Scientific Advice on Matters Related to the Management of Seal Populations: 2000

Background

Under the Conservation of Seals Act 1970, the Natural Environment Research Council (NERC) has a duty to provide scientific advice to government on matters related to the management of seal populations. NERC has appointed a Special Committee on Seals (SCOS) to formulate this advice so that it may discharge this statutory duty. Terms of Reference for SCOS and its current membership are given at the end of this document.

Formal advice is given annually based on the latest scientific information provided to SCOS by the Sea Mammal Research Unit (SMRU – a NERC University Unit based at the University of St Andrews). SMRU also provides to government scientific review of applications for licences to shoot seals, and information and advice in response to parliamentary questions and correspondence.

This report provides scientific advice on matters related to the management of seal populations for the year 2000. It begins with some general information on British seals, gives information on their current status, and addresses specific questions raised by the Scottish Executive Rural Affairs Department (SERAD). Appended to the main report are two annexes giving more detail about the status of the two species of seal around Britain: grey and common (harbour) seals.

General information on British seals

Grey seals

The grey seal is the larger of the two species of seal that breed around the coast of the British Isles. It is found across the North Atlantic Ocean and in the Baltic Sea. British waters hold about 40% of the world population of grey seals.

Grey seals come ashore on remote islands and coastlines to give birth to their pups in the autumn, to moult in spring, and at other times of the year to haul out between trips to forage for food at sea. Female grey seals give birth to a single white-coated pup, which moults and is abandoned by its mother about 3 weeks later.

Over 90% of British grey seals breed in Scotland, the majority in the Hebrides and in Orkney. There are also breeding colonies in Shetland, on the north and east coasts and in south-western Britain. Although the number of pups born at colonies in the Hebrides has remained approximately constant since 1992, the total number of pups born throughout Britain has risen since the 1960s. Total population size has also been growing steadily at an average rate of about 6% per year. In 1999, there were an estimated 123,000 grey seals in Britain.

Adult male grey seals may weigh up to 350 kg and grow to over 2.3 m in length. Females are smaller at a maximum of 250 kg in weight and 2 m in length.

Grey seals feed mostly on fish that live on or close to the seabed. The diet is composed particularly of sandeels, whitefish (cod, haddock, whiting, ling), and flatfish (plaice, sole, flounder, dab) but varies seasonally and from region to region. Food requirements depend on the size of the seal and oiliness of the prey but an average figure is 7 kg of cod or 4 kg of sandeels per day.

Common seals

Common seals are found all around the coasts of the North Atlantic and North Pacific. In Europe they are found mainly around Iceland, Norway, Denmark, Germany and in the Dutch Wadden Sea. Common seals are widespread around the west coast of Scotland and throughout the Hebrides and Northern Isles. On the east coast, their distribution is more restricted. The main concentrations are in the Moray Firth, the Tay Estuary and The Wash. Britain holds about 45% of the European population, and about 5% of the world population of common seals.

Between 1996 and 1999, 33,200 common seals were counted in the whole of Britain, of which 29,600 (89%) were in Scotland and 3,600 (11%) were in England. The total British population cannot be estimated accurately but is thought to be approximately 47,000 – 55,000 animals. The population along the east coast of England (mainly in The Wash) was severely affected by the Phocine Distemper Virus epidemic in 1988. Numbers in England have increased since then, but they are still below the pre-epidemic level.

Common seals come ashore in sheltered waters typically on sandbanks and in estuaries but also in rocky areas. They give birth to their pups in June and July and moult in August. At other times of the year, common seals haul out on land regularly in a pattern that is often related to the tidal cycle. Common seal pups are born without a white coat and can swim almost immediately.

Adult common seals typically weigh about 80-100 kg. Males are slightly bigger than females.

Common seals feed locally around haul out sites taking a wide variety of prey including sandeels, whitefish, herring and sprat, flatfish, octopus and squid. Diet varies seasonally and from region to region. Because of their smaller size, common seals require less food than grey seals, perhaps 3-5 kg per day depending on the prey species.

Current status of British grey seal populations

Each year, SMRU conducts aerial surveys of the major grey seal breeding colonies in Britain to determine the number of pups born (pup production). These sites include about 85% of the number of pups born throughout Britain. The total number of seals associated with these regularly surveyed sites is estimated by applying a population model to the estimates of pup production. Estimates of the total number of seals at other breeding colonies that are surveyed less frequently are then added in to give an estimate of the total British grey seal population. Further details are given in Annex I.

Pup production

The total number of pups born in 1999 at all regularly surveyed colonies was estimated to be 33,103. Regional estimates were 2,787 in the Inner Hebrides, 11,683 in the Outer Hebrides, 15,253 in Orkney, and 3,380 at North Sea sites.

Trends in pup production

Between 1984 and 1996, estimates of the total number of pups born at regularly surveyed colonies have increased year on year. In 1997 estimated total pup production fell for the first time, but recovered again in 1998 in line with the previously observed upward trend.

In 1999, estimated pup production declined markedly across all major breeding colonies (see table below). The greatest decline was at the Farne Islands, where pup counts are made by National Trust staff on the ground. These counts are independent and error free. That declines have occurred at the Farne Islands and at other sites where pup production is monitored by aerial survey suggests that this is a general phenomenon and not related to differences in methods or survey conditions from previous years.

Pup production and total population size estimates for the main colonies surveyed in 1999			
Location	1999 pup production	Change in pup production from 1998	Total 1999 population (to nearest 100)
Inner Hebrides	2,787	-9.5%	9,200
Outer Hebrides	11,683	-5.5%	38,500
Orkney	15,253	-6%	50,300
Isle of May + Fast Castle	2,034	-9%	6,700
Farne Islands	843	-35.5%	2,800
Donna Nook	503	+14.5%	1,700

The declines in pup production in 1999 appear to be too great (and too widespread) to be explained solely by changes in survival and fecundity related to shortage of space at breeding colonies. Environmental changes, possibly related to the availability of prey, may also be implicated.

The total number of pups born is the sum of pup production at many individual colonies, each of which varies from year to year. Total pup production should also be expected to fluctuate from year to year because of this underlying variation. There has been more variability in pup production since 1997 than in previous years but it is clear that the increase in pup production has slowed in recent years.

Population size

The size of the British grey seal population at the start of the 1999 pupping season is estimated to be 122,800 animals. Of these, 113,600 (93%) are associated with breeding colonies in Scotland and 9,200 (7%) are associated with colonies in England and Wales.

Trends in population size

The increase from 1998 to 1999 in the estimate of population size associated with annually monitored breeding sites was 6.25%, with 95% confidence limits of 3.75%-8.75%. The population at these sites is estimated to have increased by 35% (95% confidence limits 28%-43%) between 1994 and 1999.

The table below shows the predicted changes in the size of the British grey seal population over the next five years if there are no changes in survival and fecundity rates. The 95% confidence limits provide an indication of the uncertainty associated with these predictions.

Predicted population size if there are no changes in survival and fecundity rates (and no change in the number of seals associated with sites that are not surveyed regularly)					
Year	Total female population	95% confidence limits on female population		% increase from 1999	Total female + male + other sites not surveyed regularly
2000	66,500	56,500	77,000	5.4%	129,500
2001	70,000	59,000	82,500	10.9%	136,500
2002	74,000	62,000	87,000	17.3%	144,000
2003	80,000	66,000	93,000	26.8%	151,500
2004	83,500	69,500	97,000	32.3%	160,000

It should be recognised that total population size will continue to rise for some time, even if pup production does stabilise at some equilibrium level. This is because female grey seals do not begin to produce pups until they are about 5 years old. This leads to a lag between changes in pup production and resulting changes in the number of females giving birth. For a decline in pup production to affect population size immediately, that decline would have to be extremely marked.

As an illustration, if pup production remains constant at the 1999 level for the next five years, the total population size is predicted to increase by approximately 26,500 over this period, which is approximately 70% of the increase predicted for a steadily increasing pup production.

Current status of British common seal populations

Scotland

A new analysis has been conducted of the data from surveys of common seals along the north and west coasts of Scotland as far south as the southern tip of the Mull of Kintyre, and in Orkney, Shetland and the Hebrides. The results indicate that there has been an overall increase of 2.9% per year in the number of animals counted at haul-out sites since 1988. Regional variation is apparent but not statistically significant, with estimated annual rates of change ranging from –1.1% per year for Orkney to +8.5% per year for the Outer Hebrides. Further details are given in Annex II. It is not known how these trends in numbers counted at haul-out sites relate to trends in population size.

The Wash and eastern England

Two surveys of common seals in eastern England were carried out during August 1999. The Wash counts averaged 2,397, very close to the 1998 count of 2,381. The average annual rate of increase in the number of seals counted in The Wash since 1989 is 5.9% (per year), significantly greater than that estimated between 1968 and 1988 (3.5% per year). However, the 1999 count in The Wash remains 20% lower than the last count made before the 1988 Phocine Distemper Virus epidemic. Common seal populations in Denmark, Germany and the Netherlands have recovered more rapidly from the effects of this epidemic and had returned to, or surpassed, their pre-epidemic levels by 1996. Further details are given in Annex II.

Minimum estimate of the British common seal population

The most recent minimum estimate of the number of common seals in Scotland is 29,600 from surveys carried out in 1996 and 1997. The most recent minimum estimate for the east coast of England is 3,568. This comprises 3,431 seals in Lincolnshire and Norfolk in 1999 plus 137 seals in Northumberland, Cleveland, Essex and Kent between 1994 and 1997. Counts by region are given in the Table below.

Region	**1996-97**
Shetland	5,991
Orkney	8,522
Outer Hebrides	2,820
Highland	5,117
Strathclyde	6,333
Dumfries & Galloway	6
Grampian	62
Tayside	92
Fife	617
Lothian	40
TOTAL SCOTLAND	**29,600**

East coast England (1994 to 1999)	3,568
TOTAL BRITAIN	**33,168**

Questions from the Scottish Executive Rural Affairs Department

Limits to grey seal population growth

What can be done to refine predictions on the likely future trends in population size for grey seals? In particular, what is the impact of limited capacity on current breeding sites and the possibilities for colonisation of new sites?

The number of grey seal pups born each year (pup production) has been increasing steadily since the 1960s. Total population size (estimated since 1984) has also shown a constant increasing trend.

Survey data from the last three years suggest that pup production may be starting to level out. The reasons for this are unclear but are likely to be a combination of density dependent changes in survival and fecundity, and environmental changes possibly related to the availability of prey. It is important to realise that even if pup production does stabilise at some equilibrium level, total population size will continue to rise for some time. This is because of the approximate 5 year time lag between changes in pup production and recruitment into to the female breeding population.

Nevertheless, the current increase in the size of the British grey seal population cannot continue indefinitely. At some point the population will be limited, probably by a shortage of space at breeding colonies and/or food. The number of pups born at most colonies in the Hebrides and a number of colonies in Orkney has changed very little in recent years suggesting that space is already limited at these sites. It is not possible at present to predict when the colonies that are still increasing will stabilise. But as space on individual colonies becomes limited, it is expected either that the density of seals will increase or that they will begin to use areas that are less suitable for breeding. Both processes are likely to cause increased pup mortality within the colony, which in turn will lead to a decrease in the rate of increase of the population.

The ability to predict future population size is limited by lack of knowledge and uncertainty in a number of areas. These include: physical and behavioural factors that limit the spread of seals at individual colonies; how these factors affect the survival of pups on the colony and when they go to sea; and how changes in food availability affect pup survival. One of the main objectives of SMRU's research programme for the next five years is to increase our understanding of these factors that are likely to limit the growth of the British grey seal population. This will allow future changes in the size of the total population and of individual colonies to be predicted with more confidence.

There is the possibility that grey seals are establishing new breeding colonies. An integral part of the aerial survey programme is to monitor known minor colonies (approximately 40 are surveyed regularly, see Annex I) and to search other parts of the Scottish coast and islands for new colonies. The SMRU also makes use of information from interested individuals or organisations (such as Scottish Natural Heritage, Regional Countryside Rangers and the National Trust for Scotland), which may encounter new breeding colonies. At least since 1984, all the most rapid increases in pup production have occurred at small, previously established colonies rather than at new sites. However, if a consequence of increasing population size and increasing density at existing colonies is the establishment of new colonies, these will be located and included in the survey programme.

