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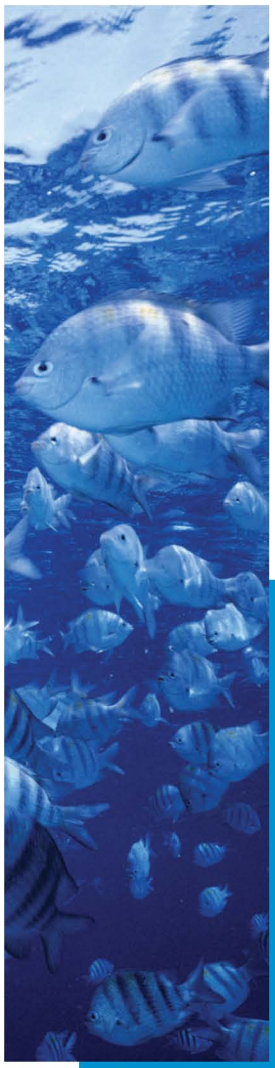
STRUCTURAL AND COHESION POLICIES



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SEALS AND FISH STOCKS IN SCOTTISH WATERS

NOTE

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POLICY DEPARTMENT B: STRUCTURAL AND COHESION POLICIES

FISHERIES

SEALS AND FISH STOCKS IN SCOTTISH WATERS

NOTE

This document was requested by the European Parliament's Committee on Fisheries.

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POLICY DEPARTMENT B: STRUCTURAL AND COHESION POLICIES

FISHERIES

SEALS AND FISH STOCKS IN SCOTTISH WATERS

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Abstract:

Fish stocks in Scottish waters show strong signs of depletion and overexploitation. Grey seals have increased over four decades but have been gradually stabilising in the last 10 years. Many harbour seal populations have declined sharply in the past 10 years. The diets of both species of seals overlap with commercial fisheries but exploitation rates of fish species by seals are much lower than they are for fisheries. Even a large reduction in the number of seals in Scottish waters would be unlikely to make any noticeable impact to the success of demersal or pelagic fisheries

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EXECUTIVE SUMMARY

The paper examines the status of Scottish fish stocks, the status of seal populations, and the evidence for interactions between fisheries and seals.

Scottish fish stocks are generally in a severely depleted state when compared with historical records. The demersal stocks are more depleted than the pelagic stocks and some pelagic stocks appear to be close to the long-term average.

Although recent indicators suggest that there has been considerable progress at reducing fishing-induced mortality, the current controls on fishing effort may not be sufficient to ensure the recovery of important commercial stocks.

There are two important species of species of seal in Scottish waters, the grey seal and the harbour seals (also sometimes known as the common seal). The best estimate of the total population of UK grey seals in 2009 was **119,400 (95% CI 92,500-156,200)** and about 90% of these occur in Scottish waters. There is a lot of uncertainty about the absolute number of harbour seals in Scotland but the total is likely to be **40,000-46,000.**

Overall, the grey seal population appears to be stable in Scotland but declines of up to 70% have been observed in some harbour seal population, especially in Orkney and Shetland, over the past decade. The cause of these rapid declines in harbour seal numbers is unknown.

Both grey and harbour seals mainly feed on fish at or close to the sea bed. In both cases sandeels tend to be the principal prey but grey seals also take demersal species such as cod, haddock and whiting. Harbour seals include more flatfish in their diet. This pattern of diet composition varies regionally and seasonally.

Grey seals eat about **190,000 tonnes** of fish each year and harbour seals eat about **80,000 tonnes** in Scottish waters. Although commercially-exploited species form an important part of their diets, fish consumption by seals is generally small compared with both the overall stock and the fish caught by the fishing industry. Grey seal predation on commercially exploited fish stocks in the North Sea is not a major source of mortality but on the west coast of Scotland is it possible that grey seal predation may be a factor limiting the recovery of cod.

Seals are a relatively small part of the total predation pressure upon fish stocks in Scottish waters compared with other predators and with fisheries. Even a large reduction in the number of seals in Scottish waters would be unlikely to make any noticeable impact to the success of demersal or pelagic fisheries.

1. INTRODUCTION

1.1. Aim and structure

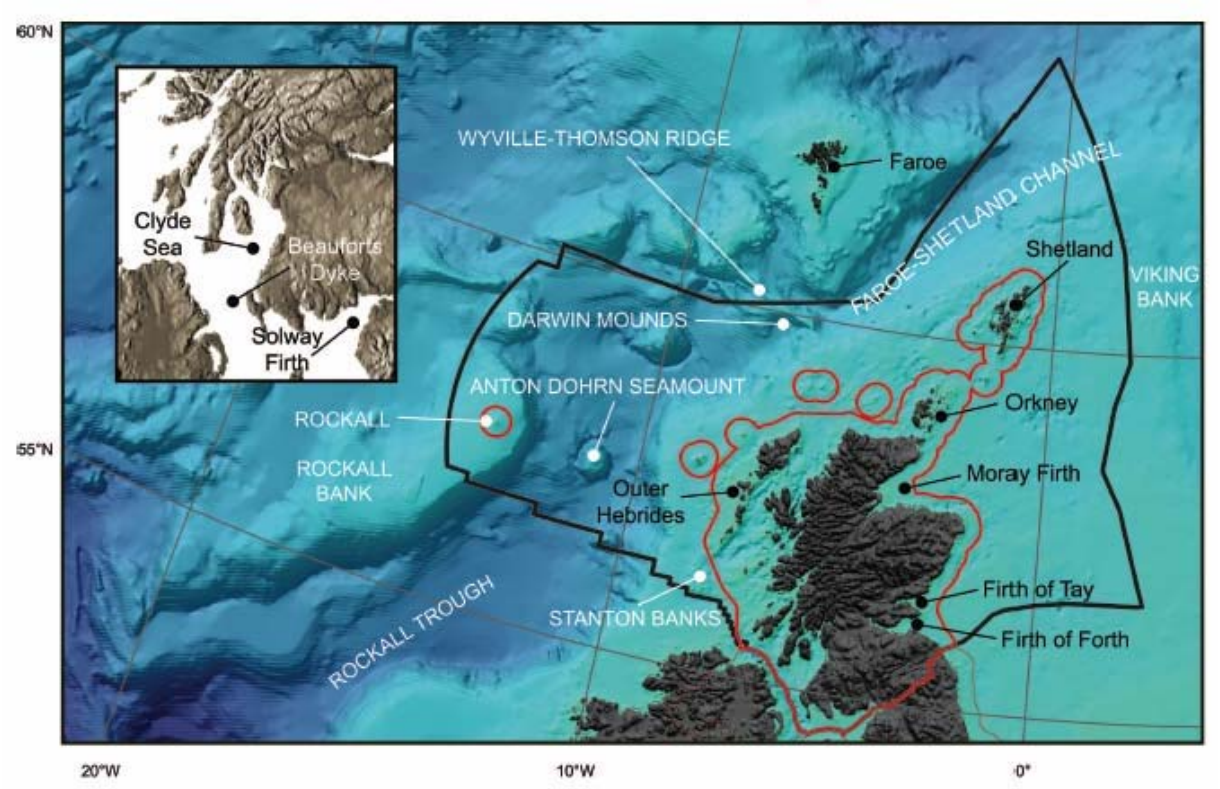
This paper examines the current knowledge of interactions between seals and fish stocks in Scottish waters. In the context of the present paper, Scottish waters is taken to mean those regions lying within the Scottish Fisheries Limits (Figure 1). This coincides approximately with the ICES Areas IVa, IVb and VIa for which fisheries statistics are gathered.

