Report of the Scientific Committee *ad hoc* Working Group on Grey Seals *Halichoerus grypus*

Tórshavn 5-8 February 1996

1-3. Opening procedures

The *ad hoc* Working Group on Grey Seals met at the Nordic House in Tórshavn, Faroe Islands, 5-8 February 1996. The Chairman, Arne Bjørge, welcomed participants (listed in Appendix 1).

The Working Group had as its terms of reference the Council's request for advice on grey seals (*Halichoerus grypus*) which was to:

> "... review and assess abundance and stock levels of grey seals (*Halichoerus grypus*) in the North Atlantic, with an emphasis on their role in the marine ecosystem in general, and their significance as a source of nematodal infestations in fish in particular."

The Working Group adopted the agenda and decided to review the available working papers area by area (see List of documents. p. 16). For the general discussion, conclusions and recommendations, the Working Group decided to discuss all areas by topic.

Invited experts D.Thompson (UK) and M. Hammill (Canada) assisted the Chairman as rapporteurs.

4. Review of grey seal stocks

4.1 Stock Identity and Breeding Distribution

The grey seal (*Halichoerus grypus*) is a medium sized phocid found throughout the temperate waters of the North Atlantic. Three distinct populations are recognized: the western North Atlantic; the eastern North Atlantic; and the Baltic Sea grey seals. An examination of mitochondrial DNA variation in samples from Canada, Norway and the Baltic Sea found no shared haplotypes between the eastern and western Atlantic (Boskovic *et al.* submitted). According to this study, the distances between these two populations suggest that they diverged 1.0-1.2 million years ago. Nucleotide divergence between Baltic Sea and Norwegian grey seals, estimated to be around 0.7%, suggests that separation of Baltic and Northeast Atlantic grey seals took place around 350 thousand years ago based on standard divergence measures (Boskovic *et al.* submitted). The Working Group commented that if the separation of Northeast Atlantic and Baltic grey seals was established by the formation of the semi-enclosed Baltic Sea, the separation may be a more recent phenomenon due to the postglacial history of the Baltic Sea basin.

In the Northwest Atlantic two major groups of grey seals are recognized, based on the location of their whelping patches. The largest group breeds on Sable Island, a 40 km long sand bar located approximately 150 km to the east of Nova Scotia. The second group, known as the non-Sable Island grey seals, is made up of animals that breed on the small islands along the eastern shore of Nova Scotia and animals that whelp on the drifting pack ice in the Gulf of St Lawrence (Mansfield and Beck 1977). Recently a new breeding site was established at the Cape Cod Peninsula in USA. Although animals from both groups show strong philopatry to their whelping sites, considerable overlap occurs between the two groups in their distribution outside of the breeding season (Stobo *et al.* 1990; Lavigueur and Hammill 1993). An

analysis of the mitochondrial DNA indicates that the two groups likely form a common stock (Boskovic *et al.* submitted).

The Northeast Atlantic grey seals are distributed from Iceland, Faroe Islands, British Isles and along the northwest coasts of mainland Europe. In Iceland the distribution is divided into two main areas (SC/4/GS/5). The majority of the population breed on the west and northwest coast, fewer at the southeast coast. Recently, grey seals established a new breeding colony in northeast Iceland. Historically, the distribution of the Icelandic grey seals has been changing. During the last 50 years it has dispersed from the west coast to the northwest and north coasts and now to the northeast coast. A few grey seals tagged in the UK have been found in Icelandic waters (E. Hauksson, pers. comm.). Thus, there is some evidence of mixing of Icelandic grey seals with other grey seal stocks in the North Atlantic, but the degree of mixing is unknown.

In the Faroe Islands, grey seals are frequently seen, and may be counted in hundreds at haul out sites, in particular at Mykineshólmur and Sumbiarbjørgini (D. Bloch, pers. comm.). No information is available on the distribution of grey seals in Faroe Islands. One grey seal tagged as a pup at North Rona, UK, in 1993 was shot in the Faroe Islands in the summer of 1994. Recently, grey seals tagged with satellite linked transmitters have migrated to the Faroe Islands. Historical and anecdotal information indicate that grey seals breed in caves on the Faroe Islands (SC/4/GS/6).

In the UK grey seal breeding colonies are found in Shetland, Orkney, North Rona, Outer and Inner Hebrides, on the north and northeast coasts of the Scottish mainland and on Isle of May, Farne Islands and Donna Nook on the North Sea coast. Smaller colonies are located in Wales and at the Scilly Islands in southwest Britain (SC/4/GS/8).