Common seal abundance

How can the current estimates of common seal abundance be improved?

An improved knowledge of abundance and trends is important in assessing whether common seal

populations are increasing or decreasing, and as one element of estimating fish prey consumption by common seals.

The information available for common seal populations is less detailed than for grey seals. This is for two reasons. Firstly, the survey method provides an estimate of the minimum number of seals, not the total population. Secondly, there are considerably less data available; only two counts from most areas of Scotland between 1980 and 1997.

SMRU currently conducts aerial surveys of common seals using either conventional aerial photography from fixed-wing aircraft (sandy sites) or thermal image photography from helicopters (rocky sites). Comprehensive surveys of Britain cannot be completed in a single year; instead they are conducted over a number of years (usually two or three) and take place approximately on a 5-year cycle. The first two comprehensive surveys were conducted during the period 1988-1994 and during 1996-1997. In addition, a number of areas have been surveyed more than twice since 1988. These include The Wash and East Anglia (surveyed annually), Shetland, Orkney, the Moray Firth, Firth of Tay, Skye, Mull and Lismore. The third comprehensive survey of Scotland is currently underway and is scheduled to be completed in 2001.

The surveys are timed to coincide with the annual moult (August) and the counts of animals ashore provide minimum estimates of abundance. Converting the counts into estimates of absolute abundance requires information on the proportion of seals ashore at the time of the surveys. There is good information for some areas (Thompson et al. 1997; Ries et al. 1998) during the pupping season (June/July), when around two-thirds of all seals are likely to be ashore, but not during the moult when the SMRU counts are made. This is because the required information is obtained using radio transmitters glued to the fur of the seals and these fall off during the moult. If the proportion of seals ashore during the moult is similar to that during the pupping season, an approximate estimate of the total number of common seals around Britain can be made by multiplying the SMRU counts by a factor of 1.5.

To obtain a more reliable estimate of the total number of common seals around Britain using the data from the SMRU surveys, data on the proportion of seals ashore during the moult are needed. SMRU's research programme for the next five years includes the development and deployment of equipment that will provide data on the proportion of seals that are ashore during the moult. Results from this work will then be used to convert counts from aerial surveys into estimates of total abundance of common seals.

With respect to determining changes in abundance over time, Annex II describes the results of an analysis of SMRU's aerial survey data to estimate trends in counts in different regions of Scotland. SMRU's research programme for the next five years includes the further development of methods to estimate trends in abundance from these and future aerial survey counts.

Interactions between seals and salmonid fisheries

What effect is the localised killing of grey and common seals around estuaries and river mouths likely to have upon seal numbers?

Under the Conservation of Seals Act 1970, licences may be granted to kill seals during the close season in the vicinity of fishing nets, to prevent damage to fishing gear or to fish actually in a net, or to prevent damage to fisheries in general. No licence is required outside the close season. The number of seals reported killed under licences issued by the Scottish Executive to prevent damage to fisheries is small (25 common seals and 30 grey seals in 1999) but the total number killed around estuaries and river mouths is unknown.

As described above and in Annex I, the population of grey seals around Britain is currently estimated to be 122,800 and to be increasing at a rate of 6.2% per year.

For common seals, only minimum estimates of population size are available and the information on trends is limited to the numbers of seals counted ashore (see above and Annex II). It is not known

how these trends in counts relate to trends in population size. However, regional differences in these estimated trends are apparent, some of which are positive and some of which are negative.

If the number of seals reported as killed under licence is an accurate reflection of the numbers actually killed, then clearly this will not have a significant effect on the British populations of either species. However, because the total number killed around estuaries and river mouths is unknown, the possibility that localised killing may be having an impact on local populations cannot be ruled out, but this would be unlikely to affect the British population as a whole.

Can this provide more than a temporary respite for the fisheries concerned?

The localised killing of grey and common seals around estuaries and river mouths may have an immediate effect on salmonid predation. How effective it is as a control depends upon where the killing occurs, whether the seals removed are those individuals that are making the most impact and how quickly these individuals will be replaced. Local variation in the foraging behaviour and diet of seals will be important.

The most important factor in determining the effectiveness of localised killing of grey and common seals around estuaries and river mouths to protect salmonids is whether the fish are being targeted by a relatively small number of individuals or by the local population as a whole. If salmonid mortality due to seals is the result of a few individuals, removing these animals may be an effective control measure for a time, at least until they are replaced by others. However, if all the animals in the local population prey on salmonids, localised killing will not be effective. The available information suggests that salmonid mortality is likely to be caused by a few individuals rather than the population as a whole.

What can be done to estimate the numbers of salmon consumed at various stages of the life-cycle by both species of seal, and to model the effects of seal predation on salmon populations?

In Scotland, total catches of salmon from commercial and sports fisheries have decreased markedly over the years since 1952 when national catch figures were first compiled. The declines in the total figures are mainly attributable to reductions in commercial netting effort on the coast and in estuaries. Indeed, sports catches have increased in an irregular trend since 1952, probably because of increased sparing of fish by prior commercial fisheries. However, the absolute increase in rod catch is much less than the absolute decrease in the net catch.

There are two main components to the fisheries. So-called grilse (one sea-winter sea absence) are available to the fisheries from July until October. Multi-sea-winter fish (mainly two-sea-winter) are available for the longer period from February onwards. The performance of the classes varies among years with substantial independence for reasons that are not understood.

Against this background, underlying trends are detected for major declines in the numbers of fish returning to homewaters throughout the North Atlantic. This is particularly the case for the older, two sea-winter fish. The production of juvenile fish from streams is generally robust to variation in adult numbers, and declines in adult numbers are attributed to lower marine survival rates. Direct evidence for major declines in marine survival rate comes tagging studies at monitored sites.

Within the two sea-winter class, extreme declines are detected among so-called spring salmon. Spring salmon are a typical feature of the major eastern rivers of Scotland. They reach the coast and enter fresh water over the winter months and in spring, eventually spawning in upland head-waters after a prolonged period of river residence. Reductions in the number of spawning spring salmon are now sufficiently large as to threaten juvenile recruitment in upland streams.

To assess the impact of seal populations on salmon populations requires information on seal numbers, distribution, dynamics, diet, and foraging behaviour but also on the numbers, dynamics and the magnitude and causes of other sources of mortality for salmon. The SMRU routinely collects data on the numbers and distribution of both grey and common seals and uses these data to investigate population dynamics. Information on diet and foraging behaviour is available on a broad scale for grey seals and from certain locations for common seals but most of this does not focus on particular estuaries or river mouths.

NERC believes that the most appropriate use of its resources is to focus on assessing seal numbers and distribution, and on understanding the general characteristics of population dynamics and foraging behaviour. This information is essential to underpin advice on scientific aspects of the management of seal populations.

To estimate the numbers of salmon consumed at various stages of the life-cycle by both species of seal, and to model the effects of seal predation on salmon populations, information needs to be collected on a finer spatial and temporal scale as part of in-depth local studies. The most appropriate way forward in these cases is through inter-disciplinary collaborative projects with other institutes.

SMRU is collaborating with FRS Freshwater Laboratory on work on common seals in Loch Shieldaig, and is discussing further collaboration to address questions related to seal predation on salmonids.

Diet of grey and common seals

How has the diet of grey seals in the North Sea changed since the assessment using data from 1985?

The assessment of grey seal diet based on data collected mainly in 1985 showed that sandeels, whitefish (cod, haddock, whiting, saithe and ling) and flatfish (plaice, sole, flounder and dab) were the main prey species. Significant regional and seasonal variations were observed (Hammond *et al.* 1994 a, b). In the North Sea, sandeels comprised approximately 50% of the diet, and whitefish a further 35%.

Grey seal diet was studied in the central North Sea in 1997 and 1998 as part of the EC-funded project ELIFONTS (Effects of Large-scale Industrial Fisheries on Non-Target Species). Results from this work showed a diet composition similar to the results from 1985 but with some variation from year to year. In particular, consumption of sandeels was significantly lower in 1998 than in 1997.

What plans are there to extend the new studies to areas other than the North Sea?

SMRU has received a commission from MAFF for a comprehensive update of the assessment of grey seal diet in the North Sea, including Orkney, in 2001/2002. Resources are currently not available to extend this work to include the Hebrides, as was done in 1985.

What plans are there to investigate the diet of common seals, particularly with respect to the occurrence of salmonid fishes?

The diet of common seals has been studied in detail in the Moray Firth (Tollit *et al.* 1996; 1997; 1998), Shetland (Brown & Pierce 1997; 1998), the Firth of Tay and St Andrews Bay (Arrizabalaga & Hammond in prep) and The Wash (Hall *et al.* 1998). These studies show that common seals eat a wide variety of prey including gadoids (mainly whiting), flatfish, herring and sandeels. All these studies used fish otoliths (ear bones) recovered from seal faeces to assess diet. Only a few salmonid otoliths have been found and salmonids consequently make up an insignificant amount of the diet estimated in this way. This may be because common seals do not eat much salmonid fish. But it may also be because salmonid otoliths are small and may be completely digested, or because seals do not always eat the heads of large fish.

The analysis of fish hard parts recovered from faeces is not the ideal method for studying the occurrence of salmonid fish in the diet of seals. Nevertheless, it is currently the best practical method available. However, new methods to investigate diet using the analysis of fatty acids extracted from seal blubber samples (Iverson *et al.* 1997; Smith *et al.* 1997; Walton *et al.* 2000) may provide valuable additional information on consumption of salmonids. SMRU plans to continue investigation of common seal diet in St Andrews Bay and to initiate studies at Loch Shieldaig as part of collaboration with FRS Freshwater Laboratory using both these methods.

Impact of culls on seal populations and fish predation

How many seals would need to be killed to stabilise the grey seal population?

The size and composition of a cull that would reduce a seal population to a given proportion of its current size depends, amongst other things, on the time scale over which the reduction is to occur, the desired age structure and sex ratio in the population, and when the cull is carried out.

However, an illustration of the scale of operation which would be necessary can be gained from a calculation of the numbers of pups or older animals which would need to be killed to stabilise the British grey seal population at its 1998 level.

This could be achieved by killing approximately half of all pups born each year. Disturbance (which will have unpredictable effects on the outcome of the cull) could be minimised by killing weaned pups at the end of the pupping season, as was the practice when seal pups were hunted commercially. At current levels of pup production this would involve killing around 18,000 pups each year, but the size of the annual cull would rise to around 25,000 as the age structure of the population stabilised. A reduction in population size would involve killing a greater number of pups each year.

The population could also be stabilised by killing around 6,000 females one-year and older each year. If a greater number were to be killed, the population would decline. The simplest way to carry out a cull of this kind would be to kill adult seals at the breeding colonies. However, attempts to reduce the population in this way in the 1970s resulted in massive disturbance. Large numbers of seals deserted the colonies that were culled and some of these animals did not return for a number of years.

In addition there is strong evidence that disturbance caused by a culls at breeding colonies can lead to the establishment of new breeding colonies. Management culls at the Farne Islands to protect habitat for breeding seabirds in the 1970s led to a reduction in pup production from over 2,000 in 1971 to less than 1,000 through the 1980s. At the same time, the initially low pup production at the Isle of May increased markedly with over 1,000 pups born by 1990. Pup production continued to increase at the Isle of May until in 1998 there were almost 2,000 pups born there, in addition to 1,300 at the Farne Islands. Similarly, an experimental cull at Haskeir and Gasker in the Outer Hebrides preceded grey seals colonising new sites in the Monach Isles.

Such responses make it very difficult to predict and monitor the long-term effects of any cull.

What is the impact of changes in seal numbers on predation of fish?

The impact of changes in seal numbers on the numbers of fish consumed each year will depend on a number of factors including the behaviour and average size of the surviving seals and their diet. Grey seal diet composition was last assessed on a Britain-wide scale in 1985. There have been substantial changes in the size of many fish stocks since then and it is likely that grey seal diet has also changed.