The present paper is structured to provide

- An overview of the state of Scottish fish stocks
- An overview of the state of Scottish seal populations
- A synthesis of the state of knowledge concerning the interaction between fish and seals
- An assessment of the effect of seals on fish stocks

The two overview sections draw heavily upon two recent documents: (1) "The future of Fisheries Management in Scotland" published in 2010 by the Scottish Government as a report of an independent panel of which Boyd was a member and (2) "Scientific Advice on Matters related to the Management of Seal Populations" published annually by the UK Natural Environment Research Council (http://www.smru.st-and.ac.uk/documents/341.pd) which both of the authors of this paper help to produce.

Figure 1: Scottish fisheries limits (black line) and the 12 nautical mile limit (red). Some of the important geographical features are shown.



Source: Baxter *et al.* (2008).

1.2. Historical status of seals

We have little information on the historical status of seals in UK waters. Remains have been found in some of the earliest human settlements in Scotland and they were routinely harvested for meat, skins and oil until the early 1900s. There are no reliable records of historical population size but the Grey Seal (Protection) Act 1914 was introduced into UK legislation, providing the first legal protection for any mammal in the UK because of a perception that there was a need to protect seals. Harbour seals were heavily exploited mainly for pup skins until the early 1970s in Shetland and The Wash (England). Grey seal pups were taken in Orkney until the early 1980s, partly for commercial exploitation and partly as a population control measure. Large scale culls of grey seals in the North Sea, Orkney and Hebrides were carried out in the 1960s and 1970s as population control measures.

Grey seal pup production monitoring started in the late 1950s and early 1960s and numbers have increased consistently since then. In recent years, there has been a significant reduction in the rate of increase.

Boat surveys of harbour seals in Scotland in the 1970s showed numbers to be considerably lower than in recent aerial surveys which started in the late 1980s, but it is not possible to distinguish the apparent change in numbers from the effects of more efficient counting methods. After harvesting ended in the early 1970s, regular surveys of English harbour seal populations indicated a gradual recovery, punctuated by two major reductions due to phocine distemper virus (PDV) epidemics in 1988 and 2002 respectively.

1.3. Legislation

The main domestic legislation relevant to the management of seals is the Conservation of Seals Act 1970 and the Marine (Scotland) Act 2010. Until 2010 the Conservation of Seals Act was applied across the UK but now only applies in England and Wales. In Scotland it was repealed and replaced by the Marine (Scotland) Act in which Section 6 is dedicated entirely to the management of seals.

There were several reasons for this change. In contrast to elsewhere in the UK, Scottish waters hold the great majority of seals and, from a Scottish perspective the Conservation of Seals Act was seen to be deficient in a number of critical ways. First, it pre-dated European legislation, especially the EU Habitats Directive, and there was a need to update domestic legislation to reflect changing priorities under that Directive. Second, the Conservation of Seals had had largely been designed to protect the interests of specific parts of the fishing industry, including the management of the direct harvesting of seals that continued in to the early 1980s. Some legitimate users of the marine environment, especially aquaculture interests, were specifically excluded from the licensing system under the Conservation of Seals Act that permitting them to protect their stock from attack by seals. Third, the Conservation of Seals Act contained a number of anomalies that had made it almost impossible to bring a successful prosecution for an offence under the Act. Fourth, under the Conservation of Seals Act seals were only protected during specific, short periods of the year meaning that anybody with a registered firearm of the appropriate calibre and power could kill as many seals as the wished during most of the year and this could be done without a license. In practice, Conservation Orders under the Act meant that this was eventually

not likely to happen over most of the range of seals in Scotland but this was also seen to be an insufficient standard compared with the standard set for the management of other wildlife.

Section 6 of the Marine (Scotland) Act has introduced year-round protection of seals in Scotland but derogations to this protection can be issued to anybody who has a legitimate reason to shoot seals. A licensing system is in the process of being introduced and will be in place by the end of January 2011. In practice, the Scottish Government will only issue licenses to those whose livelihoods or businesses are likely to be adversely affected by the direct actions of seals. This mainly includes aquaculture, the rod-and-line salmon fisheries and coastal salmon netting stations. However, a high standard of proof will be required of the presence of seals, the impact that seals are having, that all reasonable alternative measures have been taken to counter the problem created by seals and that the applicants have the capacity to despatch seals cleanly and humanely.

2. THE STATE OF FISH STOCKS

KEY FINDINGS

- Scottish fish stocks are generally in a severely depleted state when compared with historical records. The demersal stocks are more depleted than the pelagic stocks and some pelagic stocks appear to be close to the long-term average.
- *Nephrops* (Norway lobster) stocks appear to be in a healthy state and the indicators for *Nephrops* probably reflect the status indicators for healthy fish stocks.
- An appropriate objective for fish stocks could be to recover their status indicators to a level similar to *Nephrops*. However, the management measures available to achieve this are likely to succeed through reductions in fishing effort (i.e. direct fisheries-induced mortality of fish) rather than through the management of other factors such as predators like seals, seabirds, dolphins and porpoises.
- Although recent indicators suggest that there has been considerable progress at reducing fishing-induced mortality, the analysis suggests that current controls on fishing effort may not be sufficient to ensure recovery of stocks to a level equivalent to the long-term mean. This is especially the case for cod and sandeels.

2.1. Quality of information

There is detailed information about most of the key stocks of commercially-exploited fish in Scottish waters and this can be used to assess the current status of those stocks. Exceptions to this come from the inshore sector where there are no regular stock assessments for lobsters, crabs and various other shellfish. Data for Norway lobsters (*Nephrops*) extend back to 1993 but the data for the main pelagic species (mainly mackerel and herring) and most of the demersal species (mainly cod, haddock, whiting and saithe) extend back to about 1960.

Data for sandeels are available from 1983 for some locations. Although these data resources reflect a substantial, long-term effort to measure the variation in stock levels, there are some stocks for which there are fewer data, such as anglerfish (also known as monkfish), and there are almost no data for non-commercial fish species such as skates, rays, dogfish, sharks, gurnards, and several species of flatfish.

The International Council for the Exploration of the Sea (ICES) provides an annual assessment of the status of stocks and this is summarised in Table 1. Of the 12 fish stocks listed here, only four are without immediate concern. These are NW Atlantic mackerel, haddock (North Sea and Rockall) and saithe. West of Scotland haddock is classed as being exploited sustainably but the present biomass is close to the lower limit of biomass so this classification may not be correct. Haddock is subject to fluctuations in biomass because of large inter-annual fluctuations in recruitment.

2.2. ICES assessment of the status of fish stocks

The status of many of the other stocks listed in Table 1 is poorly understood because of uncertainty around estimates of stock size, the life-history or population dynamics of the species, or the apparent levels of fishing mortality. In some of these cases there may be no concern, but we do not have sufficient information to be able to say this. In others, such as North Sea whiting, there may be real cause for concern. Even in the case of *Nephrops*, stocks of which appear to be healthy, ICES is recommending reduced exploitation rates. Perhaps the species of greatest concern is monkfish because of a lack of data. In this case, a highly profitable fishery that represents an important proportion of the Scottish demersal fishery has been allowed to develop and there is almost no information about the status of monkfish stocks upon which to build a rational assessment or a TAC.

Rather than relying simply upon the ICES assessments, and in order to provide a different view of the status of stocks, we have conducted a simple analysis of the long-term data from fish stocks within Scottish waters.

2.3. Status of fish stocks

Marine ecosystems can exhibit high levels of natural variation and fish populations can track this variation in different ways. However, over time we would expect most fish stocks to fluctuate to different extents around an average level, assuming that the ecosystem was being sustained as a coherent entity. Only if there was directional change within the ecosystem, as might happen under the influence of climate change for example, would we expect that some stocks might show a directional shift through time, but that shift would probably show some stocks increasing while others decline.

The time scale over which data have been collected about fish populations in Scottish waters (about 50 years in most cases) is probably only now about sufficient to examine how fish stocks have fluctuated within the context of natural variation and historical levels of fishing. This has allowed assessment of the current status of fish stocks compared with the average level of stocks.