Grey seal breeding sites are located along the mainland coast of Europe from the Kola Peninsula, northern Russia, along the Norwegian coast, the German and Dutch Wadden Sea to France. The largest breeding groups are reported from Kola, Russia, and Froan in Central Norway (Anon. 1996).

In the Baltic Sea, grey seals normally breed on ice during late winter. There are large year to year differences in ice conditions and coverage, and the location of breeding varies between years. Due to mild winters, in Estonia the pups have been born on shore in recent years. Grey seals are still absent from most of their former range in the southern Baltic Sea (Anon. 1996).

In the Northeast Atlantic most grey seals breed in autumn from September to December, and the breeding season of Northeast Atlantic grey seals is therefore quite distinct from the late winter breeding of Baltic grey seals.

4.2 Distribution and movements outside breeding season

Knowledge on the distribution and movements of grey seals is available from anecdotal information, sightings, recovery of tags from bycaught or shot animals, or animals found dead on shore, and more recently from information provided by telemetry and pelage recognition programmes.

4.2.1 Distribution patterns

In the Northwest Atlantic, grey seals are found as far north as Cape Chidley in northern Labrador, throughout the Gulf of St Lawrence and along the Atlantic coast as far south as Virginia in the United States (Katona et al . 1993).

Sable Island animals appear to have a postbreeding pelagic phase (January-April) during which time they disperse from the island. This is followed by a spring moulting phase (May-June), then by a summer dispersal away from the island (July-September). At this time animals disperse towards the Nova Scotia, Maine and Newfoundland coasts and into the Gulf of St Lawrence. This is followed by a return to Sable Island during the fall and early winter (October-December) (Stobo *et al.* 1990).

This general movement pattern is also true for non Sable Island grey seals. The largest concentration of non-Sable Island grey seals is found in the Gulf of St Lawrence, where whelping occurs on the drifting pack ice in the southern Gulf during January-February. Tag returns and satellite telemetry indicate that after breeding adult grey seals move out of the Gulf onto the Scotian shelf (Lavigueur and Hammill 1993; Goulet, Barrette and Hammill unpublished data; Hammill, Lydersen and Kovacs unpublished data), where they remain offshore until the spring moult. The pups tend to remain with the pack ice as it drifts around the west side of the Cape Breton Coast into the Atlantic. However, in some years ice drift is slow, or there is little ice available which breaks up early in the season. When this occurs, many animals move ashore, where mortality may be high along the north coast of Nova Scotia and the west coast of Cape Breton Island. During May-June, both adults and juveniles move ashore to moult. Although some animals moult throughout the Gulf, most appear to move into the northern Gulf, around Anticosti Island and along the north shore (Clay and Nielsen 1985). After the moult, animals disperse, with many animals moving into the St Lawrence estuary (Lavigueur and Hammill 1993). During the fall, grey seals in the Gulf return to the southern Gulf for the breeding season, but this movement occurs slowly and late in the year (Goulet, Barrette and Hammill unpubl.data).

Between 1988 and 1993 SMRU (Sea Mammal Research Unit, UK) carried out a series of helicopter-based thermal image surveys around Scotland, and annual surveys of the Wash in south-east England during the common seal moult in August. The numbers of grey seals seen were also recorded. All sections of the Scottish coast were surveyed at least once over the six year period. Grey seals were found in groups throughout the Western Isles, along the west and north coasts of Scotland, throughout the Orkney and Shetland Isles and at various points down the east coast as far as the Wash. Concentrations of grey seals in summer were closely associated with breeding sites, with additional large haul outs in the estuaries of the Wash, the River Tay and the inner Moray Firth (SC/4/GS/8). There do not appear to be large scale shifts in population distribution as seen in Canada.

Recoveries of grey seals tagged in the UK suggest that there is a general dispersal of pups away from their natal sites, with recoveries from the entire North Sea basin as far as 67° on the coast of Norway. Migration rates between areas indicated that most 0+ age class seals remain within the sea area closest to their natal site, but that extensive movements occur between adjacent areas, with consequent mixing of pups from different breeding sites (SC/4/GS/8).

Swimming tracks of adult seals obtained from satellite and real time acoustic tracking showed large scale movements of up to 2,100 km and demonstrated frequent interchange between major haul-out areas. However, most seals spent most of their time on short (mean 2.7 days) and local (mean 47 km from haul-out site) foraging trips. For example, Farne Islands' seals spent 78% of their time within 50km of the islands. Foraging 'hotspots' could be identified. These were visited repeatedly by several seals and seemed to be associated with particular seabed sediment types (SC/4/GS/8).

