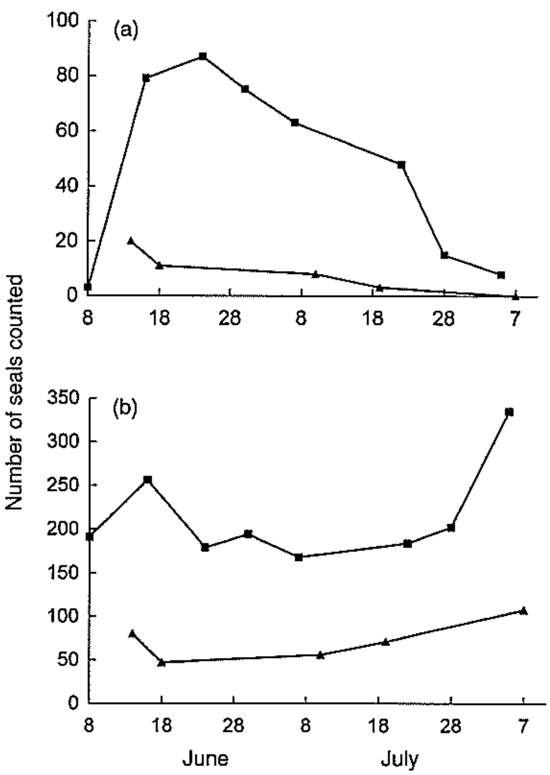

Fig. 4. Counts of (a) pups and (b) all other age classes of harbour seals during boat surveys conducted along the same standard route during the summers of 1985 (squares) and 1998 (triangles). Data from 1985 are from Thompson & Harwood (1990).

Table 2. Aerial survey counts of harbour seals at sites within the study area during the moult of 1985 and 1989

Site	1985	1989
Wyre	101	86
Rousay	16	34
Holm of Scockness	318	380
Egilsay	31	0
Mainland	46	0
Eynhallow	632	587
Total	1144	1087

route were markedly lower in 1998 than in 1985, both for pups (Fig. 4a) and all other age classes (Fig. 4b). The number of seals at four other sites on the mainland Orkney and Rousay coasts opposite Eynhallow was also low during June and July; the mean count of seals, excluding pups, was 56·5 (SD = 14·9, $n = 4$) and the mean count of pups was 9 (SD = 12·1, $n = 4$).

ABUNDANCE OF SEALS BEFORE AND AFTER THE EPIZOOTIC

Aerial surveys during the August moult recorded a total of 6616 and 7070 harbour seals hauled-out in 1985 and 1989, respectively. Survey results for study area sites shown in Fig. 1 are presented in Table 2. These sites contained 17·3% and 15·4% of the total Orkney count in 1985 and 1989, respectively. In both surveys, Eynhallow held the largest concentration of harbour seals recorded in the whole of Orkney. The Holm of Scockness (sites 15–17) was also within the top four sites in both surveys.

Discussion

Counts made during the pupping season should provide a robust comparison between time periods because identical methodology was used in 1984–87 and 1998. These data indicate that the number of harbour seals seen at haul-out sites in this part of Orkney is reduced markedly compared to 10–15 years ago. Pup numbers were also much lower, and changes in age structure suggest a reduction in local recruitment. Because harbour seals do not remain ashore throughout the breeding season, changes in abundance at haul-out sites could result either from real changes in local abundance, or changes in the amount of time that individual seals spend at sea. The latter could result from reductions in food availability leading to increased foraging effort. Similarly, differences in age structure could result either from a genuine change in population structure, or from age-specific variation in haul-out behaviour (Härkönen, Harding & Lunneryd 1999). While we cannot currently discriminate between these possibilities, these hypotheses could be tested by repeating studies of individual haul-out frequency conducted at these sites during the 1980s (Thompson *et al.* 1989). However, harbour seals typically spend around 60% of their time ashore (Yochem *et al.* 1987; Härkönen & Heide-Jørgensen 1990; Thompson *et al.* 1997). If the reduction in mean counts from around 200 to 50 (Fig. 2) resulted from behavioural changes, seals would be spending only 15% of their time ashore. While such factors may have contributed to the lower counts in 1998, changes in counts at haul-out sites are more likely to have resulted from a genuine change in overall local abundance.