The current status of stocks is expressed using the current indices of abundance (averaged over the last 6 years in order to reduce the effects of random fluctuation) as a percentage change from the long-term average. This means that, if stock levels in the past 6 years have been below the long-term average then the current status will be a negative percentage. On the other hand, if the current status is above the long-term average then it will be a positive percentage. The period of 6 years is used in this case because this is the normal time interval within the Habitats Directive for assessing whether species are in favourable conservation status.

Although this method differs from the ICES criteria involving biomass targets and limits (Table 1), the messages are probably more intuitive and are generally similar. A particular difference comes from the messages about *Nephrops* fisheries, which are generally more positive in the present analysis than in the ICES assessment.

The results of our analysis are shown in Figures 2 and 3. In Figure 2 we show the relative status of stocks of demersal and pelagic fish stocks and in Figure 3 we show the relative status of different stocks of *Nephrops*. The broad message is that, with few exceptions, the various metrics used to indicate the abundance of commercial fish

species are negative (red) whereas the metrics for *Nephrops* are positive (green). This shows that most fish stocks are below the long-term average whereas *Nephrops* are current above the long-term average. Nevertheless, *Nephrops* has been assessed against a much shorter time series than the stocks of fish so the result is less robust for *Nephrops* (Figure 3) than it is for the fish stocks (Figure 2).

Focusing on fish stocks (Figure 2), the magnitude of the extent to which stocks depart from the long-term mean is represented by the size of the bar in each case. This shows that cod (both North Sea and West Coast), North Sea haddock, West Coast herring and North Sea Norway pout, sandeels and whiting are all showing indices of reductions in stocks that are considerably below the long-term average. None of the stocks show evidence of being under-exploited (i.e. there are no green bars of a similar magnitude to the red bars).

Notably, landings (Figure 2d) show a similar pattern to the status of stocks suggesting that the fortunes of the industry are also driven by the level of the stocks. This probably reflects the effects of management actively reducing fishing quotas when stocks are relatively low.

If management was to set an objective of maintaining stocks at a level that is close to the long-term average, which would be a reasonable target, then this assessment would suggest that there should be greatly reduced fishing on those stocks that are showing signs of depletion. Consequently, the only stocks that show clear signs of a status that could sustain current levels of fishing are North Sea plaice, saithe and herring and NE Atlantic mackerel. Even though in some of these cases there is evidence of some level of stock depletion (i.e. some bars are red), the bars are relatively small meaning that current exploitation levels are probably close to being sustainable.

Even this assessment, and especially the target of recovering fish stocks to close to their long-term average level, may not be sufficiently conservative. This is because the long-term averages used here are not reflective of unfished stocks because the historical population indicators used in Figure 2 include historical depletion caused by fishing. Under these circumstances, appropriate targets for the indicators of stock levels might be somewhat above the long-term average (i.e. the target might be to ensure the indicators recover from red to green in Figure 2).

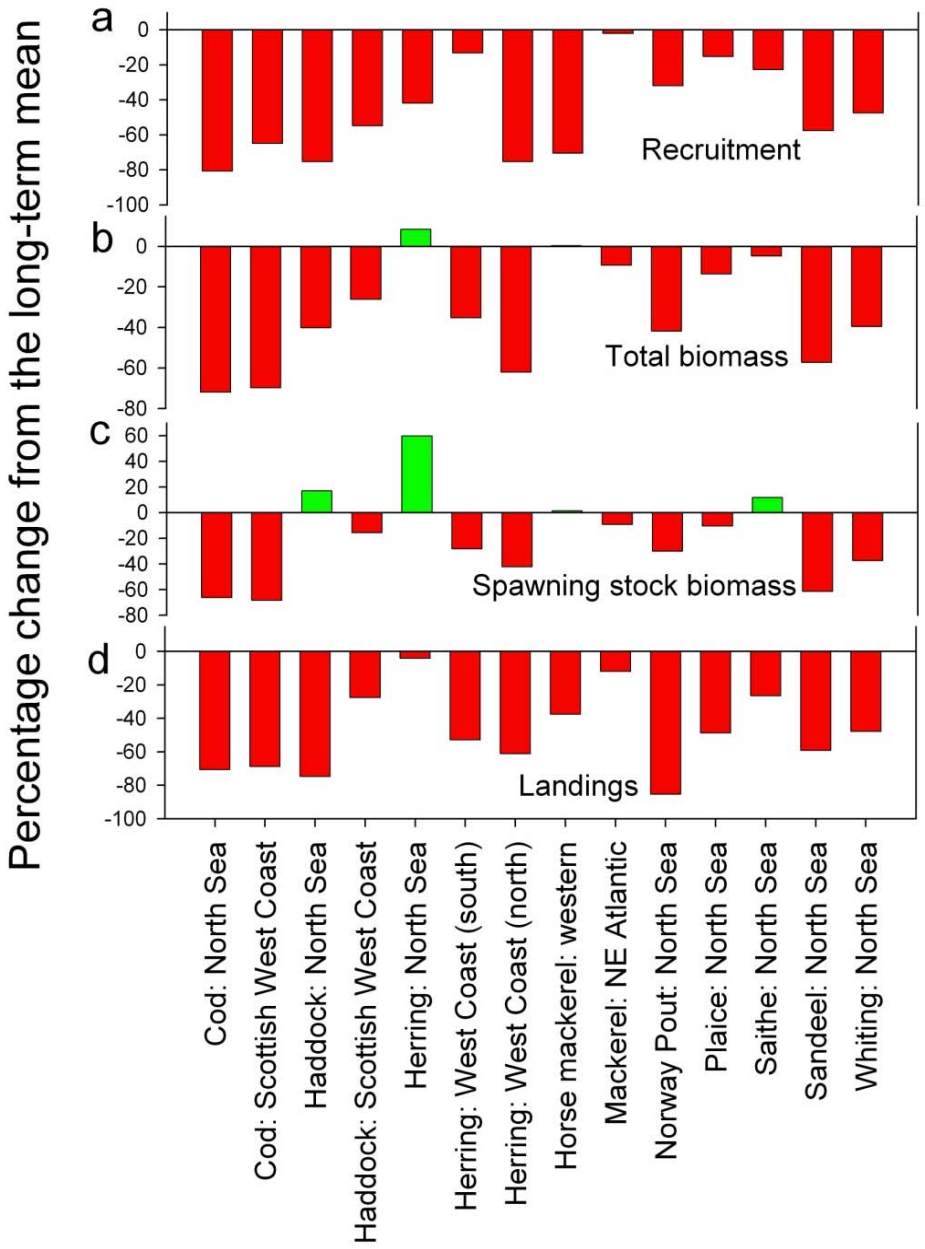
An important feature of any assessment of stock status is also the effectiveness of the management response to stock depletion. The extent to which conservation measures are being effective may be reflected in the relative level of fishing pressure on each stock. This is broadly indicated by the proportional death rate of fish in a stock (known as *F*) that is caused by fishing. In a well managed stock that is showing depletion, we would expect the conservation measures to reduce the death rate so that the death rate should be well below the long-term average death rate.

Figure 4 shows the level of death rate in fish stocks caused by fishing relative to the long-term mean. In this case, negative values (green) show that the death rate is lower now than in the past whereas positive values (red) show that it is higher. This shows clearly that for most stocks there has been a substantial reduction in fishing-induced mortality, suggesting that there has been management intervention to prevent over-exploitation. Nevertheless, for some stocks, especially North Sea and West Coast Cod, and sandeels, this evidence suggests that the management response has been insufficient when compared with the level of depletion of these stocks (Figure 2).

Based upon the analysis presented in Figure 3, it would appear that *Nephrops* stocks are being exploited at a sustainable rate and the stocks may be increasing.