4.2.2 Tagging and Telemetry Programmes

Conventional flipper tagging programmes have been conducted on grey seals in Canada since the 1970s. On Sable Island all pups were tagged between 1977 and 1990 (Stobo *et al.* 1990). For the non-Sable Island component of the population, tagging has been more sporadic. Approximately 2000 pups were tagged in each of 1984 ,85, 86, 89, 90, 94 and 96 on the pack ice in the Gulf of St. Lawrence. Smaller

numbers (<1000) have been tagged on small islands along the eastern shore of Nova Scotia between 1984 and 1996. Tag recoveries have been used to estimate pup production of the non-Sable Island component (Hammill *et al.* 1990; Lavigne and Hammill 1993) and to examine the seasonal distribution of grey seals (Stobo *et al.* 1990; Lavigne and Hammill 1993).

In Britain flipper tags have been used extensively on grey seals since the 1960s. Early results from studies on the east coast showed a wide dispersal of pups. The last major tagging effort was in 1980 in the Hebrides, Orkney and Farne Islands. Most recoveries were from the 0+ age class. Recovery patterns were used to derive recapture effort and migration rate estimates between sea areas centered on the major breeding areas.

A flipper tagging programme began in central Norway in 1977 and more recently in Finnmark and at the Kola Peninsula.

In the UK VHF radio transmitters have been used to study movements of grey seals between the Farne Islands and Isle of May between November 1988 and December 1990. Automatic receiving stations (Nicholas *et al.* 1992) were placed at five sites along the coast. Movements between haul-out sites and activity patterns of 19 grey seals were recorded. In addition, the movements, dive behaviour and physiology of 11 grey seals were monitored using VHF and acoustic-telemetry. Seals were tracked from small boats and were recorded making extensive movements between haul-out areas and making foraging trips up to 80km offshore.

In the UK, satellite transmitters interfaced with depth and swim speed data loggers, have been deployed on 23 adult grey seals in the North Sea and approximately 15 in the Hebrides. In 1995 new miniaturized transmitters were deployed on weaned grey seal pups in the Outer Hebrides. Further deployments are planned for 1996. The same devices have been deployed on 5 grey seals in central Norway (Bjørge 1995) and on eight grey seals in the Baltic Sea (Sjøberg *et al.* 1993; SC/4/GS/8).

A total of 13 satellite tags have been deployed on grey seals in the Gulf of St. Lawrence. During October 1995 four satellite tags were deployed on grey seals on Sable Island. There are plans to deploy eight more on animals at Sable Island and five in the southern Gulf of St. Lawrence during the summer of 1996 (M. Hammill, pers. comm.).

4.2.3 Mark Recapture Techniques

Local population estimates, rates of movement between haul-outs and survival rates can be estimated using mark recapture techniques. Historically, plastic or metal tags were used to mark seals. These provide limited information due to tag loss, low rates of tag recovery and the fact that recoveries are often from dead animals.

Automated photo-identification techniques have recently been developed which use natural marks on seal pelage to identify individuals.Photographs of the side of the head are digitised and a standard sample of the pattern is extracted. Specially developed image processing software compensates for view point and seal posture. Images of the same seal produce a high similarity index when compared by a computer program. Pairs of photographs with high similarity measures are then compared by eye to confirm matches. Once entered into the database, each image is compared with all other entries to develop a capture history for each seal (Hiby 1995; SC/4/GS/8).

In a three year study in the North Sea, over 10,000 images were obtained giving 4,050 identifications, of which 2,400 were classed as well as marked. The study provided local summer population estimates and migration rates between haul-out areas. The catalogue is being maintained and expanded and is

producing estimates of survival rates and updated population estimates. Comparisons between summer haul-out and breeding season catalogues will yield estimates of reproductive rates.

4.3 Population size and status

Grey seals were at one time very abundant and widely distributed along the Canadian east coast and in the Gulf of St Lawrence, where they were first hunted by Amerindians. Extensive hunting by Europeans, particularly after the disappearance of the walrus in the Gulf and on Sable Island, resulted in the depletion of the grey seal population by the mid-1800s (Lavigueur and Hammill 1993). By the early 1900s grey seals were still considered to be widely distributed, but there was no particular hunt for them owing to their small numbers. During the 1950s the grey seal in eastern Canada was considered to be uncommon or rare.