However, new information on diet alone will not allow the effects of changes in seal numbers on fish stocks to be predicted reliably, because of the wide range of prey species taken by seals and because of the interactions between these species, their other predators and commercial fisheries. Research on the responses of seals and other fish predators to changes in the availability of their preferred prey is required before the effects of these interactions can be assessed.

Any projected changes in fish consumption resulting from a cull will simply reflect percentage changes in the number of seals unless a number of important interactions are taken into account. These include changes in seal age/sex structure as a result of a reduction in numbers and, most importantly, predation on fish by other fish, seabirds and other marine mammals. For example, a reduction by 25% in the number of grey seals in the North Sea in 1998, approximately 15,000 seals, would lead to a reduction in fish consumed of approximately 28,000 tonnes per year. For common seals, a reduction by 25% in the total number of seals throughout Britain would result in a reduction in annual consumption of about 18,000 tonnes of prey.

Using a simple model without taking these key interactions into account, an illustration of the trade off between reduction in seal population and reduction in fish consumed can be calculated. Using the North Sea as an example, to stabilise the population at the 1998 level would required the removal of

about 9,000 pups each year increasing to 13,000 pups in 2003. This would result in a reduction in the amount of fish consumed in 2003 of 41,500 tonnes, approximately half of which would be sandeels.

In interpreting the results of these simple calculations the following points need to be noted:

- The amount of fish not eaten is based on diet information from 1985; this may have changed significantly in recent years
- The amount of fish not eaten is small compared to catches taken by fisheries
- The amount of fish available to fisheries would be even smaller if predation on fish by other fish, seabirds and other marine mammals were taken into account
- The considerable uncertainty in any estimate of fish 'freed up' for fisheries would likely be within the range of uncertainty of fish stock assessments, forecasts, or reported catches.

The potential impact of changes in seal numbers on predation of salmonids cannot be predicted because of the lack of data on predation rates, and because the effects are more likely to depend on where and which animals are culled.

The above calculations were completed last year and were based on data through to 1998. The declines in pup production observed in 1999, as described above, would result in slightly different numbers if the calculations were repeated now.

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NERC Special Committee on Seals

Terms of Reference

1. To undertake, on behalf of Council, the provision of scientific advice to the Scottish Executive and the Home Office on questions relating to the status of grey and common seals in British waters and to their management, as required under the Conservation of Seals Act 1970.
2. To comment on SMRU's core strategic research programme and other commissioned research, and to provide a wider perspective on scientific issues of importance, with respect to the provision of advice under Term of Reference 1.
3. To report to Council through the Science and Technology Board

Current membership

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The Status of British Grey Seal Populations

1. Surveys conducted in 1999

Each year SMRU conducts aerial surveys of the major grey seal breeding colonies in Britain to determine the number of pups born. In addition, new sites where grey seal pups have been reported or which appear to be suitable for colonisation are visited regularly. During 1999, four or five surveys were flown over all the major sites in the Hebrides, Orkney, and in the Firth of Forth. Ground counts of the numbers of pups born at the Farne Islands were made by National Trust staff. Similar counts at Donna Nook on the Humber Estuary were made by members of the Lincolnshire Trust for Nature Conservation and on South Ronaldsay by SNH staff. Locations of the main British grey seal breeding sites are shown in Figure 1.

2. Estimated pup production

The number of pups born (pup production) at regularly surveyed colonies is estimated each year from counts from the aerial survey photographs using a model of the birth process and the development of pups. The method used to obtain the estimates for this year's advice was similar to that used for the past several years (but see section 4 below).

Total pup production in 1999 at all annually surveyed sites is estimated to be 33,103. Estimates of pup production at all major breeding sites in England and Scotland (except Loch Eriboll, Helmsdale and Shetland) between 1984 and 1999 are shown in Figure 2. Pup production estimates for the main island groups (the Inner Hebrides, the Outer Hebrides and Orkney) are shown in Figure 3a and for the North Sea sites in Figure 3b. The time series of data for these groups are given in Table 1. For colonies not surveyed by air, pup numbers are counted directly on the ground either annually (Farne Islands, Donna Nook, South Ronaldsay) or less frequently (SW England, Wales, Shetland).

3. Trends in pup production

Between 1984 and 1996 estimates of the total number of pups born at regularly surveyed colonies have increased year on year. In 1997 estimated pup production fell for the first time, but recovered again in 1998 in line with the previously observed upward trend.

In 1999, estimated total pup production declined markedly across all major breeding areas. The declines from 1998 to 1999 were:

- 6% in the Outer Hebrides and Orkney
- 10% in the Inner Hebrides
- 9% at the Isle of May
- 36% at the Farne Islands (central North Sea).

Pup production increased at Donna Nook (southern North Sea) by 15%.

The greatest decline was at the Farne Islands, where pup counts are made by National Trust staff on the ground. These counts are independent and error free. That declines have occurred at the Farne Islands and at other sites where pup production is monitored by aerial survey suggests that this is a general phenomenon and not related to differences in methods or survey conditions from previous years.

The declines in pup production in 1999 appear to be too great (and too widespread) to be explained solely by changes in survival and fecundity related to shortage of space at breeding colonies. Environmental changes, possibly related to the availability of prey, may also be implicated.

Nevertheless, the 1999 results suggest that it would be valuable to investigate again whether the data support significant changes in the parameters of the all-age population model, as was done in 1998 following the decreased estimated pup production in 1997. This will be done during the coming year.

Pup production at individual breeding colonies varies from year to year. Total pup production should also be expected to continue to fluctuate from year to year because of this underlying colony-specific variability. Since 1997, pup production has been more variable than previously; nevertheless, it is clear that the increase in pup production has slowed in recent years.

4. Pup production model assumptions

The model used to estimate pup production from aerial survey counts of whitecoat and moulted pups assumes that the parameters defining the distribution of birth dates are variable from site to site and year to year, but that those defining the time to moult and time to leave the colony remain constant. The pup production estimate is sensitive to the value used for the latter parameter and hence there is an argument for allowing this parameter to vary between colonies.

Figure 4 compares the total pup production estimate for all annually monitored sites using the constant value for mean time-to-leave (Method I) with that generated when time-to-leave is estimated together with the parameters of the birth curve (Method II).

The main difference in results from the two methods is a discrepancy from 1992 onwards which may be due to a change in survey protocol. For example, from that year photographic coverage was extended inland on some islands and, as moulted pups tend to move inland, this may have resulted in an increase in the moulted pup count, equivalent to a slight increase in the time-to-leave parameter. However, no difference has been found between the trajectories from islands where coverage has or has not increased. Another possible explanation is that some late moulted pups may have been missed in the counts from earlier years. Allowing time-to-leave to be a free parameter may account for some of these changes. Some minor year-to-year differences are apparent in Figure 4. For example the decline in pup production estimated for 1997 is less pronounced when time-to-leave is a free parameter in the model.

Previously, the time-to-leave parameter has not been re-estimated on a regular basis because the data series for many breeding sites were too short to allow reliable estimation of both the time-to-leave and the birth date parameters, especially given the difficulty of classifying pups to stage from the photographs. One possible consequence of using a fixed time-to-leave is that changes in pup production may be overestimated. For example, an increased number of seals on a breeding site may delay the departure of pups born early in the season and hence bias the pup production estimate upwards. Figure 4 shows that the pup production trajectory is slightly lower using the method in which time-to-leave is allowed to vary, as expected.

Given the above uncertainties, it is appropriate to consider results from both methods of estimating pup production. Results from the previously used method (Method I) are presented in the main body of this report. Results from the new method (Method II) are given for comparison in Appendix 1. Work will continue to determine the most appropriate method for future use.

5. Estimation of population size associated with regularly surveyed sites

The total number of seals associated with the sites surveyed regularly since 1984 (when the current survey methodology was established) is estimated by fitting a population model to the series of total pup production estimates from these sites, to data on population pregnancy rates collected between 1978 and 1981, and to data on population age structure from management culls at the Farne Islands. This method was substantially modified in 1996. It takes account of year to year variation in juvenile

survival and age at first pregnancy, and makes use of more of the available data on these population parameters.

The estimated sizes of the (age 1+) female and total population at all annually monitored breeding sites are 63,108 and 109,121 respectively. Table 2 gives these estimates for the period 1984-1999. Figure 5 shows the initial pup production estimates and the revised pup productions estimated by the population model. The corresponding results calculated using the new method (Method II) for estimating pup production (see above) are given in Appendix 1.

Population size is estimated for Britain as a whole, not regionally. Estimates of pup production and total population size (in proportion to pup production) for the main colonies surveyed in 1999 are given below. These colonies account for more than 85% of all pups born each year.

Pup production and total population size estimates for the main colonies surveyed in 1999

Location	1999 pup production	Change from 1998	Total 1999 population (to nearest 100)
Inner Hebrides	2,787	-9.5%	9,200
Outer Hebrides	11,683	-5.5%	38,500
Orkney	15,253	-6%	50,300
Isle of May + Fast Castle	2,034	-9%	6,700
Farne Islands	843	-35.5%	2,800
Donna Nook	503	+14.5%	1,700

6. Confidence limits

Ninety-five percent confidence limits on the pup production estimates at each site are within 14% of the point estimate. The exact limits depend on a number of factors including the number of surveys flown in a particular year. It is also possible to calculate 95% confidence limits for the estimate of the female component of the population; for 1999, these are ±16% of the estimate (i.e. 54,000 - 73,000 for the estimate of the female population in 1999). The size of the male component has been estimated by assuming that the number of sexually mature males is 60% of the number of mature females, and that males become sexually mature at four years of age. The procedure used to generate confidence limits on the estimate of female population size could, in principle, be repeated for the combined female and male population. However, there are no current data on the relative numbers of males and females in the population that could be used for this purpose.

7. Population size at sites surveyed less frequently

The total population associated with breeding sites not surveyed regularly has been calculated using the ratio of total population to pup production for the main areas. Less than 15% of all pups are born at these sites each year. Confidence limits cannot be calculated for these estimates because they are obtained by simple extrapolation of single counts. The resulting figures are given below.

Pup production and total population size estimates for breeding sites not surveyed regularly

Location	Date of last survey	Pup production (to	Total population

		nearest 100)	(to nearest 100)
Mainland Scotland & South Ronaldsay	Helmsdale (including Berriedale) 1997 Loch Eriboll 1998 South Ronaldsay 1998	1,700	5,600
Shetland	1977	1,000	3,300
Southwest Britain	Southwest England 1973 Wales 1994	1,500	4,700

Table 3 shows Scottish breeding sites which are either not surveyed annually or have recently been included in the survey programme. These and other potential breeding sites are checked when flying time, flying conditions and additional circumstances permit.

8. Total size of the British grey seal population

Taken together, these figures provide an estimate of 122,800 for the size of the British grey seal population (age 1+) at the start of the 1999 pupping season: 113,600 (93%) seals are associated with breeding sites in Scotland and 9,200 (7%) with breeding sites in England and Wales. Britain holds approximately forty percent of the world population of about 300,000 grey seals.

9. Trends in population size

The increase, from 1998 to 1999, in the estimate of population size associated with annually monitored breeding sites was 6.25 %, with 95% confidence limits of 3.75%-8.75%. The population at these sites is estimated to have increased by 35% (95% confidence limits 28%-43%) between 1994 and 1999.

If there are no changes in survival and fecundity rates (and no change in the number of seals associated with the sites that are not surveyed regularly), the population is predicted to increase further at much the same rate, as shown in the following table. Note that, as expected, predictions become more uncertain (confidence intervals become wider) the farther into the future the prediction is made.

Predicted population size if there are no changes in survival and fecundity rates (and no change in the number of seals associated with sites that are not surveyed regularly)

Year	Total female population	95% confidence limits on female population		% increase from 1999	Total female + male + other sites not surveyed regularly
2000	66,500	56,500	77,000	5.4%	129,500
2001	70,000	59,000	82,500	10.9%	136,500
2002	74,000	62,000	87,000	17.3%	144,000
2003	80,000	66,000	93,000	26.8%	151,500
2004	83,500	69,500	97,000	32.3%	160,000

It should be recognised that total population size will continue to rise for some time, even if pup production does stabilise at some equilibrium level. This is because female grey seals do not begin to produce pups until they are about 5 years old. This leads to a lag between changes in pup production and resulting changes in the number of females giving birth. For a decline in pup production to immediately affect population size, that decline would have to be extremely marked.