Stock assessments for monkfish, which are not considered further here, have only been carried out since 2005, but these suggest that current stocks may be showing signs of depletion.

Figure 2: The percentage change from the long-term average for the recruitment, total biomass, spawning stock biomass and recorded fisheries landings for 14 commercially exploited fish stocks within Scottish territorial waters



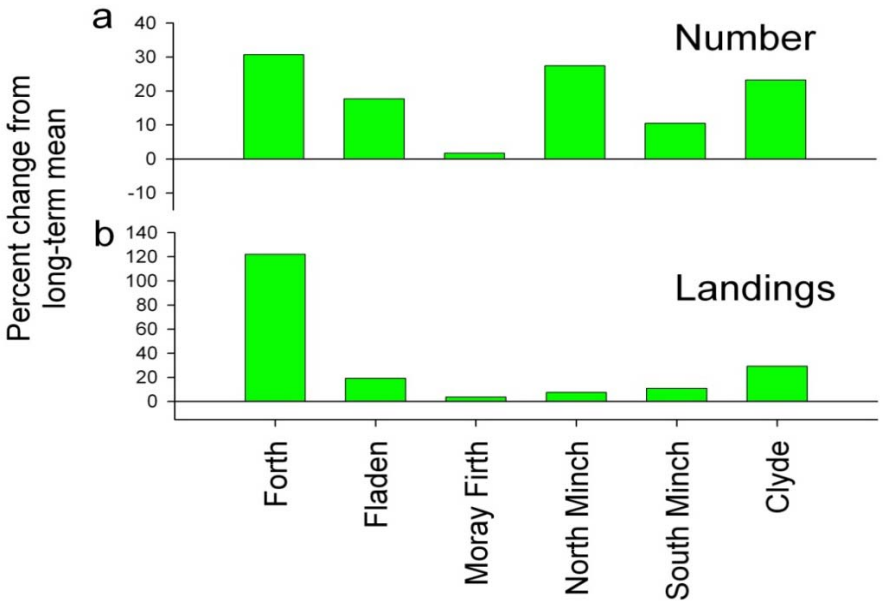
Source: Adapted from "Enquiry in to Future Fisheries Management". An independent report to the Scottish Government (2010)

Table 1: The ICES status assessment for the major Scottish fish stocks, together with information about the ICES advice about the precautionary limits for biomass and for fishing mortality (*F*). "ND" means that no values have been defined, usually because there is insufficient information available. The approximate value of the stock to the Scottish fishery is shown.

Stock	ICES Status assessment	Approx. current biomass	Precaution-ary biomass	Lower limit of biomass	Precautionary *F*	Upper limit of *F*	TAC (tonnes)	UK catch last year (tonnes)	Approx value (£million)
NW Atlantic Mackerel	Full reproductive capacity	2.6 mt	2.3 mt	1.67 mt	0.23	0.42	317,748	183,157	64.6
Herring: North Sea	At risk of reduced reproductive capacity	1.0 mt	1.3 mt	0.8 mt	0.12	ND	93,773	25,275	4.0
Herring: West of Scotland	Uncertain	90kt	ND	50kt	ND	ND	24,420	13,539	2.8
Haddock: North Sea	Full reproductive capacity	190kt	140kt	100kt	0.7	1.0	26,965	27,507	24
Haddock: West of Scotland	Harvested sustainably	20kt	30kt	22kt	0.5	ND	2,673	2,737	2
Haddock: Rockall	Full reproductive capacity	20kt	9kt	6kt	0.4	ND	4,987	4,738	2.2
Cod: North Sea	Reduced reproductive capacity	60kt	150kt	70kt	0.65	0.86	27,848	11,216	13.6
Cod: West of Scotland	Reduced reproductive capacity	6kt	22kt	14kt	0.6	0.8	320	182	0.45
Whiting: North Sea	Unknown	100kt	ND	ND	ND	ND	13,400	8,426	8.5
Whiting: West of Scotland	Unknown	ND	22kt	16kt	0.6	1.0	431	329	0.368
Saithe	Full reproductive capacity	200kt	200kt	106kt	0.4	0.6	61,537	13,727	7.3
Monkfish	Unknown	ND	ND	ND	ND	ND	16,912	11,224	28
Nephrops	Stable	ND	TACs set as a fixed proportion of observed abundance estimates Current harvest rate greater than recommended					22,100	95.5

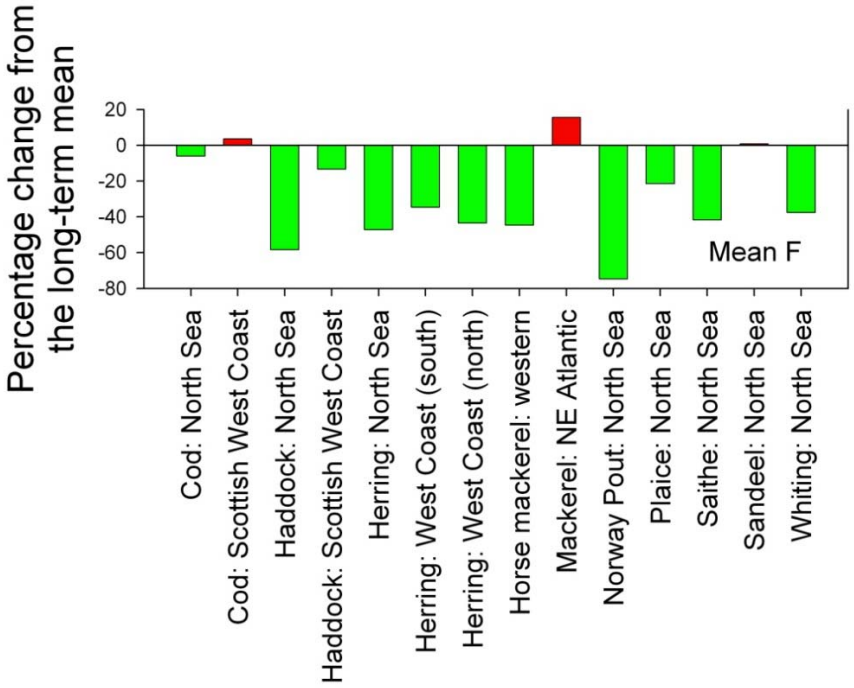
Source: Adapted from "Enquiry in to Future Fisheries Management". An independent report to the Scottish Government (2010)

Figure 3: The percentage change from the long-term average for the estimated total number and the recorded fisheries landings of *Nephrops norvegicus* from six of the main fishing grounds.



Source: Adapted from "Enquiry in to Future Fisheries Management". An independent report to the Scottish Government (2010)

Figure 4: The percentage change from the long-term average for the fisheries-induced death rate for 14 commercially exploited fish stocks within Scottish territorial waters



Source: Adapted from "Enquiry in to Future Fisheries Management". An independent report to the Scottish Government (2010)

3. STATUS OF SEAL POPULATIONS

KEY FINDINGS

- The best estimate of the total population of UK grey seals in 2009 was **119,400 (95% CI 92,500-156,200)** and about **90%** of these occur in Scottish waters.
- Although the pattern of population change varies between regions, overall, the grey seal population in Scotland appears to be stable or declining slowly. The likelihood of a decline in Scotland is because most increases are now occurring in the southern part of the North Sea in the English coast.
- There is a lot of uncertainty about the absolute number of harbour seals in Scotland but the total is likely to be **40,000-46,000.**
- There have been **declines of up to 70%** in harbour seal populations in Orkney, Shetland and eastern Scotland since 2000.
- There is no reliable information to suggest what seal population sizes were before 1960 for grey seals and before about 1990 for harbour seals.