Grey seal pup production on Sable Island has been determined by complete enumeration between 1977 and 1990. Counts on Sable Island indicate that pup production has increased from 2,181 pups in 1977 to 9,712 in 1989 at an exponential rate of increase of 12.6% per year (Stobo and Zwanenburg 1990). Non Sable Island pup production estimates have been determined from mark-recapture experiments conducted between 1984 and 1990, where the pups were marked on the whelping patch and later shot during scientific collection programmes or by recapturing the animals live on Sable Island 3-10 months later. Using the best estimates, pup production increased from between 5,200 and 6,700 animals during the mid 1980s to between 8,300 and 10,700 during 1989-90 at an annual rate of increase of 8.8% (Hammill et al submitted). It is evident that the Sable Island and non Sable Island components of the population have undergone very different trajectories since the 1970s. During the 1970s, roughly 69% of the population was of non-Sable Island origin comprised mostly of animals in the Gulf of St Lawrence. However, by 1993 less than 43% of the total population of approximately 143,000 animals was of Gulf origin. Differences in the trajectories of the two groups likely result from the effects of the government sponsored cull of non Sable Island animals in the whelping areas, as well as higher probable mortality rates for pups born on the unstable pack ice in the Gulf of St Lawrence (Hammill *et al.* 1995).

Grey seals were first counted in Iceland in 1982. In the period 1982 to 1990 the population seems to have been stable or slightly increasing, but since 1992 and after that time the population appears to have been declining. The abundance of the grey seal around Iceland is now about 8,000 animals. In 1982 the population was estimated as 12,500 (9,550-14,400) animals (SC/4/GS/5).

Historical (Landt 1800) and anecdotal information indicate that grey seals breed in caves on the Faroe Islands. The population size was unknown, but supported a harvest (Johannessen 1967) and a bounty system between 1963 and 1967. A total of 970 seals was reported killed during this system (Reinert 1982). There is at present no estimate available for pup production in the Faroe Islands.

Approximately 40% of the world population of the grey seal breeds on 37 widely dispersed sites around the British Isles. The total number of births at all the major breeding sites in northern Britain has been monitored by aerial photographic surveys since the 1960s (SMRU). Pup productions at other sites at South Ronaldsay in Orkney, at the Farne Islands and in the Humber Estuary have also been estimated annually, from ground counts conducted by staff from Scottish Natural Heritage, the National Trust and Lincolnshire Trust for Nature conservation. Pup production estimates for Shetland and Wales are based on occasional surveys by SMRU and Dyfed wildlife trust (SC/4/GS/8).

Details of the aerial survey and photo-analysis techniques have been described fully by Hiby *et al.* (1988). The essential features are: a minimum of four flights are conducted over each site each year to trace the rise and fall in pup numbers ashore; the photographs provide complete coverage of the breeding site; the quality of the images is sufficient to allow pups to be distinguished from similar shaped and

sized objects such as sheep and rocks, and allows pups to be classified into one of two developmental stages. Since 1985 colour transparency film has been used, facilitated by the development of an image motion compensation system (Hiby *et al.* 1987). This system provides a spatial resolution of about 5 cm on the ground and allows a proportion of moulted pups to be distinguished from whitecoats.

Since 1991 each site has been photographed at least four times at 10-day intervals. However, the timing and number of flights in previous years has been more variable.

Because the length of time pups remain ashore is short relative to the spread of birth dates, there is no time at which all the pups born are present. The number present at any time is a function of the birth rate up to that time and the rate of disappearance. Birth rate is estimated by fitting the count series to an underlying statistical model of the way in which the number of pups ashore varies through the season. (Rothery and McCann 1987, Hiby *et al.* 1988). An estimation procedure which produces maximum likelihood estimates of pup production for each site is fully described by Hiby *et al.* (submitted).

Population size is estimated by fitting a demographic model to the entire series of pup production estimates obtained since 1984. The size of the British grey seal population is defined as the number of seals born at a British breeding site which are alive at the start of the breeding season. The population is estimated as a whole because at present there is no objective basis for partitioning this geographically defined unit into biologically meaningful sub-units. The demographic model has been described fully by Hiby *et al.* (submitted).

The number of females in the population is estimated from the entire time series of pup production estimates. The size of the male component is then inferred from the female population estimate and information on relative survival values. The aim of this exercise is to derive an estimate of absolute abundance each year. These can be viewed as a time series, but being a long lived, annually breeding species the total population estimates provide a heavily damped indicator of changes in the population. The time series of pup production estimates provides a much more sensitive indicator of changes in numbers and distribution (SC/4/GS/8).

The demographic model is applied to all sites which are monitored annually, i.e. Inner and Outer Hebrides, North Rona, Orkney, the Isle of May and Farne Islands. Together these sites account for almost 90% of the pup production in Britain. The total population estimate for the annually monitored sites was 96,577 in 1994. By adding the most recent available estimates from all other breeding sites and multiplying by the total population:pup production ratio estimated from the model, an estimate of 108,500 for the total British grey seal population in 1994 is obtained. Of these, 99,300 seals are associated with breeding sites in Scotland and 9200 with sites in England and Wales.