As an illustration, if pup production remains constant at the 1999 level for the next five years, the total population size is predicted to increase by approximately 26,500 over this period, which is approximately 70% of the increase predicted for a steadily increasing pup production.

Legends to Figures

Figure 1 Grey seal breeding sites in Great Britain.

Figure 2 Total estimated pup production for all major breeding colonies in Scotland and England (excluding Loch Eriboll, Helmsdale and Shetland) from 1984 to 1999.

Figure 3 Trends in pup production at the major grey seal breeding areas since 1984. Production values are shown with their upper and lower 95% confidence limits where these are available. These limits assume that the various pup development parameters which are involved in the estimation procedure remain constant from year to year. Although they therefore underestimate the total variability in the estimate, they are useful for comparison of the precision of the estimates in different years.

(a) Outer Hebrides, Orkney and Inner Hebrides

(b) Isle of May, Farne Islands and Donna Nook

Note that the scale of these two figures differs by an order of magnitude.

Figure 4 Comparison of pup production trajectory estimated using a constant time to leave parameter (as in Figure 1) with that generated when this parameter is re-estimated for each breeding colony in each year.

Figure 5 Estimated size of the (age 1+) total and female population at all major breeding sites in Scotland and England from 1984 to 1998, shown with estimated pup production and the revised pup production estimated from the population model. The time to leave parameter is constant for all colonies.

Grey seal breeding sites
in Great Britain

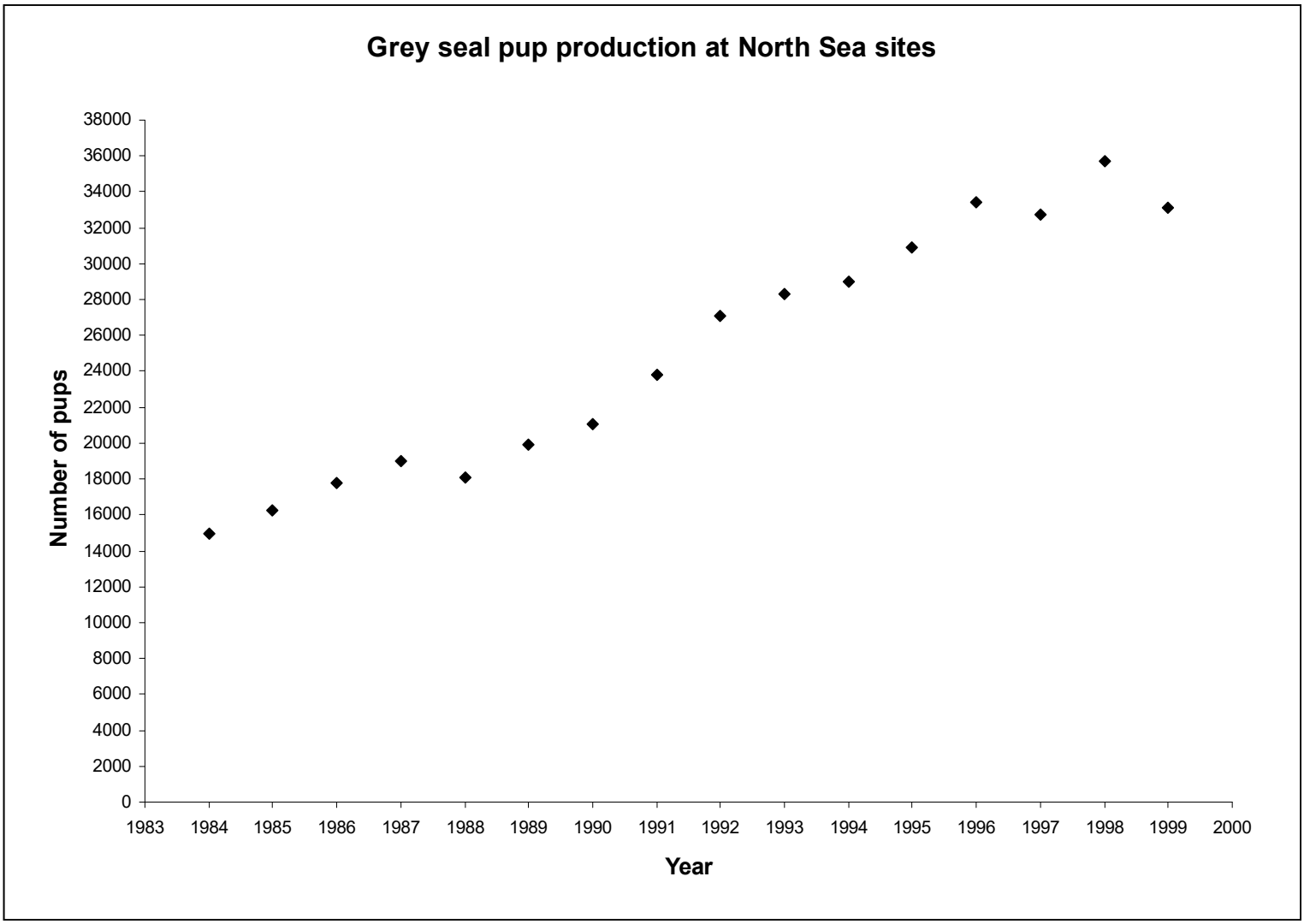
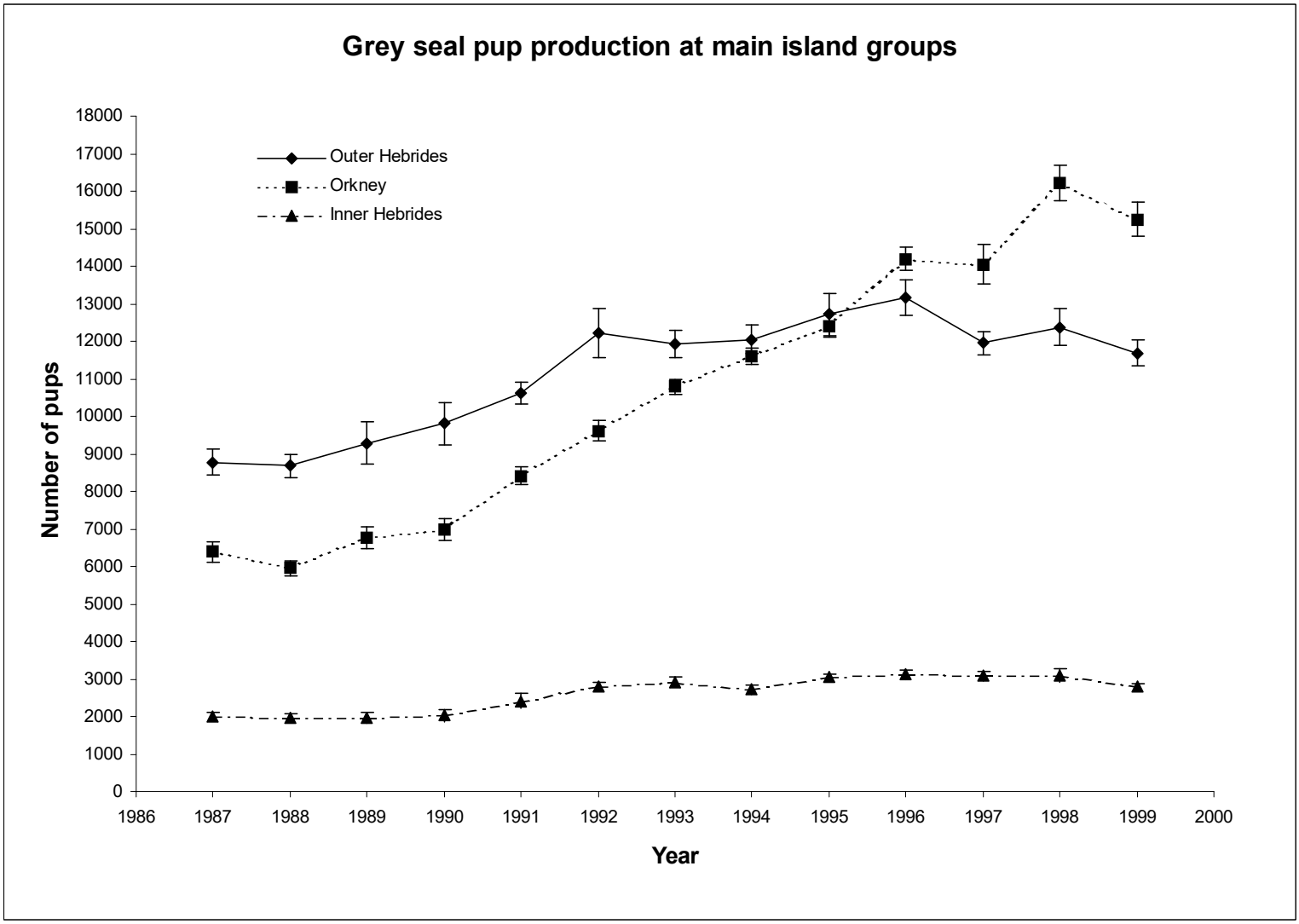

Grey seal pup production at North Sea sites
Number of pups
38000
36000
34000
32000
30000
28000
26000
24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
Year

Figure 2


Grey seal pup production at main island groups
Outer Hebrides
Orkney
Inner Hebrides
Number of pups
Year
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
16000
17000
18000
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1987
1988
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1990
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1992
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1994
1995
1996
1997
1998
1999
2000

Figure 3a

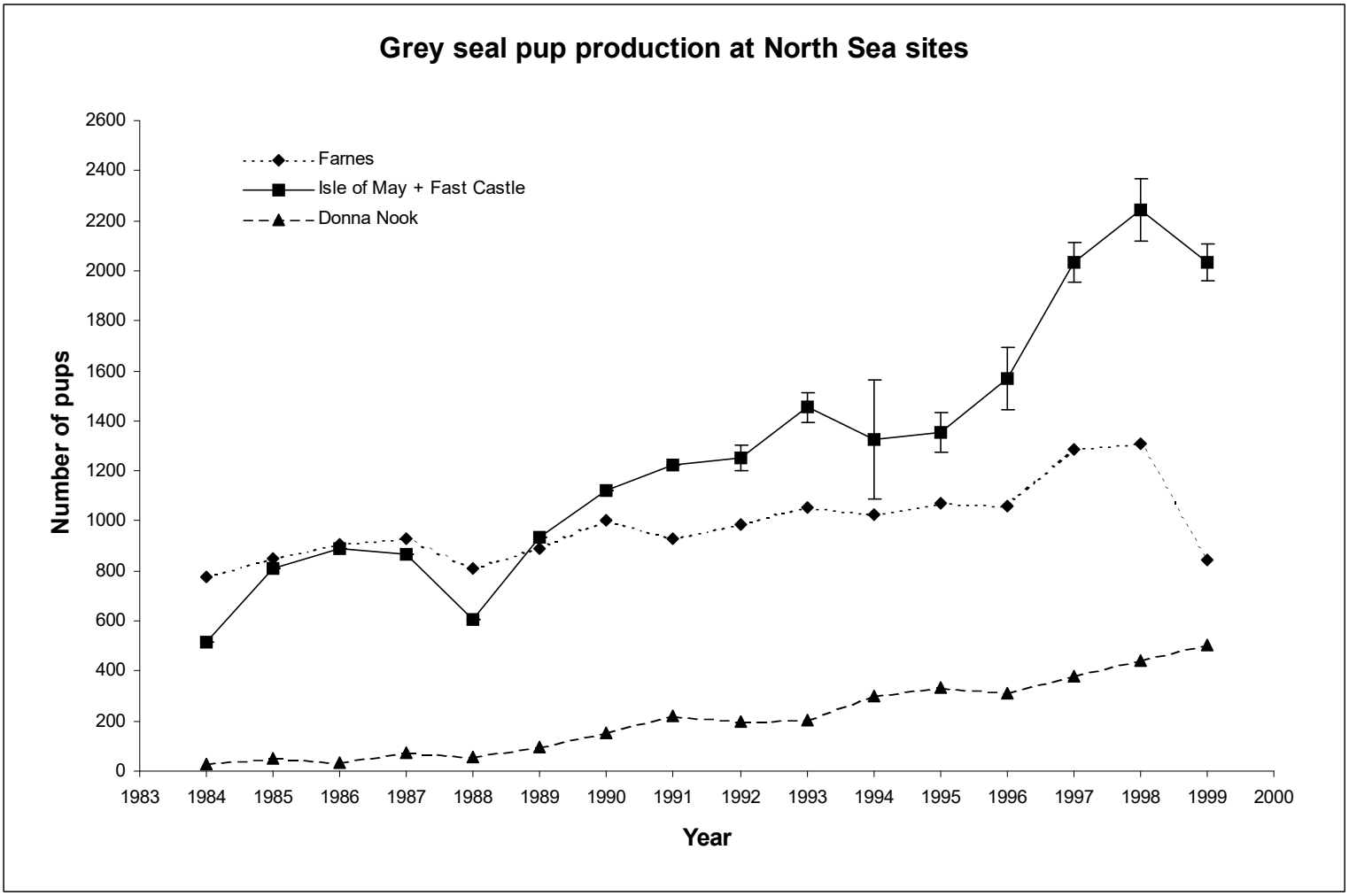

Grey seal pup production at North Sea sites
Farnes
Isle of May + Fast Castle
Donna Nook
Number of pups
Year
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000