There are two species of seal indigenous to Scottish waters. These are the grey seal (*Halichoerus grypus*) and the harbour seal (*Phoca vitulina*). The harbour seal is also known sometimes as the common seal. Several other species of Arctic seals occur occasionally in Scottish waters but the numbers involved are so small they are not important in terms of fisheries interactions.

3.1. Grey seals

The grey seal is the larger of the two resident UK seal species. Adult males can weigh over 300kg while the females weigh around 150-200kg. Grey seals are long-lived animals. Males may live for over 20 years and begin to breed from about age 10. Females often live for over 30 years and begin to breed at about age 5.

Grey seals forage in the open sea and return regularly to haul out on land where they rest, moult and breed. They may range widely to forage but most foraging trips are short and relatively close to shore (average 2.3 days; average maximum range 40km from haulout sites, McConnell *et al.,* 1999). Compared with other times of the year, grey seals in Scotland spend longer hauled out during their annual moult (between December and April) and during their breeding season (between August and December). Individual grey seals based at a specific haulout sites often make repeated trips to the same region offshore, but will occasionally move to a new haulout site and begin foraging in a new region. Grey seals often move between haulout sites. Although movements have been observed to occur between the North Sea and the Outer Hebrides, the large majority of trips to sea (88%) are return trips to the same haulout site (McConnell *et al.,* 1999).

In the UK, grey seals typically breed on remote uninhabited islands or coasts and in small numbers in caves usually in the autumn. Preferred breeding locations allow mothers with young pups to move inland away from busy beaches and storm surges. Seals breeding on exposed, cliff-backed beaches and in caves may have limited opportunity to avoid storm

surges and may experience higher levels of pup mortality as a result. Breeding colonies vary considerably in size; at the smallest only a handful of pups are born, while at the biggest, over 5,000 pups are born annually. In general grey seals are highly sensitive to disturbance by humans hence their preference for remote breeding sites.

Approximately 45% of the world's grey seals breed in the UK and 90% of these breed at colonies in Scotland with the main concentrations in the Outer Hebrides and in Orkney. There are also breeding colonies in Shetland, on the north and east coasts of mainland Britain and in SW England and Wales. Although the number of pups born throughout Britain has grown steadily since the 1960s when records began, there is clear evidence that the growth is levelling off. The numbers born in the Hebrides have remained approximately constant since 1992 and growth has been levelling off in Orkney and possibly at some colonies in the northern North Sea

3.1.1. Pup production

Variation in the number of pups born in a seal population can be used as an indicator of change in the size of the population and with sufficient understanding of population dynamics may allow estimation of the total numbers of seals. Aerial surveys of the major grey seal breeding colonies in Scotland are carried out each year to determine the number of pups born (pup production).

The total number of pups born in 2009 at all annually surveyed colonies was estimated to be 42,296. Regional estimates were 3,396 in the Inner Hebrides, 12,113 in the Outer Hebrides, 19,150 in Orkney, and 4,047 at North Sea colonies in Scotland (including Isle of May, Fast Castle) (Table 2). A further 3,247 pups were estimated to have been born at other scattered colonies in Scotland.

Table 2 : Grey seal pup production estimates for the main colonies surveyed in 2008

Location	2009 pup production	Average annual change in pup production from 2004-2009
Inner Hebrides	3,396	-0.5%
Outer Hebrides	12,113	-.1%
Orkney	19,150	+0.5%
Isle of May + Fast Castle	4,047	+8%
All other colonies including Shetland & mainland	3,247 **	
Total (Scotland)	**41,953**	**+1.0%***

*Average annual change in pup production calculated from annually monitored sites only

**Estimate from several surveys in Shetland to provide most up-to-date estimate

Source: Report of the UK Special Committee on Seals (2009)

Overall, there has been a near-continual increase in pup production since regular surveys began in the 1960s. In both the Inner and Outer Hebrides, the rate of increase declined in the early 1990s and production has been relatively constant since the mid 1990s. The rate of increase in Orkney has declined since 2000 and pup production has been relatively constant since 2004. Overall pup production at colonies in the North Sea continues to increase, although it appears to have levelled off in the Scottish sections of the North Sea.

On a longer timescale, during the most recent 5-year period (2004-2009) the total pup production for all annually monitored colonies in the Inner and Outer Hebrides and Orkney has remained almost constant.

3.1.2. Population size

Because pup production is used to estimate the total size of the grey seal population, the estimate of total population alive at the start of the breeding season depends critically on the factors responsible for the recent deceleration in pup production. The recent levelling off in pup production must be a result of some combination of reductions in the reproductive rate or survival of pups, juveniles or adults but recent evidence suggests that changes in the survival of pups is the most likely cause.

The estimated population size associated with all annually monitored colonies in the UK in 2009 was 106,200 (95% CI 82,000-138,700). The number for the whole UK is given because the current model does not distinguish between grey seals in the North Sea that breed in England as opposed to Scotland. Combining these with the annually monitored sites gives a 2009 estimated UK grey seal population of **119,400 (95% CI 92,500-156,200).** About **90% of this population is likely to be within Scottish waters**.

3.1.3. Population Trends

The population trajectory based upon this model indicates that **the grey seal population has been increasing at around 0.5% pa for the past five years**. Population growth in the Inner and Outer Hebrides has effectively stopped. The population trajectory in Orkney appears also to have levelled off. The only location where the population is now increasing is in the North Sea and most of this is occurring along the coast of England.

3.1.4. UK grey seal population in a World context

The UK grey seal population represents approximately 45% of the world population on the basis of pup production. The other major populations in the Baltic and the western Atlantic have been increasing, but at a faster rate than in the UK (Table 3).

Table 3: Relative sizes of grey seal populations. Pup production estimates are used because of the uncertainty in overall population estimates

Region	Pup Production	Years when latest information was obtained	Possible population trend[2]
UK	**46,900**		**Increasing**
Ireland	1,600	2005	Unknown[1]
Wadden Sea	400	2008	Increasing [2]
Norway	1,200	2003	Unknown[2]
Russia	800	1994	Unknown[2]
Iceland	1,200	2002	Declining[2]
Baltic	4,000	2003	Increasing[2,4]
Europe excluding UK	**9,200**		**Increasing**
Canada - Sable Island	52,600	2007	Increasing[3]
Canada - Gulf St Lawrence + Eastern Shore	14,400	2007	Declining[5]
USA	1,100	2002	Increasing
WORLD TOTAL	**124,200**		**Increasing**

[1] Ó Cadhla *et al.* (2007)
[2] Haug *et al.* (2007)
[3] Bowen *et al.* (2007)
[4] Baltic pup production estimate based on mark recapture estimate of total population size and an assumed multiplier of 4.7
[5] Thomas *et al.* (2007)

Source: Report of the UK Special Committee on Seals (2009)

3.2. Harbour seals (also known as common seals)

Harbour seals (*Phoca vitulina*) are found around the coasts of the North Atlantic and North Pacific from the subtropics to the Arctic. Five subspecies of harbour seal are recognized. The European subspecies, *Phoca vitulina vitulina*, ranges from northern France in the south, to Iceland in the west, to Svalbard in the north and to the Baltic Sea in the east. The largest population of harbour seals in Europe is in the Wadden Sea. Until recently the centre of harbour seal distribution had been in Orkney and Shetland but rapid declines in the population as well as increases in the Wadden Sea have caused an apparent shift in the distribution, although this is not because individual animals have moved.

Adult harbour seals typically weigh 80-100 kg. Males are slightly larger than females. Like grey seals, harbour seals are long-lived with individuals living up to 20-30 years.

Harbour seals normally forage within 40-50 km around their haul out sites but much longer trips occur in some areas at least (e.g. Sharples *et al.,* 2009). Approximately 30% of European harbour seals are found in the UK although this proportion has declined from approximately 40% in 2002. About 85% of UK harbour seals are found in Scotland. Harbour 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 with concentrations in the major estuaries of the Firth of Tay and the Moray Firth.