Ninety-five percent confidence intervals on the pup production figures at each location are estimated to be within 14% of the point estimate. Ninety-five percent confidence intervals on the overall population estimate have been derived for the Farnes population. These were within 23% below and 38% above the point estimates. In Orkney pup production increased by approximately 4% p.a. between 1964 and 1982. Between 1970 and 1982 an average of 950 moulted pups were killed annually in a commercial hunt. Between 1984 and 1994 pup production increased by around 9-10% p.a.. In the Outer Hebrides pup production increased by approximately 6% p.a. between 1961 and 1982. The commercial hunt was less intensive and of shorter duration than in Orkney, with an average take of 515 p.a. between 1973 and 1979. Between 1984 and 1994 pup production has increased by around 5-6%, although in the last two years the increase has been only around 2% p.a.. In the Inner Hebrides pup production increased by 7.6% p.a. between 1984 and 1994. This area was not surveyed regularly before 1984. Coincident with the lower rate of increase in the Outer Hebrides, pup production in the Inner Hebrides in 1994 was lower than the 1992 value. The North-East English/South-East Scottish population was initially restricted to

the Farne Islands. Between 1956 and 1971 pup production increased by 7% p.a., reaching a peak of 2,041. A series of control measures were carried out between 1971 and 1982 to reduce this population. Pup production was reduced to 1,238 p.a., but the measures had the effect of moving a proportion of the Farnes seals to the Isle of May, approximately 90km to the north. Since 1983 the combined population has continued to increase at 7% p.a (SC/4/GS/8).

Pup production has not increased uniformly at all colonies. For example, in the Outer Hebrides the Monach Isles have accounted for most of the increase since 1984. In Orkney, sites which produced a third of the total in 1987 have not increased at all while the total production increased at 10% p.a.. The patterns of variable growth rates at colonies within small geographical areas mean that it is not possible to monitor the pup production by counting only a few sites. Nor is it adequate to monitor just the current breeding sites, as newly colonised sites can increase rapidly in size. Calf of Eday and Copinsay in Orkney were not used for breeding before 1990, but by 1993 they contributed 7.5% of the total production. If a new colony is not included until it has grown to a significant size the estimated rate of increase will be over-estimated.

A discontinuity in the Orkney time series between 1982 and 1984 was probably due to improvements in photographic techniques. There is some indication of a similar effect in the Outer Hebrides although this could be the result of a decrease in pup production due to a cull of adult females in 1977. The immediate effect of the 1977 cull on pup production is obvious and is larger than would be expected purely as a result of the number of females killed (SC/4/GS/8).

Total pup production fell in 1988 and recovered by 1992. This is coincident with the phocine distemper epidemic which killed around 17,000 harbour seals (*Phoca vitulina*) in Europe. There was no evident increase in grey seal mortality at the time, but these figures suggest that there was an effect on fecundity or recruitment into the breeding population.

The reduced growth rate in the last two seasons in the Western Isles suggests that there may have been a decrease in fecundity. If fecundity has declined it would be misleading to extrapolate population size to future years using historical trends.

Figures of pup production are available for all known breeding sites along the mainland coast of northwest Europe, However, most figures are based on single counts. No confidence limits are therefore established for these figures. In most cases in Norway and Russia there are no time series available to evaluate trends in populations. The most recent counts, and therefore minimum figures for pup production are: 358 in Russia (Haug *et al.* 1994); 473 in Norway; 9 in Germany; 25 in the Dutch Wadden Sea; and 2 in France (Anon. 1995).

4. 4 Life history

In the Northwest Atlantic, whelping begins in late December and continues into late January on the small islands of Amet Island, and Deadman Island in the Gulf of St Lawrence, along the Nova Scotia Eastern Shore and on Sable Island (Mansfield and Beck 1977). Whelping also occurs on the drifting pack ice in the southern Gulf of St Lawrence, beginning in early to mid January and continues into early February (Hammill, unpublished data). Lactation lasts for approximately 15-16 days (Iverson *et al.* 1993; Baker *et al.* 1995). At birth the pups weigh 15-17 kg, gain 2.4-3.0 kg/d and are weaned at a mass of 51-56 kg (Bowen *et al.* 1992; Iverson *et al.* 1993; Baker *et al.* 1995). Males have been observed to be heavier at birth, grow faster and to be weaned at a greater mass (Baker *et al.* 1995), but this has not been observed in all studies (Bowen *et al.* 1992; Iverson *et al.* 1993).