If the observed reductions in the number of seals hauled out do reflect a real change in abundance, these may have resulted either from increased rates of emigration out of our study area, or declines in birth rate or survival. Numbers of harbour seals in many other parts of the North Sea were reduced in 1988 as a result of an outbreak of phocine distemper virus (PDV) (Heide-Jørgensen *et al.* 1992), providing one possible reason for changes in survival in our study area. However, although the presence of this disease was confirmed in seals from Scottish waters, mortality in these areas was generally low (Heide-Jørgensen *et al.* 1992). This is reflected in our results from the aerial survey conducted in 1989, the year following the outbreak. Our total count for Orkney was slightly higher than that obtained from the 1985 survey, and 1989 counts of harbour seals within our main study area were only 5% lower than in 1985. While we cannot rule out the possibility that other disease events may have subsequently influenced survival, the observed reduction of numbers in 1998 does not appear to be a direct consequence of the 1988 PDV epizootic.

Redistribution of harbour seals can occur at various temporal and spatial scales. For example, local day-to-day movements have been reported in other areas in relation to changes in weather conditions or levels of disturbance (Kovacs, Jonas & Welke 1990). Movements between Eynhallow and adjacent sites within 5–10 km certainly occur (Thompson 1989), but our boat surveys throughout the study area showed that this did not account for the lower numbers on Eynhallow in 1998. Alternatively, seals may have moved further afield to other haul-out sites. Aerial counts throughout Orkney in 1985 and 1989 showed that there were a number of alternative haul-out sites within 15–50 km of Eynhallow (Thompson & Harwood 1990). Although these sites could not be visited in 1998, they have been surveyed since 1989 as part of a broader monitoring programme of Scottish harbour seals (Hiby *et al.* 1996). However, these larger-scale surveys were designed to provide an estimate of the number of seals in Orkney and similar regions, and consisted only of single counts at each site in each year. Consequently, there is no information on within-year variations in numbers at different sites, and it is not possible to use these data to determine whether there have been changes in relative abundance at a more local scale within Orkney.

If local changes in abundance do result from redistribution, one possible cause is an increase in disturbance at sites within the study area. However, discussions with long-term residents and our own personal observations provide no evidence of increased levels of disturbance or persecution at these sites. If anything, disturbance on Eynhallow was probably greater in the 1980s due to more intensive research activity and related capture attempts. Furthermore, some culling was known to occur on sites such as the Holm of Scockness during the 1980s (P.M. Thompson, unpublished data), but this did not appear to deter animals from using the site during this period. Similarly, many sites in Shetland also continued to be used regularly during the 1960s despite heavy pup mortality from hunters (Bonner, Vaughan & Johnston 1973).

Changes in levels of predation by aquatic predators may provide another potential explanation for the observed declines in abundance, either by influencing site choice or mortality rates. Killer whales *Orcinus orca* L. have been observed attacking seals around Egilsay (Fig. 1) in the last 5 years (C. Hibbert, personal communication), whereas there were no reports of these predators during the earlier study period in the 1980s. In other parts of their range, killer whales can inflict significant levels of mortality on harbour seals (Jefferson, Stacey & Baird 1991). Predation by sharks is believed to have played a major role in the dramatic decline of the harbour seal population on Sable Island in Canada (Ellis 1998). Sharks have been observed foraging on seals in Shetland waters in recent years. However, based on observations on Sable Island, where shark attacks are common, one would expect more evidence of wounded survivors or mutilated carcasses if this was a significant cause of mortality in Scottish waters.