Figure 3b

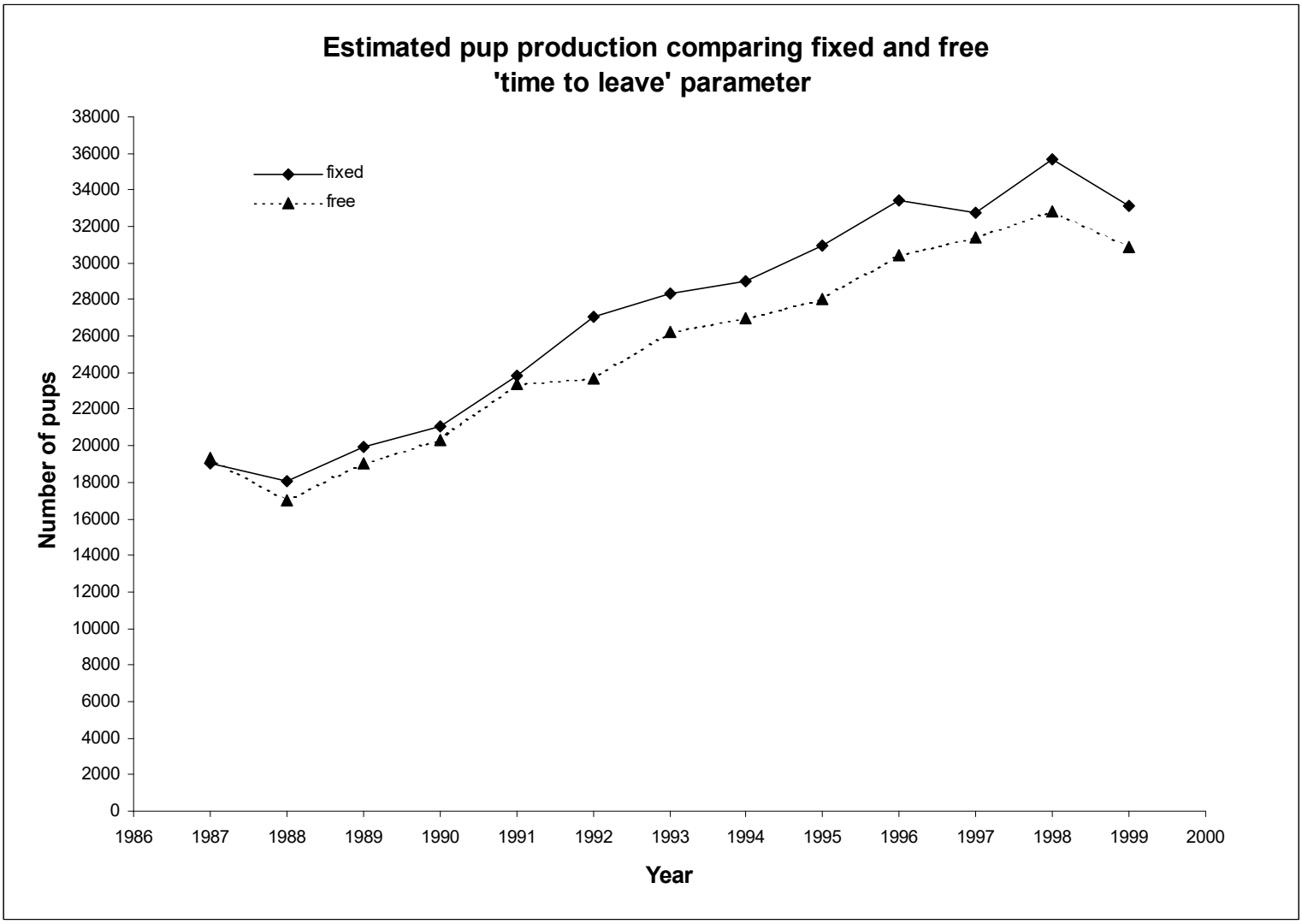

Estimated pup production comparing fixed and free 'time to leave' parameter
fixed
free
Number of pups
Year
38000
36000
34000
32000
30000
28000
26000
24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000

Figure 4

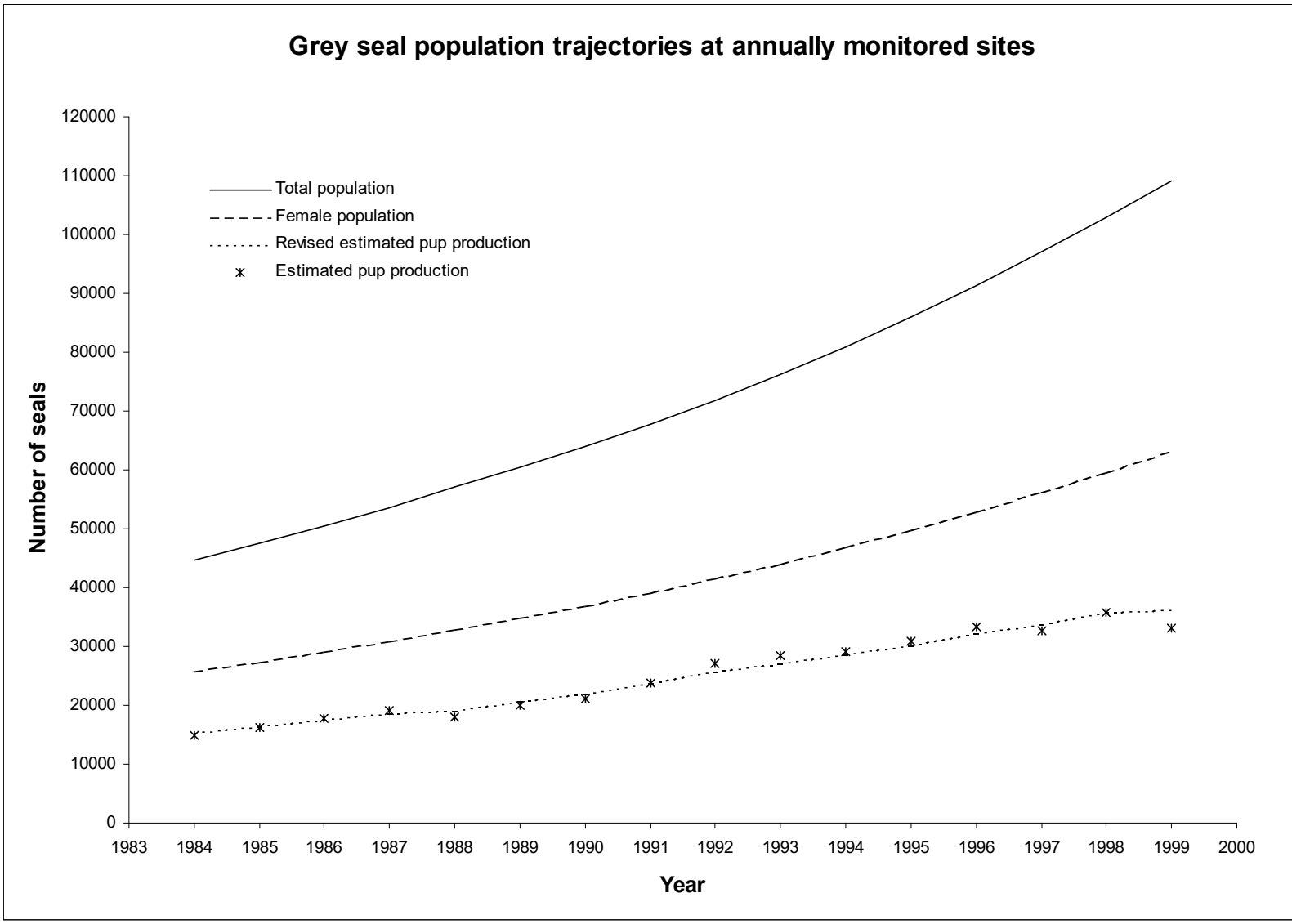

Grey seal population trajectories at annually monitored sites
Total population
Female population
Revised estimated pup production
Estimated pup production
Number of seals
Year
120000
110000
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000

Figure 5

Table 1. Estimates of pup production for the North Sea, Orkney, Outer Hebrides and Inner Hebrides, 1960-1999, using Method I (see text for details).

YEAR	North Sea	Orkney	Outer Hebrides	
1960	1020	2048		
1961	1141	1846	3142	
1962	1118			
1963	1259			
1964	1439	2048		
1965	1404	2191		
1966	1728	2287	3311	
1967	1779	2390	3265	
1968	1800	2570	3421	
1969	1919	2316		
1970	2002	2535	5070	
1971	2042	2766		
1972	1617		4933	
1973	1678	2581		
1974	1668	2700	6173	
1975	1617	2679	6946	
1976	1426	3247	7147	
1977	1243	3364		
1978	1162	3778	6243	
1979	1620	3971	6670	
1980	1617	4476	8026	

Table 1 continued.

YEAR	North Sea	Orkney	Outer Hebrides	Inner Hebrides
1981	1531	5064	8086	
1982	1637	5241	7763	
1983	1238			
1984	1325	4741	7594	1332
1985	1711	5199	8165	1190
1986	1834	5796	8455	1711
1987	1867	6389	8777	2002
1988	1474	5948	8689	1960
1989	1922	6773	9275	1956
1990	2278	6982	9801	2032
1991	2375	8412	10617	2411
1992	2437	9608	12215	2816
1993	2710	10790	11915	2923
1994	2652	11593	12054	2719
1995	2757	12412	12713	3050
1996	2938	14195	13176	3117
1997	3698	14051	11946	3076
1998	3989	16231	12373	3087
1999	3380	15253	11683	2787

Table 2. Estimated size of the population associated with all major grey seal breeding sites in Scotland and eastern England, except Loch Eriboll, Helmsdale and Shetland. Estimates refer to the number of seals aged 1 and over at the start of the breeding season using Method I (see text for details).

YEAR	Pup Production	Female Population	Female + Male Population
1984	14,992	25,799	44,672
1985	16,265	27,443	47,523
1986	17,796	29,095	50,365
1987	19,035	30,917	53,520
1988	18,071	32,963	57,092
1989	19,926	34,948	60,510
1990	21,093	36,964	63,957
1991	23,815	39,151	67,711
1992	27,075	41,510	71,762
1993	28,338	44,087	76,213
1994	29,018	46,799	80,902
1995	30,932	49,738	86,002
1996	33,426	52,868	91,439
1997	32,771	56,153	97,133
1998	35,680	59,451	102,798
1999	33,103	63,108	109,121

Table 3. Scottish grey seal breeding sites that are not surveyed annually or have recently been included in the survey programme.