In the Northwest Atlantic mean age for females giving birth for the first time is 5.5 y (sd=0.12). Reproductive rates for female grey seals using the presence or absence of a fetus are 0.18, 0.86 and 0.88 for females aged 4+, 5+ and > 6+ y. Among males a marked increase in testes weight is observed at age 3+ y. The mean age of physical sexual maturity is 5.6 y, and by age 7 virtually all males are sexually mature (Hammill and Gosselin, in press). However, animals do not appear to be able to hold tenure in the whelping patch until the age of 11-12 y (Godsell 1991).

Harwood and Prime (1978) reported from UK waters that 17% of grey seal females became pregnant at age four, 60% at age five, and the pregnancy rate was 90% for age six and older females. Grey seals examined by Harwood and Prime were sampled at the Farne Islands between 1972 and 1975. Boyd (1985) found that grey seal females in 1978-81 had their first pregnancy, on average, one year earlier. Boyd indicated that there may have been a decline in age at first pregnancy, alternatively that the difference between methods used by him and by Harwood and Prime (1978) have resulted in different estimates.

Little information was available on life history parameters from Iceland, the Faroe Islands and Norway.

4.5 Exploitation

Beginning in 1927, the Canadian government paid fishermen a bounty upon receipt of a harbour seal snout. In 1949, the system was changed to require presentation of the lower jaw before payment of the bounty. Since it is possible to identify the species by the lower jaw it became apparent that grey seals had been submitted in small numbers (Mansfield and Beck 1977). Between 1967 and 1984, the Department of Fisheries and Oceans conducted an annual cull at breeding colonies in the Gulf of St Lawrence and along the Nova Scotia eastern shore (Zwanenburg and Bowen 1990). From 1978 until 1990, a bounty was paid to licenced fishermen who submitted lower jaws from grey seals and information on date and location of capture. A total of 4,379 individuals were taken under the bounty program throughout its duration. Captures were initially quite high following introduction of the bounty program, but with the exception of a large number of returns in 1987 (753), declined steadily until 1990, when only 79 returns were received (Lavigueur and Hammill 1993).

In Iceland there is a directed hunt of grey seals. At earlier times grey seals were hunted, especially the pups for their skin, but also for their meat. Skins from grey seals have not been very valuable in Iceland in recent years, and hardly ever exported. Before 1982 records of number of seals killed were unreliable (SC/4/GS/5). In 1982 organizations of the fishing industry and fisheries in Iceland started promoting seal hunting, and since that time reliable information on catches is available (Anon. 1994).

Since 1982 shot grey seals have been utilized in food mixtures for fur-animals. The skin has been used in leather and garments. Some of the meat is also used for human consumption (SC/4/GS/5).

In UK waters a total catch of 16,501 and 4,527 grey seals were reported for the decades 1970-79 and 1980-89, respectively. Since 1990 a total of 45 has been reported taken (Anon. 1995). In Norway there is a hunting season from 1 December to 30 April in areas north of approximately 62°N. Hunting is known to occur (Haug *et al.* 1994), although no system is established to record effort or catch statistics in this hunt.

In the Faroe Islands fish-farmers are permitted to shoot seals near fish farms. According to Mikkelsen *et al.* (SC/4/GS/6) the number killed may be significant, and may have prevented the Faroese grey seal population from increasing over the last decade. Also in several other countries grey seals may be killed legally if they approach fish farms. Although numbers of seals shot in order to protect fish farms or standing fishing gear are believed to be significant in some areas, levels of such kills are virtually

unknown. By-catches of grey seals in fishing gear are known to occur. Return of tags indicates that seals less than one year of age are particularly vulnerable to entrapment in fishing gear (Bjørge and McConnell 1986). A total by-catch of 300 grey seals in 1994 is reported from the Baltic Sea population (Anon. 1995). In general, levels of by-catches of grey seals, and of other marine mammals species, are poorly documented.

4. 6 Conclusions and Recommendations

Outside the breeding season there is extensive overlap in distribution of grey seals from different breeding colonies. There is evidence of inter-annual site fidelity of sexually mature grey seals (Wiig and Øien 1988; McConnell *et al.* 1992; Pomeroy *et al.* 1994; Twiss *et al.* 1994). However, the degree of exchange of animals and genetic flow between breeding groups within the three populations of grey seal is not well studied, but some mixing between groups has been reported (Harwood *et al.* 1976). The Working Group appreciated the recent information on stock identity made available by analyses of mt DNA. The Working Group encouraged further sampling for genetic analysis and noted that frozen blood or skin samples are relevant for such analyses.

The Working Group **recommended** that samples are taken when live capture seals and shot samples or bycatches are available and advised a sample size of 20-30 animals from each breeding unit. Further, the Working Group **recommended** exchange of samples between laboratories on both sides of the Atlantic.