3.2.1. Current status of British harbour seals

The population along the east coast of England (mainly in The Wash) was reduced by 52% following the 1988 phocine distemper virus (PDV) epidemic. A second epidemic in 2002 resulted in a decline of 22% in The Wash, but had limited impact in Scotland. Counts in the Wash and eastern England have failed to demonstrate any recovery since the epidemic, in contrast to the adjacent European colonies which have experienced rapid growth since 2002.

Major declines have now been documented in harbour seal populations around Scotland. Up to 70% of harbour seals in Orkney, Shetland, the Moray Firth and the Firth of Tay have disappeared since 2000.

Harbour seals spend the largest proportion of their time on land during the moult and they are therefore visible during this period to be counted in aerial surveys. The estimated number of seals in a population based on these methods contains considerable levels of uncertainty. A large contribution to uncertainty is the proportion of seals not counted during the survey because they are in the water. We cannot be certain what this proportion is, but it is known to vary in relation to factors such as time of year, state of the tide and weather.

Combining the most recent counts (2006-2008) at all sites produces a minimum estimate of 29,532 harbour seals in Scotland (Table 4). Accounting for seals not visible during surveys leads to an estimate of **40,000-46,000 animals for the total Scottish population**.

3.2.2. Population trends

A complete survey of Shetland in 2009 counted the same number of seals as in 2006, equivalent to 50% of the mid 1990s counts. A partial survey of Orkney produced counts 2.2% higher than the same areas in 2008, but 64% lower than the same areas in 2001. These latest results suggest that the Orkney harbour seal population declined by 67% since the late 1990s and has been declining at an average annual rate >13% since 2001.

Counts in the Outer Hebrides in 2008 were 35% lower than the peak count in 1996. Regular surveys over the intervening period suggest that there has been a sustained but annual decline of around 3% since 1996.

Counts of parts of the Strathclyde region in 2009 were 15% higher than counts of the same areas in 2007. A count of the entire Strathclyde region in 2007 was 25% lower than in 2000 but similar to counts in the mid 1990s. If the subsample counted in 2009 was representative, the overall population will be intermediate between the 1990s and early 2000 counts.

Surveys in 2007 confirmed that the west coast of Highland Region has not showed any decline and surveys in 2008 confirmed that the North coast of Highland Region also had not declined since the previous survey in 2005.

Table 4: Counts of harbour seals by region

Harbour seal Management Area	Current estimate (2007-2009)	Previous estimate (2000-2005)	Earlier estimate (1996-1997)
Shetland	3,003 (2009)	4,883 (2001)	5,991 (1997)
Orkney	2,874 (2008, 2009)	7,752 (2001)	8,523 (1997)
Highland	112 (2008)	174 (2005)	265 (1997)
Outer Hebrides	1,804 (2008)	2,067 (2003)	2,820 (1996)
West Scotland, Highland	4,696 (2007, 2008)	4,665 (2005)	3,160 (1996, 1997)
West Scotland, Strathclyde	5,834 (2007, 2009)	7,003 (2000, 2005)	5,651 (1996)
South-west Scotland, Firth of Clyde	811 (2007)	581 (2005)	923 (1996)
South-west Scotland, Dumfries & Galloway	23 (2007)	42 (2005)	6 (1996)
East Scotland, Firth of Forth	148 (2007)	280 (2005)	116 (1997)
East Scotland, east coast Fife Ness to Fraserburgh	228 (2007)	406 (2005)	648 (1997)
East Scotland, Moray Firth	871 (2007)	959 (2005)	1429 (1997)
TOTAL SCOTLAND	**20,404**	**28,812**	**29,532**

Source: UK Special Committee on Seals (2009)

Surveys of the east coast populations in 2009 showed a continuing rapid decline in the Firth of Tay population, a slight increase in the Moray Firth and a large increase in the English East coast populations. The Firth of Tay count continued the recent trend of rapid decline. This population is within a Special Area for Conservation and has declined at an average annual rate of 20% since 2002. The 2010 count was 84% lower than the peak count in 2000.

4. INTERACTION BETWEEN SEALS AND FISH

KEY FINDINGS

- The principal source of information about seal diet comes from the analysis of faecal material (scats). Surveys of grey seal diet took place in 1985 and 2002. Information about the diets of harbour seals is much less comprehensive.
- Both grey and harbour seals mainly feed on fish at or close to the sea bed. In both cases sandeels are major prey but grey seals also take demersal species such as cod, haddock and whiting. Harbour seals include more herring and flatfish in their diet. Diet composition for both species varies regionally and seasonally.
- **Grey seals eat about 190,000 tonnes of fish each year and harbour seals eat about 80,000 tonnes in Scottish waters**. Although commercially-exploited species form an important part of their diets, fish consumption by seals is generally small compared with both the overall stock and the fish caught by the fishing industry. Grey seal predation on commercially exploited fish stocks in the North Sea is not a major source of mortality but on the west coast of Scotland is it possible that grey seal predation may be a factor limiting the recovery of cod.

4.1. Predation by seals

Direct observation of seal diet is not generally possible. Instead, reliable information on fish predation by seals comes from the analysis of the hard remains of their prey recovered from faecal material (scats) collected from haul-out sites on land. The well-established argument about the impact of an increasing grey seal population on the status of commercial fish stocks has meant that studies have focussed primarily on grey seals. Major assessments of grey seal diet around Scotland were undertaken in 1985 and 2002 from which estimates of predation relative to the size of various fish stocks and their catches have been made. These results are summarised below.

Some information on harbour seal diet exists regionally but there has been no comprehensive Scotland-wide study. However, such a study began in 2010, as part of which grey seal diet is also being reassessed with the aim of providing up-to-date assessments of the predation of both species of seal on fish stocks and investigating evidence for competition between grey and harbour seals. Currently available information is summarised below.

4.2. Grey seals

Studies of grey seal diet in 1985 and 2002 (Hammond *et al,.* 1994 a, b; Hammond and Grellier, 2006; Hammond and Harris, 2006) had the following main objectives: to estimate grey seal diet composition and consumption of commercial fish species by grey seals around Britain in 2002, seasonally and regionally; and to relate changes in grey seal diet composition and consumption between 1985 and 2002 to changes in the abundance of fish prey.

4.2.1. Methods

Diet composition was estimated using scat sampling methods. Scats were collected on a monthly or quarterly basis throughout 2002 along Britain's North Sea coast, in Orkney, Shetland (2002 only) and the Hebrides. Fish otoliths and cephalopod beaks recovered from scats were identified, measured and graded for the amount of digestion.

At the University of St Andrews captive seal facility, 86 feeding trials with seven grey seals and 18 prey species were conducted to derive estimates of digestion coefficients to account for partial digestion and recovery rates to account for complete digestion of otoliths and beaks (Grellier and Hammond, 2006).

For diet composition, measurements of otoliths and beaks recovered from scats were used to estimate the weight of prey associated with each structure, which were summed over species and expressed as percentages in the diet by weight. For consumptions, the amount of prey in the scat samples was converted to energy, equated to estimated energy requirements for the population in the region, converted back to weight, and expressed as tonnes consumed per annum. Estimates of diet were then compared with recorded catches/landings and with estimates of stock biomass for 1985 and 2002 from ICES assessments.

4.2.2. North Sea and Orkney

In the North Sea and Orkney, marked changes in grey seal diet composition were found between 1985 and 2002. The core species (sandeels, cod and other gadoids) were similar in both time periods, but the proportions they contributed were different both regionally and seasonally.