	Location	Survey method	Last surveyed, frequency	Number of pups
Inner Hebrides	Colonsay/Oronsay mainland	SMRU visual	1994, every 2-3 years	None seen
	Loch Tarbert, Jura	SMRU visual	1998, every 3-4 years	None seen
	West coast Islay	SMRU visual	1998, every 3-4 years	None seen
	Ross of Mull, south coast	SMRU visual	1998, infrequent	None seen
	Treshnish small islands, incl. Dutchman's Cap	SMRU photo & visual	1999, annual	~20 in total
	Staffa	SMRU visual	1998, every other year	~5
	Little Colonsay, by Ulva	SMRU visual	1998, every 3-4 years	6
	Meisgeir, Mull	SMRU visual	1998, every 3-4 years	1
	Craig Inish, Tiree	SMRU photo	1998, every 2-3 years	2
	Cairns of Coll	SMRU photo	1998, every 2-3 years	13
	Muck	SMRU photo	1998, every other year	12
	Rum	SNH ground	1999, annual	10-15
	Canna	SMRU photo	1998, every other year	34
	Rona	SMRU visual	1989, infrequent	None seen
	Ascrib Islands, Skye	SMRU photo	1998, every other year	32
	Heisgeir, Dubh Artach, Skerryvore	SMRU visual	1995, every other year 1989, infrequent	None None
Outer Hebrides	Barra Islands Fiaray & Berneray	SMRU visual	1999, every other year	76
	Sound of Harris islands	SMRU photo	1999, every 2-3 years	317
	St Kilda	Warden's reports	Infrequent	Few pups are born
	Shiants	SMRU visual	1998, every other year	None
	Flannans	SMRU visual	1994, every 2-3 years	None
	Bernera, Lewis	SMRU visual	1991, infrequent	None seen
	Summer Isles	SMRU visual	1989, infrequent	None seen
	Faraid Head	SMRU visual	1989, infrequent	None seen
	Eilean Hoan, Loch Eriboll	SMRU visual	1998, annual	None
	Rabbit Island, Tongue	SMRU visual	1998, every other year	None seen
Orkney	Sule Skerry	SMRU photo	1998, 1999	15, 7
	Sanday, Point of Spurness	SMRU photo	1999, every 2-3 years	30
	Sanday, east and north	SMRU visual	1994, every 2-3 years	None seen
	Papa Stronsay	SMRU visual	1993, every 3-4 years	None seen
	Holm of Papa, Westray	SMRU visual	1993, every 3-4 years	None seen
	North Ronaldsay	SMRU visual	1994, every 2-3 years	None seen
	Calf of Flotta	SMRU photo	1999, annual	110
	North Fara, Cava & Rysa	SMRU photo	1999, first	108
Others	Firth of Forth islands & Inchcolm	Anecdotal SMRU photo	Infrequent 1997	<10 4

Appendix 1

Estimates of pup production and population size using free time-to-leave parameter in the pup production model (Method II).

Table 1. Estimates of pup production for the North Sea, Orkney, Outer Hebrides and Inner Hebrides, 1960-1999, using Method II (see text of Annex I for details).

YEAR	North Sea	Orkney	Outer Hebrides	
1960	1020	2048		
1961	1141	1846	3142	
1962	1118			
1963	1259			
1964	1439	2048		
1965	1404	2191		
1966	1728	2287	3311	
1967	1779	2390	3265	
1968	1800	2570	3421	
1969	1919	2316		
1970	2002	2535	5070	
1971	2042	2766		
1972	1617		4933	
1973	1678	2581		
1974	1668	2700	6173	
1975	1617	2679	6946	
1976	1426	3247	7147	
1977	1243	3364		
1978	1162	3778	6243	
1979	1620	3971	6670	
1980	1617	4476	8026	

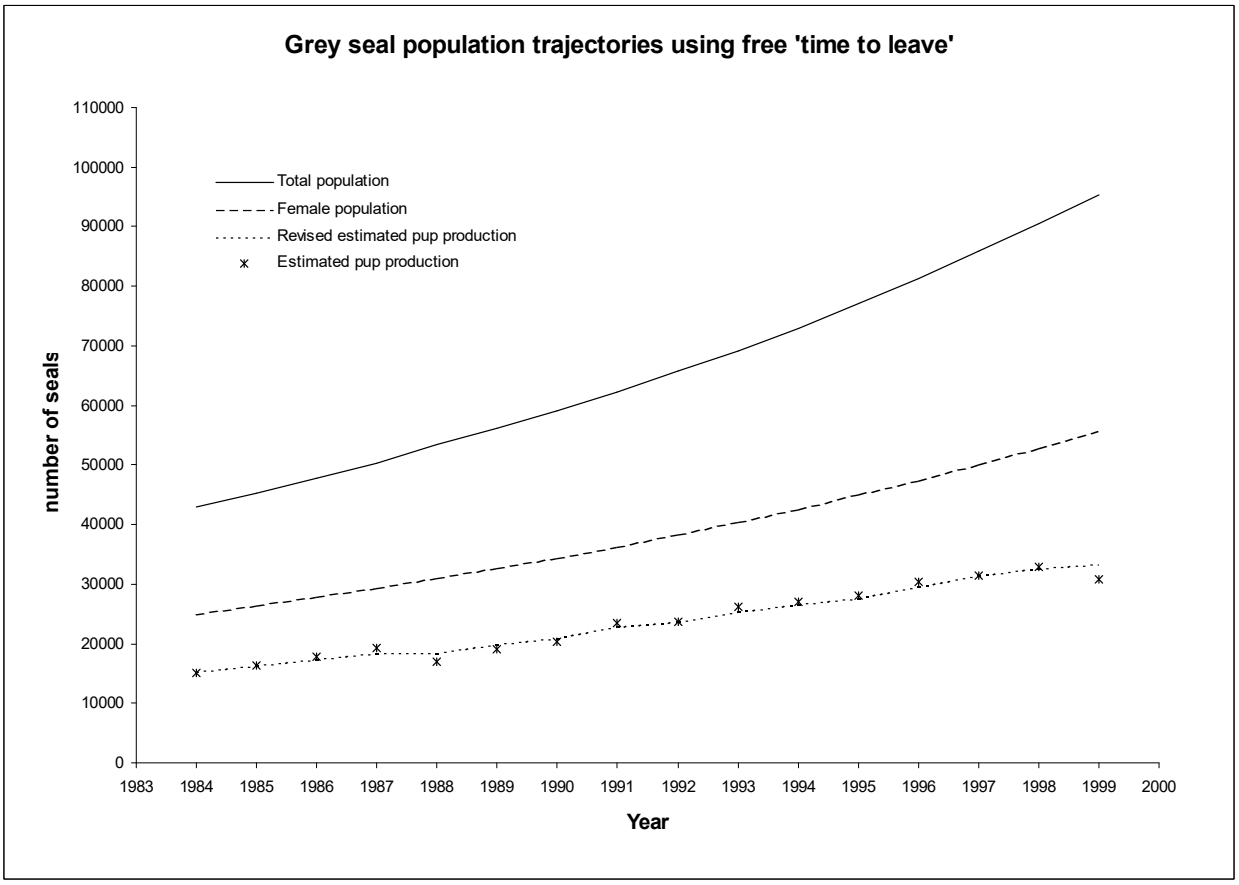
Table 1 continued.

YEAR	North Sea	Orkney	Outer Hebrides	Inner Hebrides
1981	1531	5064	8086	
1982	1637	5241	7763	
1983	1238			
1984	1325	4741	7594	1332
1985	1711	5199	8165	1190
1986	1834	5796	8455	1711
1987	1867	6656	8638	2180
1988	1474	5557	8031	1937
1989	1922	6667	8522	1950
1990	2278	6881	9155	1977
1991	2375	8468	10181	2349
1992	2437	8631	9876	2757
1993	2710	9812	10678	3044
1994	2652	10999	10707	2606
1995	2757	11585	10817	2836
1996	2938	12735	11821	2928
1997	3698	13118	11626	2989
1998	3989	15202	10725	2939
1999	3380	13425	11033	3033

Table 2. Estimated size of the population associated with all major grey seal breeding sites in Scotland and eastern England, except Loch Eriboll, Helmsdale and Shetland. Estimates refer to the number of seals aged 1 and over at the start of the breeding season using Method II (see text of Annex I for details).

YEAR	Pup Production	Female Population	Female + Male Population
1984	14,992	24,968	42,881
1985	16,265	26,377	45,286
1986	17,796	27,805	47,713
1987	19,341	29,337	50,327
1988	16,999	31,101	53,387
1989	19,061	32,767	56,223
1990	20,291	34,439	59,046
1991	23,373	36,274	62,166
1992	23,700	38,336	65,705
1993	26,244	40,383	69,185
1994	26,964	42,618	73,016
1995	27,995	45,011	77,129
1996	30,422	47,456	81,309
1997	31,431	50,124	85,897
1998	32,855	52,797	90,452
1999	30,871	55,675	95,373

Figure 1 **Estimated size of the (age 1+) total and female population at all major breeding sites in Scotland and England from 1984 to 1998, shown with estimated pup production and the revised pup production estimated from the population model, using Method II (see text of Annex I for details).**



The Status of British Common Seal Populations

1. Common seals surveys in eastern England 1999

In 1988, the numbers of common seals in The Wash declined by approximately 50% as a result of the phocine distemper virus (PDV) epidemic. Prior to this, numbers had been increasing. Following the epidemic, from 1989, the area has been surveyed once or twice annually in the first half of August each year (Figure 1, Table 1).

Two aerial surveys of common seals were carried out in Lincolnshire and Norfolk during August 1999 (Table 1). The average of The Wash counts (2,397) was very close to the 1998 count (2,381). The average annual rate of increase in the number of seals counted in The Wash since 1989 is 5.9% (SE = 0.90%). This is significantly greater than the average annual rate of increase between 1968 and 1988 of 3.5% (SE = 0.29%).

The 1999 counts in The Wash remain lower (by 20%) than the pre-epidemic count in 1988. This is in contrast to populations on the east and south sides of the North Sea which recovered rapidly from the effects of PDV and, by 1996, were similar to or exceeded their pre-epidemic levels. The 1999 counts at Blakeney Point (Table 1) were similar to those in 1998, remaining higher than previous years.

2. Minimum estimate of the British common seal population

The most recent minimum estimate of the number of common seals in Scotland is 29,600 from surveys carried out in 1996 and 1997. The most recent minimum estimate for the east coast of England is 3,568. This comprises 3,431 seals in Lincolnshire and Norfolk in 1999 plus 137 seals in Northumberland, Cleveland, Essex and Kent between 1994 and 1997. Counts by region are given in the Table below.

Region	**1996-97**
Shetland	5,991
Orkney	8,522
Outer Hebrides	2,820
Highland	5,117
Strathclyde	6,333
Dumfries & Galloway	6
Grampian	62
Tayside	92
Fife	617
Lothian	40
TOTAL SCOTLAND	**29,600**

East coast England (1994 to 1999)	3,568

TOTAL BRITAIN	**33,168**

3. Trends in counts of common seals in Scotland

Last year, an analysis of the count data from SMRU's surveys of moulting common seals from 1988 to 1997 was presented (SCOS 99/2 Annex II). This analysis estimated rates of change in the counts for a number of regions around Scotland and an overall rate of change. These data have been reanalysed to take into account concerns that the date and time of surveys may influence the results, factors that had not been incorporated in the previous analysis.

The results show that, allowing for the effects of time of day and date, the overall estimated annual rate of change is 2.9% per year. This is in close agreement with the rate estimated by aggregating areas surveyed on the same dates (2.6% per year; 95% confidence limits 1.5% - 4.3%).

In addition, a preliminary analysis has been conducted to investigate whether a minimum size of survey region that would allow demographic changes in local populations to be distinguished from geographical shifts in distribution can be inferred from the data. Results show that aggregating counts over areas greater than 40 x 40 km should eliminate most changes attributable to movement between sites. Details of these analyses are given in Appendix 1. Work on the most appropriate way to aggregate the count data will continue.