The distribution in space and time of foraging activity is essential for further understanding of the impact of grey seal on marine resources and the marine ecosystem. Such information can be obtained by pelage recognition programmes (Hiby 1995) and satellite tracking of free ranging seals. Where there are by-catches of grey seals in fishing operation, conventional flipper tags may also contribute to this knowledge. The Working Group **recommended** the use of satellite linked tags for further studies of distribution of grey seals at sea. The costs of satellite tags often limits the number of seals monitored. The Working Group therefore encourages any development of new, less expensive tags for long range telemetry.

Most abundance estimates are obtained from pup counts. The Working Group underlined the need for full descriptions of the methods used to obtain these estimates, of the statistical properties of the estimates and of actual and potential bias in the estimates. The Working Group **recommended** when possible multiple surveys and establishment of confidence limits with the estimates of pup production. When multiple surveys within years are not possible, the Working Group **advised** that well defined and described surveys may be used to establish an index of trend in pup production. The Working Group recognized the potential for photo-identification techniques to provide population estimates when or where pup production estimates cannot be estimated.

Population models show that seal populations in general are more sensitive to changes in mortality than to changes in fecundity rates. Changes in adult mortality have the largest impact on populations. Hunting mortality may be established from catch statistics, but such statistics are not always available, e.g. catches in the hunting season in northern Norway. The Working Group **recommended** further studies to investigate pup mortality, juvenile mortality, adult mortality, fecundity, age at first reproduction and growth parameters.

The Working Group refers to the hunting season for grey seals in Norway and **recommended** that a system for recording catch statistics is established as soon as possible. The Working Group further **recommended** that all countries having fishing operations within the range of the grey seal establish a system for obtaining and reporting by-catches of grey seals (and other marine mammals). Observer

schemes are regarded as the most reliable method to obtain by-catch information. Observer schemes, however, are expensive and difficult in practical terms in fisheries where a large number of small units are operating. The method for obtaining by-catch statistics should therefore be modified to match the respective fisheries. From a scientific point of view, it is important that methods used are well documented so that the statistical properties of by-catch estimates may be explored.

The grey seal hunt in Iceland is well documented. Since the fishing industry started their programme to augment the harvest in 1982, about half the pup production and an additional hunt of one year old and older seals are taken each year. Estimates of pup production and age samples of one year old and older seals are also available. This is an example where the annual hunt seems to have a significant and clearly detectable impact on the population size and trend. The Working Group **recommended** that the age distribution of this population is further studied if age samples become available, and that the effect of harvest on demography and population size is documented.

5. The role of the grey seal in the marine ecosystem

5.1 Food preference and consumption

5.1.1 Canadian waters

Over 40 different prey including many commercially important fish species have been identified in the diet of Northwest Atlantic grey seals (Benoit and Bowen 1990a). Like most pinnipeds, strong regional and seasonal changes in grey seal diet composition have been observed. In the northern Gulf of St Lawrence capelin (*Mallotus villosus*) lumpfish (*Cyclopterus lumpus*), herring (*Clupea harengus*), and cod (*Gadus morhua*) are the most important prey species accounting for over 60% of the diet by frequency of occurrence (Benoit and Bowen 1990b; Murie and Lavigne 1992; Proust 1996). Seasonal changes in diet are evident with capelin and lumpfish being important prey during the period May to July, with cod and herring becoming the dominant prey species during August and September (Benoit and Bowen 1990b; Proust 1996). In the southern Gulf of St Lawrence cod, herring and flatfish were the most important prey (Benoit and Bowen 1990a). In grey seals collected from the Atlantic side of Nova Scotia and Sable Island consumed cod, herring, hake (*Merluccius bilinearis*), sand lance (*Ammodytes dubius*) and flatfish (*Pleuronectiformes*) formed the most important prey (Bowen *et al.* 1993; Bowen and Harrison 1994). Near Sable Island sand lance, although an important component of the diet throughout the year, account for a greater percentage of the diet by weight during the winter than during summer. Cod and silver hake were consumed primarily during the late summer when these species move into the shallower water over the offshore banks surrounding Sable Island (Bowen and Harrison 1994). Some differences between nearshore diets and the offshore diets of animals from around Sable Island have also been noticed (Bowen and Harrison 1994). In grey seals collected from the Eastern Shore of Nova Scotia, herring and mackerel (*Scomber scombrus*) (Bowen *et al.* 1993) replaced sand lance and flatfishes as important foods.