Wider-scale movements between sites may occur in response to changes in local food availability. Several seabird populations in Orkney and Shetland have experienced dramatic breeding failures due to a reduction in the local availability of sandeels *Ammodytes* spp. during the last 15 years (Monaghan 1992). The diet of harbour seals in Orkney, and indeed many other areas, is also dominated by sandeels although they also take a much wider variety of prey (Pierce, Boyle & Thompson 1990). Consequently, one might expect seals to be more buffered against changes in the availability of a specific prey type, even if it was formerly important. Nevertheless, it is possible that observed local changes in harbour seal abundance and age structure in 1998 may be related to changes in sandeel availability. Such changes may have led to a redistribution of seals, with them moving closer to alternative foraging areas. On the other hand, if alternative prey were scarce or of inferior quality, this could ultimately lead to reductions in the seals' breeding success and survival. For example, reductions in the availability of prey stocks, due either to natural climatic variability or over-fishing, are believed to be the most likely factor causing major declines of several species of pinnipeds and seabirds in the Bering Sea (Merrick, Loughlin & Calkins 1987; Pascual & Adkinson 1994). Over the last 20–30 years, populations of the other major top marine predator in Orkney (i.e. grey seals) have risen steadily (Hiby *et al.* 1996). This may mean that harbour seals could be also be suffering from local competition with grey seals, which also prey heavily on sandeels (Hammond, Hall & Prime 1994). In other areas, harbour seals forage much closer to haul-out sites than grey seals, but the diet of the two species does appear similar where they occur together (Thompson *et al.* 1996; McConnell *et al.* 1999). If harbour seals are restricted to local foraging areas, this may make them vulnerable to local competition from grey seals. Recent studies have also shown that intraspecific variation in harbour seal foraging range is related to body size, with larger seals travelling further from haul-out sites on longer foraging trips (Thompson *et al.* 1998). Consequently, larger adult seals may be impacted less by local changes in prey availability, while the diving and foraging ability of younger seals could be further compromised by their small body size (Schreer & Kovacs 1997). This, in turn, could impact upon juvenile survival and/or increase the probability of juvenile dispersal. These factors highlight how the impact of changes in prey availability may differ among different age classes of harbour seals, potentially leading to the changes in age structure observed in this population between 1985 and 1998.

Determining whether these local changes in abundance and group structure are due to redistributions or a change in survival or reproduction is crucial to understanding the ecological and management consequences of our findings. Harbour seals in other areas are known to switch haul-out sites in order to move closer to alternative foraging areas. However, most reported movements occur only between seasons (Fancher & Alcorn 1982; Brown & Mate 1983) and any interannual variation in site use has previously been reported only during the non-breeding season (Thompson *et al.* 1996). Furthermore, many breeding pinnipeds show a high degree of site fidelity to breeding sites (Pomeroy *et al.* 1994), and redistribution of adults seems less likely at this time of year, particularly as foraging effort is reduced during the pupping and moulting periods. Nevertheless, this could provide an explanation for the lack of yearling seals on Eynhallow during 1998, as non-breeding animals would be expected to be less constrained in their site use at all times of year. If so, wider-scale surveys incorporating assessments of the age structure of different groups could be used to determine whether sites in other parts of Orkney have an excess of young animals.

It remains unclear whether the observed changes in age structure result from lower pup production, decreases in juvenile survival, age-dependent changes in rates of emigration or some combination of these factors. Nevertheless, the association between the reduction in abundance and changes in relative age structure provides an opportunity to assess whether similar patterns of change are occurring at other sites. Given the limited baseline information on abundance in other areas, follow-up surveys have limited power to detect changes in abundance. In contrast, comparative studies of relative age structure at different sites in Orkney, and in other UK breeding areas, could quickly determine whether or not the lack of recruits in our Eynhallow study area was typical.

IMPLICATIONS FOR IDENTIFICATION AND MONITORING OF SAC

Observed changes in the local abundance of seals may have been due either to redistribution of seals or to a reduction in survival or reproduction. Either way, these results have implications for the identification, management and monitoring of the SAC required for harbour seals under the EC Habitats Directive. Little is known about the consistency with which harbour seal haul-out sites are used over periods greater than a decade or two. Eynhallow held the largest group of seals during surveys across Orkney in 1979 (Sea Mammal Research Unit, unpublished data), 1985 and 1989 (Thompson & Harwood 1990; this study) and was generally considered a stronghold for this species at that time. If observed reductions were due to local redistribution, this suggests that site use is flexible over longer periods, and highlights the importance of identifying and protecting a sufficiently broad suite of sites within SAC. Alternatively, these local changes in abundance may reflect real changes in population status that are occurring over a much wider scale, including those areas of Orkney, such as the Sanday coast, that have been proposed as SAC. Currently, there are insufficient data available to determine whether or not similar changes in abundance have occurred in these other areas. Efforts must be made to determine the current status of harbour seals both within and outside these protected areas. Without such information, future monitoring will have limited power to assess the success of the management plans developed for SAC.

In conclusion, our data have highlighted significant reductions in the local abundance of harbour seals in an area that was used regularly by this species during the 1980s. Further work is now required to determine whether this is simply a local phenomenon, or whether the observed declines are more widespread. Concurrent changes in age structure provide an opportunity to determine rapidly the spatial scale of these changes. Alongside molecular studies of population structure, such work could provide a useful insight into the most appropriate scales for studying and managing harbour seal populations.

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