4. Common seal surveys carried out in 2000

Thermal image and fixed-wing surveys were carried out at nominated and prospective common seal SAC sites in early July 2000 (the end of the common seal breeding season) and of most of the Scottish west coast, including the Outer Hebrides, during the first half of August 2000. These surveys were commissioned by Scottish Natural Heritage. The August counts form the first part of SMRU's third survey of common seals around Scotland. Fixed-wing surveys of the east coast of England, including Holy Island and the Tees Estuary, were carried out in August 2000. The results from these surveys will be presented in 2001.

Table 1. Numbers of commons seals counted on the east coast of England since 1988. Data are from fixed-wing aerial surveys carried out during the August moult.

Date of survey	13.8.88	8.8.89 12.8.89	11.8.90	2.8.91 11.8.91	1.8.92 16.8.92	8.8.93	6.8.94 12.8.94	5.8.95 15.8.95	2.8.96	2.8.97 8.8.97	7.8.98 14.8.98	3.8.99 13.8.99
Blakeney Point	701	- 307	73	- -	- 217	267	- 196	438 392	372	250 371	535 738	715 602
The Wash	3087	1531 1580	1532	1226 1551	1724 1618	1759	2277 1745	2266 1902	2151	2561 2360	*2367 2381	2320 2474
Donna Nook	173	- 126	57	- -	18 -	88	60 146	115 36	162	240 262	294 201	321 286
Scroby Sands	-	- -	-	- -	- -	-	61 -	- 49	51	58 72	52 -	69 74
The Tees	-	- -	-	- -	- -	-	- 35	- -	-	- -	- -	- -
Holy Island (Northumberland)	-	- -	-	- -	- -	-	- 13	- -	-	- 12	- -	- -
Essex & Kent	-	- -	-	- -	- -	-	- -	90 -	-	- -	- -	- -

*** One area used by common seals was missed on this flight (100 – 150 seals); this data point has been excluded from analyses.**

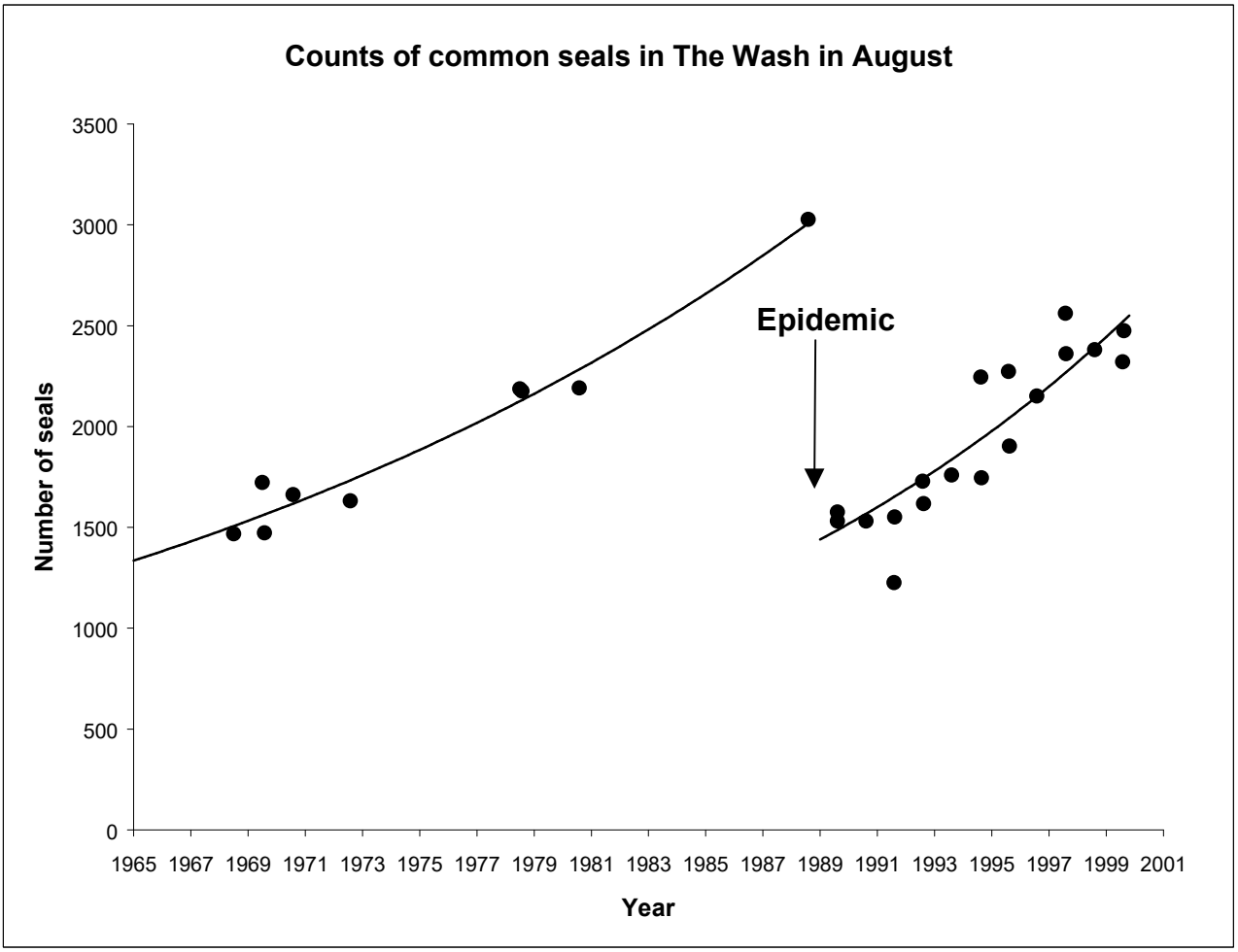


Figure 1. Counts of common seals in The Wash in August.

Appendix 1

Annual rates of change in counts of Scottish common seals

1. The effect of variation in size of survey region

At last year's SCOS meeting and subsequently, interest was expressed in what inferences could be drawn from SMRU's thermal image surveys which are relevant to alternative strategies for monitoring of common seals. In particular, do these surveys suggest a minimum size of survey region that would allow demographic changes in local populations to be distinguished from geographical shifts in distribution? An analysis of the data has been conducted to investigate deviations from the overall increase observed from 1988 to 1996, the two years with the most extensive coverage of contiguous areas, when the size of the basic survey block is varied. The following figures illustrate preliminary results of these studies.

Figure 2 gives the covariance between adjacent square blocks of survey area of increasing size. The highly negative values between adjacent blocks with sides of one to four km, results from year to year shifts in the centre of each local distribution of a few hundred metres to a few kilometres. Such movements might be simply from one side of a headland to the other in response to a change in wind direction and are thus of no interest in relation to demographics. The positive values between blocks of more than four km sides may result from movement of animals between centres of local distribution.

To investigate the scale of such movements, the sum variance between the two years over all blocks comprising the total survey area was calculated, again over increasing block size. Given no spatial correlation between changes the sum variance would be independent of block size; summing over negative correlations would decrease the sum variance and summing over positive correlations would increase it. The results given in Figure 3 show an initial decrease, resulting from the shifts in centre of local distribution, followed by an increase and a subsequent decrease after about 40 km. The results suggest that by summing counts over areas greater than 40 km square most changes attributable to movement could be eliminated. However these results are preliminary and further analysis is needed to verify this.

2. The effect of survey date and time of day

In order to be able to present raw data summed over the largest possible areas the analysis presented last year (SCOS 99/2 Annex II) grouped the survey "subregions" (stretches of coastline between headlands or other landmarks readily identifiable during survey flights) into eleven large areas, each of which had been completely surveyed in at least two years between 1988 and 1997. These analyses did not take account of the possible effects of the date and time of survey. Thompson & Harwood (1990, Journal of Applied Ecology, **27**, 924-938, Figure 2) suggest that numbers hauled out during the moult may be greatest in late afternoon and Thompson (1989, Journal of Zoology, **217**, 281-294, Figure 4) suggests that peak numbers may not be reached till the second week in August. The data have therefore been reanalysed with each subregion count modelled individually using the time and date of the survey for that subregion.

Quadratic functions for date and for time of day were incorporated in the analysis in the expected count functions for each subregion. Rate of change over time was assumed to be exponential (either at the same rate over all areas or at a rate specific to the local government region for that subregion). The initial subregion population size and maximum haulout proportion were subsumed into a seperate parameter for each subregion. Figures 4 and 5 show the estimated quadratic functions for date and time of day. The parameters of these functions were statistically significant.

The resulting estimated region-specific rates of change were:

Region	Estimated annual rate of change
Shetland	4.0%
Orkney	-1.1%
Hebrides	8.5%
Highlands	2.3%
Strathclyde	6.2%

Regional variations in estimated annual rate of change were not statistically significant. The overall estimated annual rate of change was 0.029. This is very similar to the overall rate estimated previously (0.026 with 95% confidence limits from 0.015 to 0.043). The 95% confidence limits on the new rates of change (and quadratic parameters) presented above have not yet been calculated; however, the overall annual rate of change is significantly greater than zero.

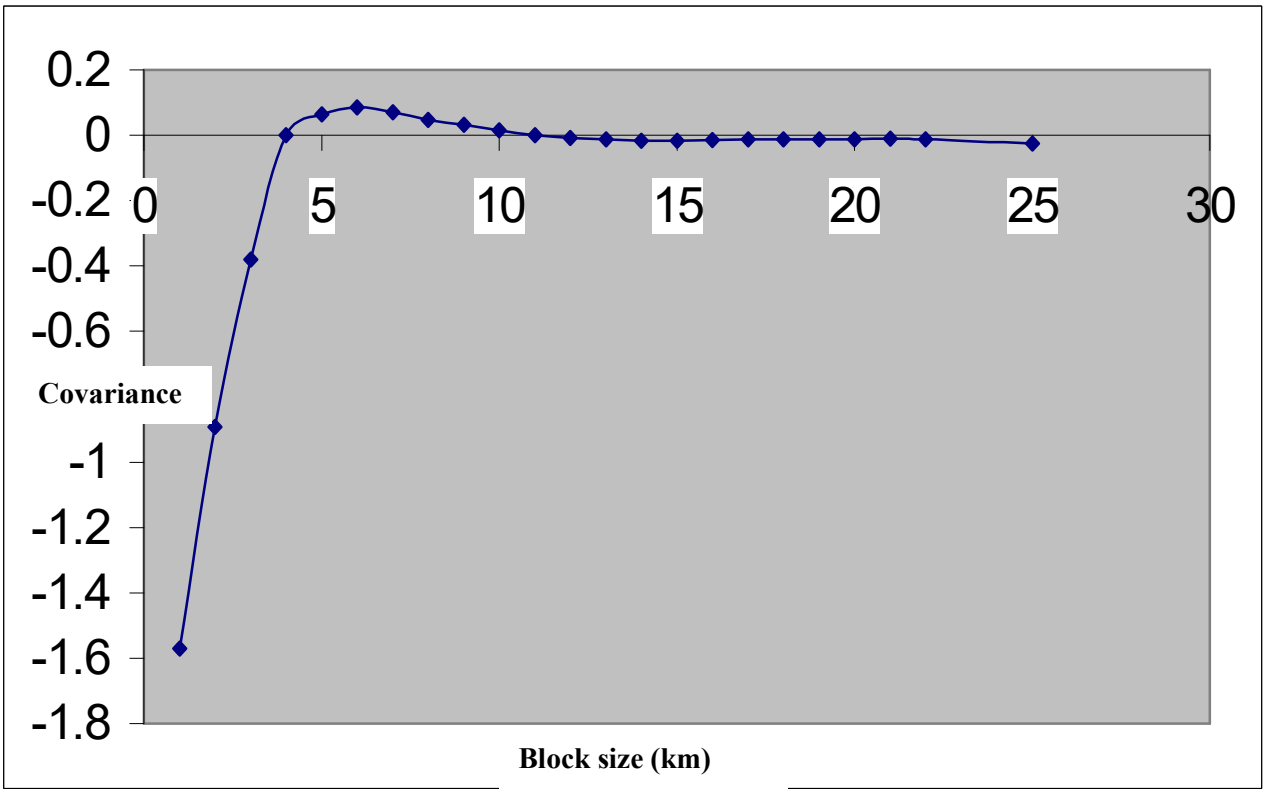


Figure 2. Covariance vs block size.