At Donna Nook (SW North Sea), benthic prey (dragonet and seascorpions) were more important and sandeel less important in 2002 than in 1985 and much less cod but much more whiting were consumed in 2002 compared with 1985. Along the NE coast of Britain, the overall changes were less pronounced; the percentage of gadoids in the diet was lower and the percentage of sandeel was higher in 2002 compared with 1985. Within the gadoids, however, the percentage of cod in the diet declined almost 5-fold, and the percentage of haddock increased by an order of magnitude. In Orkney, the overall change in diet between 1985 and 2002 was dominated by an increase in the percentage of gadoids and a decrease in the percentage of sandeel. There was a particularly large increase in the percentages of cod and haddock taken in the first quarter of the year. In Shetland, the diet in 2002 was greatly dominated by sandeel, with some gadoids.

Estimates of annual consumption of commercially important fish prey by grey seals increased markedly from 39,000 tonnes in 1985 to 116,000 tonnes in 2002, in line with the increase in grey seal population size (Table 5). The estimated amount of sandeel consumed increased from 29,000 t in 1985 to 69,000 t in 2002, and estimated consumption of cod increased from 4,100 t to 8,300 t. Per capita prey consumption overall was 4.7 $kg.d^{-1}$ (1.72 $tonnes.yr^{-1}$). Consumption per seal decreased between 1985 and 2002 for cod (by ~30%) and sandeel (by ~15%), remained about the same for whiting, approximately trebled for plaice, and approximately quadrupled for haddock.

Table 5: Grey seal prey consumption in the North Sea and Orkney in (a) 1985 and (b) 2002, compared to catches/landings and estimates of total stock biomass (TSB) in Sub-Area IV for species assessed by ICES Working Groups

Species	Estimated seal consumption (t)	Catch/landings (t)	Estimated TSB (t)
(a) 1985			
Cod	**4,150**	244,000	475,000
Whiting	**776**	106,000	480,000
Haddock	**619**	258,000	1,160,000
Saithe (IV+VIa)	**2,297**	226,000	712,000
Norway pout	**42**	205,000	643,000
Sandeel	**28,832**	707,000	3,220,000
Sole	**135**	24,000	53,000
Plaice	**571**	221,000	560,000
Herring	**113**	614,000	3,460,000
Sprat	**3.0**	-	187,000
(b) 2002			
Cod	**8,344**	67,000	225,000
Whiting	**2,453**	47,000	327,000
Haddock	**6,538**	108,000	806,000
Saithe (IV+VIa)	**2,628**	122,000	730,000
Norway pout	**892**	77,000	494,000
Sandeel	**68,916**	807,000	2,600,000
Sole	**144**	17,000	55,000
Plaice	**5,215**	131,000	355,000
Herring	**378**	371,000	4,040,000
Sprat	**2.3**	-	662,000

Source: Hammond and Grellier (2006)

Estimates of cod, whiting, haddock, saithe, Norway pout, sandeel, sole and plaice TSB are from the stock assessments conducted by the ICES Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak in 2004 (**http://www.ices.dk/products/CMdocs/2005/ACFM/ACFM0705.pdf**).

Estimates of saithe TSB are from the stock assessment for Sub-Area IV and Division VIa combined, conducted by the ICES Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak in 2004

Estimates of herring and sprat TSB are from the stock assessment conducted by the ICES Herring Assessment Working Group for the Area South of 62º North in 2004 (**http://www.ices.dk/products/CMdocs/2005/ACFM/ACFM1605.pdf**).

In summary, sandeel, cod, other gadoids and plaice are the most important prey of grey seals in the North Sea. In 2002, sandeel continued to be consumed in substantial quantities (Table 5). The amount of cod consumed per seal declined slightly between 1985 and 2002 but the stock declined much more. The amounts of haddock and plaice consumed per seal increased markedly between 1985 and 2002 in the face of stock declines.

4.2.3. West of Scotland

Sandeel, gadoids and herring were the main prey of grey seals in the Hebrides. Benthic species (especially in the Inner Hebrides) and flatfish (especially in summer) were also important. Within this area there was substantial seasonal and regional variation.

In the northern Inner Hebrides, dragonet, sandeel, cod and haddock were the main species in the diet. In the Minch, the diet was dominated by sandeel in quarter 1, and by cod, haddock, ling and sprat in the rest of the year. In the southern Inner Hebrides, sandeel and cod were the main prey. Sandeel dominated the diet in all seasons in the northern Outer Hebrides, with herring (quarters 2-4), cod (quarter 1) and ling also important. In the Monach Isles, the dominant species in the diet were sandeel (particularly in quarters 1 and 4) and herring (particularly in quarters 2 and 3). Gadoids made up most of the rest of the diet throughout the year, especially ling and rockling in quarter 1, and cod and haddock in the rest of the year. In the southern Outer Hebrides, sandeel (mainly in quarter 1) and gadoids (especially haddock) were dominant and plaice was a significant contributor to the diet in quarters 2 and 3.

There was limited evidence of major changes in grey seal diet composition west of Scotland between 1985 and 2002. The main general differences were a decreased proportion of sandeel and an increased proportion of herring in 2002 compared to 1985. Among the gadoid species, the contribution of cod and whiting to the diet (equivalent to the amount consumed per seal) remained about the same, haddock increased and saithe, pollock and ling decreased in 2002 compared to 1985. Species that featured strongly in the diet in 2002 but not in 1985 included lemon sole, rockling, bullrout and dragonet. Megrim contributed about 7% to the diet in 1985 but was virtually absent in 2002.

Estimated annual consumption of prey by grey seals in the Hebrides area increased between 1985 and 2002 from 53,000 t to 77,000 t, in line with the increase in the grey seal population in this area. Estimated cod consumption increased by about one-third from 5,400 t to 7,100 t between 1985 and 2002 but the estimated amount of sandeel consumed was about the same in both years.

Per capita prey consumption was 5.0 $kg.d^{-1}$ (1.8 $t.yr^{-1}$). Between 1985 and 2002, there was little change in the consumption of cod and whiting per seal but marked decreases for saithe, pollock, ling and sandeel. Consumption per seal of haddock and herring increased threefold.

In summary, sandeel, herring, cod and other gadoids are the most important prey of grey seals west of Scotland. Although the amount of cod and whiting taken per seal declined slightly between 1985 and 2002, the stocks declined a lot more (Table 6). The amount of herring and haddock consumed per seal both increased 3-fold in this period.

Table 6: Grey seal prey consumption in the Hebrides area in (a) 1985 and (b) 2002, compared to catches/landings and estimates of total stock biomass (TSB) in ICES Division VIa for species assessed by ICES Working Groups

Species	Estimated seal consumption (t)	Catch/landings (t)	Estimated TSB (t)
(a) 1985			
Cod	**5,372**	27,000	43,000
Whiting	**1,386**	24,000	46,000
Haddock	**1,519**	42,000	105,000
Saithe (IV+VIa)	**2,297**	226,000	712,000
Herring	**2,755**	39,000	357,000
Megrim (1990)	**3,733**	2,200	12,000
(b) 2002			
Cod	**7,131**	2,400	11,000
Whiting	**1,628**	3,900	13,000
Haddock	**6,645**	16,000	87,000
Saithe (IV+VIa)	**2,628**	122,000	730,000
Herring	**12,251**	32,000	272,000
Megrim	**9**	1,800	7,600

Source: Hammond and Harris (2006)

Estimates of cod, haddock and whiting TSB are the results of exploratory assessments by the ICES Northern Shelf Demersal Stock Assessment Working Group in 2004 (http://www.ices.dk/products/CMdocs/2005/ACFM/ACFM0105.pdf)

Estimates of herring TSB are from the stock assessment conducted by the ICES Herring Assessment Working Group for the Area South of 62º N in 2005 (http://www.ices.dk/products/CMdocs/2005/ACFM/ACFM1605.pdf).