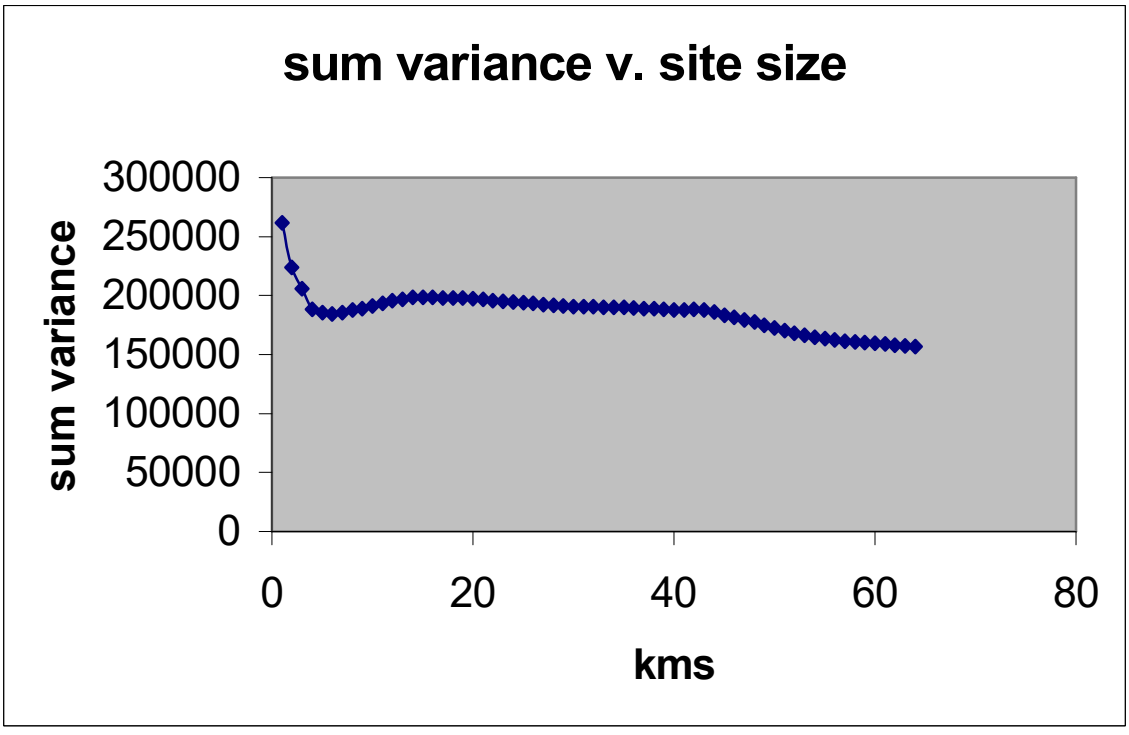


Figure 3. Sum variance between two survey years over all blocks.

Figure 4. Estimated quadratic function for percentage of seals hauled out vs time of day

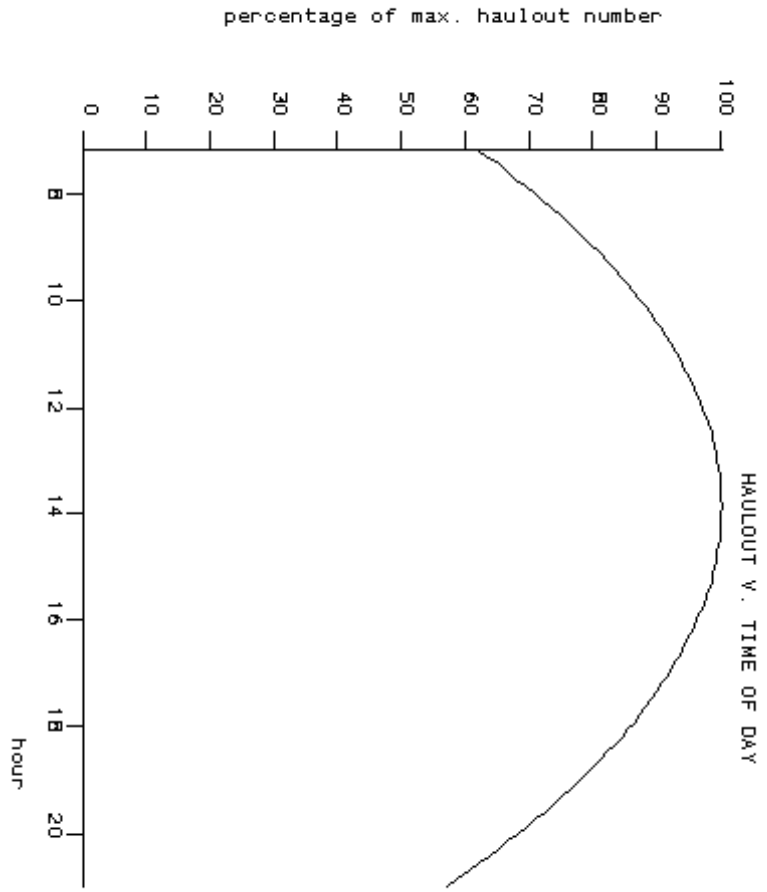
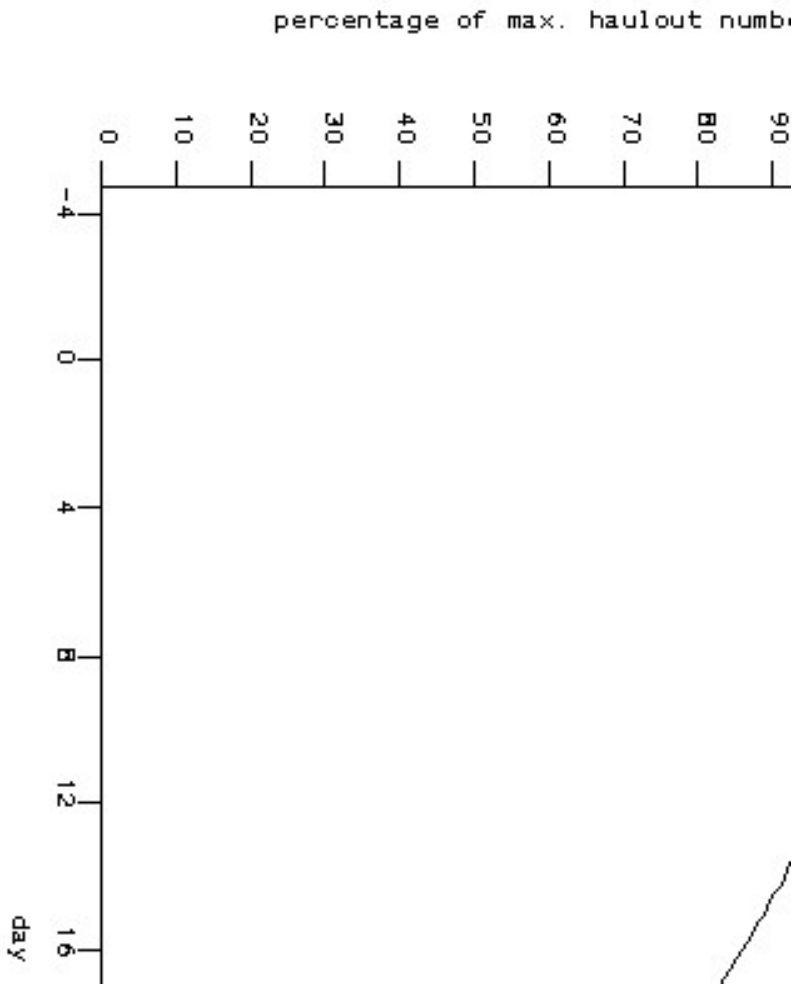


Figure 5. Estimated quadratic function for percentage of seals hauled out vs date



Appendix 2
Trends in counts of common seals in the Moray Firth

The University of Aberdeen has been studying the behavioural and population ecology of common seals in the Moray Firth since 1987. Throughout this period, 2-10 shore-based counts have been made at all major haul-out sites in the inner Moray Firth during both pupping (15 June-15 July) and moult (1-31 August) periods. These data therefore provide an index of abundance of seals in this study area in each year of the study which, based on telemetry data, accounted for approximately 60% of the population.

The resulting data on changes in this index of the abundance of Moray Firth common seals are presented in Figure 1. Mean counts from the time-series of counts during the pupping and moult periods were highly correlated ($r = 0.8$, $n=11$, $p<0.01$). Following a slight reduction in numbers resulting from the 1988 phocine distemper virus (PDV) outbreak, there was an increase in annual mean counts between 1989 and 1993 (Pupping: $F_{1,3}=17.11$, $r^2=0.85$, $p<0.05$; Moult: $F_{1,3}=24.12$, $r^2=0.89$, $p<0.05$). However, unlike the sustained increase seen in other parts of the North Sea, there has been a 3-4% decline in annual mean counts in the period 1992 – 1999 (Pupping: $F_{1,6}=7.7$, $r^2=0.56$, $p<0.05$; Moult: $F_{1,5}=26.15$, $r^2=0.84$, $p<0.001$).

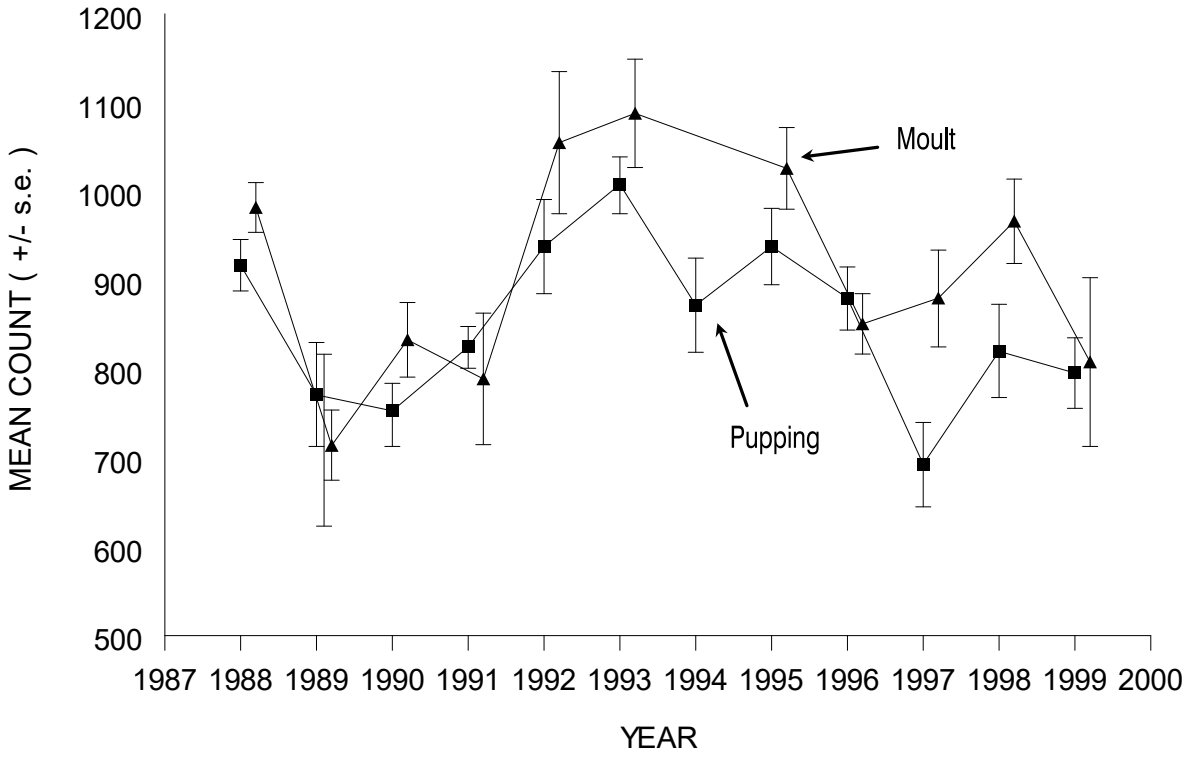


Figure 1. Changes in the mean number of seals counted at inner Moray Firth haul-out sites during the pupping and moult periods.