Estimates of saithe TSB are from the stock assessment for Sub-Area IV and Division VIa combined, conducted by the ICES Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak in 2004.
(http://www.ices.dk/products/CMdocs/2005/ACFM/ACFM0705.pdf).

Estimates of megrim TSB are the results of an exploratory assessment conducted by the ICES Northern Shelf Demersal Stock Assessment Working Group in 2004 (http://www.ices.dk/products/CMdocs/2005/ACFM/ACFM0105.pdf). The assessment only goes back as far as 1990.

Conclusions

Significant changes in grey seal diet and in the impact of seal predation on fish stocks were found between 1985 and 2002. These changes between 1985 and 2002 are a result of three factors: an overall increase in consumption of prey by grey seals (driven by the increase in seal numbers); the changes in diet composition; and declines in most fish stocks.

Based on the diet estimated in 2002 and the current estimate of the total population, an approximate current estimate of the total amount of fish prey consumed by **grey seals in Scottish waters as a whole is 190,000 t.yr^{-1}**.

Grey seal predation on fish stocks in the North Sea was at levels that were unimportant in 1985; estimated prey consumption was less than 1% of estimated stock size for all species and little more relative to catches/landings (<2% for cod and ~4% for sandeel). In 2002, consumptions relative to stock size of most prey species were several times higher but only for cod (3.7%) sandeel (2.7 %) and plaice (1.5 %) were the percentages greater than 1%. However, seal predation compared to fisheries catches was much higher in 2002 (>5% for whiting, haddock and sandeel and >10% for cod). We conclude that, although very much higher in 2002 than in 1985, **grey seal predation on commercially exploited fish stocks in the North Sea is not a major source of mortality**.

West of Scotland, grey seal predation relative to available estimates of fish stock size was mostly much higher in 2002 than in 1985. This was especially true for cod where grey seal predation was a substantial proportion of estimated stock size. Problems with the robustness of stock assessments west of Scotland preclude a more detailed assessment but but it is not unreasonable to infer that **grey seal predation may be a factor limiting the recovery of cod west of Scotland**. Relative to catches/landings, grey seal predation in 1985 was ~20% for cod but otherwise <10% for other species, but was very much higher in 2002 (~40% for whiting, haddock and herring and almost 300% for cod).

4.3. Harbour seals

Diets of harbour seals in Scottish waters have been described in SE Scotland, the Moray Firth, Shetland, and the Hebrides.

In the Moray Firth, harbour seal diet was studied in the late 1980s and early 1990s (Pierce *et al.,* 1991; Tollit and Thompson, 1996; Tollit *et al.*, 1997). The main prey species were sandeel, gadoids (whiting, cod), clupeids (herring sprat), flatfish (especially flounder), and octopus. Significant between-year and seasonal fluctuations were observed and there was evidence that diet composition was dominated by either pelagic species or species dwelling on or strongly associated with the seabed, depending upon the relative abundance of pelagic schooling prey.

In Shetland, there were seasonal patterns similar to those in the Moray Firth; sandeels were important in spring and early summer, and gadoids (mainly whiting and saithe) in winter. Pelagic species (mainly herring, garfish and mackerel) were important in late summer and autumn. Overall, gadoids accounted for about half the diet, sandeels about 30% and pelagic fishes 10-15% (Brown and Pierce, 1998).

In the Inner Hebrides harbour seals consumed a wide range of species, the most important of which were scad, herring and whiting (Pierce and Santos, 2003). Overall, gadoids

comprised 50-90% of the diet but sandeels were a very minor part even in the summer months.

Off SE Scotland, studies in 1998-2003 investigated harbour seal diet in the Firth of Tay and also in St Andrews Bay (Sharples *et al.*, 2009). In St. Andrews Bay, diet was heavily dominated by sandeels, especially in winter and spring. Gadoids (whiting, cod) and flatfish (dab, plaice, flounder) were the other main prey. The proportion of sandeels in the diet was remarkably consistent over years (71-77%). In the Firth of Tay, sandeels were prevalent in winter, but the diet in the rest of the year was dominated by salmonids, showing marked differences in diet at a fine spatial scale.

No formal attempt has been made to estimate the amount of each prey species consumed by harbour seals. However, based on estimated population size and an approximate estimate of daily energy requirement, **harbour seals are currently likely to consume around 80,000 t of fish prey per year in Scottish waters**.

5. EFFECT OF SEALS ON FISH STOCKS - OVERVIEW

The question of the impact that grey seals may have on fish stocks and, therefore, fish catches is important in light of these results. Might grey seals limit the ability of cod and other gadoid stocks to recover in the North Sea and west of Scotland? Alternatively, might declines in fish stocks impact grey or harbour seal population growth? We are unable to answer these questions in any definitive way. However, the available information indicates strongly that **the effects of predation by both species of seals on overall stock abundance of most fish species is likely to be insignificant**.

It is important to see the 270,000 t of fish estimated to be consumed annually in Scottish waters by seals in the context of predation by other species. Recent estimates of cetacean abundance (Hammond *et al.,* in review) indicate approximately 120,000 harbour porpoise, 8,000 minke whale and 30,000 dolphins in Scottish waters. Together, these species likely consume around 300,000 t of fish prey annually; a similar amount to seals. Equivalent consumption estimates for seabirds are approximately twice this figure. It is also important to recognise that most fish are eaten by other fish. Fish predation on fish in the North Sea was estimated at more than 2,000,000 t annually in 2000 and is likely at a similar level today.

There is considerable protection for seal populations in Scotland. In the case of grey seals the general picture is one of stability of populations after a period of sustained increase over several decades. However, the recent declining population trends for harbour seals are a real cause for concern and a reminder of how rapidly populations can decline. We do not know why the harbour seal population has experienced such a rapid decline. We have no reason to believe that grey seals are likely to decline in a similar manner but the experience with harbour seals highlights that risks do exist. For example, if the same pattern were to be repeated for grey seals, the population growth that has occurred over a period of about 5 decades could be eroded in less than 10 years. While there are management options to curtail growth in seal populations we have no tools available, beyond benign protective legislation, to curtail declines in seal populations.

Why are seals important? Although we do not fully understand their role within the marine ecosystem, we can say that their presence represents a healthier and more diverse ecological structure in Scotland's seas than would be the case if they were absent or at very low numbers. They prey on a relatively small proportion of the total prey available but they rely on a broad range of fish species not all of which are of commercial importance. In most circumstances seals are not an important competitor with fisheries and their presence can be seen as an indication that there is a productive ecological system which is also likely to be capable of sustaining economically viable levels of fishing.

It is not the case that commercial fish eaten by seals are inevitably lost to fisheries. The majority of predation on fish is by other fish, and other predators (cetaceans and seabirds) inflict higher mortalities on fish than seals**. Even a large reduction in the number of seals in Scottish waters would be unlikely to make any noticeable impact to the success of demersal or pelagic fisheries.** Only in the case of some small salmon fisheries, where point-defence against seal predation is much the most effective and cost-effective form of management, is it possible that there may be an effect of seals upon fisheries; however, even in this situation the evidence is uncertain.

Overall, the exploitation rates by fisheries in Scottish waters have been higher over the past five decades than appear to be sustainable in the long-term and the indicators are that management is not being effective at reducing the levels of exploitation. During the same period grey seals have shown a sustained increase in abundance but it is notable that in the areas where fishing has been most curtailed because of reduced stock levels, the west coast of Scotland, grey seal pup production has been stable for about 2 decades. Nevertheless, even though grey seals are unlikely to have been the cause of stock declines, it is possible that they could be a factor preventing the recovery of cod on the west coast of Scotland.

More generally, we do not know if the increase in grey seal abundance is directly related to the declines in fish stocks. However, given that the overall relative capture rate by seals is much lower than that of fisheries it is more likely that fisheries are the main cause of declines in stock sizes.

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NOTES

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