Several studies have observed that grey seals feed primarily on fish <40 cm in length, which for most species represent size ranges too small for the commercial fishery (Benoit and Bowen 1990b; Murie and Lavigne 1992; Bowen *et al.* 1993; Bowen and Harrison 1994; Proust 1996). Some notable differences have been observed between studies or within studies between years. For example Bowen *et al.* (1994) observed that grey seals consumed larger herring during the fall on the Scotian shelf (mean length=34.5 cm) than did grey seals feeding on herring during summer in the northern Gulf (mean length=24.9)(Benoit and Bowen 1990b). More recently Proust (1996) observed that grey seals feeding on cod in a sample obtained in 1988 had a mean length of 32.1 cm, while cod consumed in a sample obtained in 1992 had a mean length of 39.6 cm. These differences in the length-frequency distributions

of prey consumed may be related to the relative abundance of particular year classes in the population (Proust 1996).

The possibility of competition between marine mammals and fisheries often generates considerable controversy with fishers on one side of the debate and environmental groups on the other (Hammill *et al.* 1995). Historically, this competition has been of limited importance because many species of marine mammals were harvested for food or other commercial purposes. However, during the last 20 years, there has been a marked shift in public attitudes towards harvesting of marine mammals, resulting in a dramatic decline in the demand for their products. Consequently, harvests have declined, and many populations appear to be increasing. Also, since both fishers and marine mammals often "forage" in the same area, marine mammals are perceived as having a negative impact on commercial fisheries (Hammill *et al.* 1995).

In order to estimate total fish consumption, information is required on the size, structure and dynamics of the seal population, the geographical and temporal distribution of animals, individual energy requirements, and diet composition. Consumption of Atlantic cod by the Northwest Atlantic grey seal has recently been examined for the Scotian shelf and Gulf of St Lawrence (Mohn and Bowen 1994; Hammill *et al.* 1995). Depending on model assumptions (Hammill *et al.* 1995), particularly assumptions concerning the seasonal distribution of the grey seal population in Atlantic Canada, cod consumption has increased from less than 4,000 tons in the Gulf of St Lawrence and 1,500 tons on the Scotian Shelf in 1970 to nearly 40,000 tons in 1993, including 17,000 tons in the Gulf of St Lawrence and 17,000 tons on the Scotian Shelf and 4,000 tons in other areas throughout Atlantic Canada (Hammill and Mohn 1994; Hammill *et al.* 1995). Owing to low biomass estimates, the cod fishery in Atlantic Canada has been closed since 1992.

Thus in relative terms the consumption of 40,000 t of cod by grey seals is significant compared to current harvests by the industry. The impact of this consumption on the recovery of Northwest Atlantic cod stocks is difficult to assess, since >80% of this consumption would be prerecruits to the commercial fishery and it is likely that some compensatory mortality occurs which would reduce the magnitude of this impact. Recently, Mohn and Bowen (1994) have attempted to assess the impact of grey seal consumption of cod on the Scotian shelf, but these efforts have been hampered by the lack of information on natural mortality rates of juvenile cod.

5.1.2 Icelandic Waters

The most prominent (% occurrence) prey species found in the stomach of grey seals in Icelandic coastal waters are lumpsucker, the common spider crab (*Hyas sp*), catfish, cod, the hermit crabs (*Eupagurus sp.*) and bull-rout, but several other fish species were recorded. During the feeding season from January-September, grey seals feed mostly on cod, lumpsucker, sand eel and catfish. Sand eel is the dominant species at the south coast while lumpsucker, cod and catfish dominate in all other areas of Icelandic coastal waters (SC/4/GS/5).

In the breeding season, sand eel still dominates at the south coast, while bull-rout, spider crabs, sand eel and cod are important in northwest, and cod dominates in the northeast (SC/4/GS/5).

5.1.3 Faroese waters

Mikkelsen *et al.* (SC/4/GS/6) reported that diet composition varied between sampling sites in the Faroe Islands. At Svínoy (n=13) in the northeast cod dominated the diet and other gadid species were frequent. At Sandoy (n=14), wolffish (*Anarchicas lupus*) was the most frequent species, closely followed by

lemon sole (*Microstomus kitt*). Off Mykines (n=13) at the western point of the Faroe Islands, sandeel dominated the diet.

5.1.4 UK waters

The Sea Mammal Research Unit has studied the diet of grey seals around the UK coast for over 10 years by analysis of hard remains in faecal sample found on haul-out sites. During the last three years studies have concentrated on the assessment of diet at the Farne Islands, in the North Sea, during the summer months. The following descriptions of the diet and food consumption patterns are extracted from SMR, cited in SC/4/GS/9.

Grey seal faeces were collected from haul-out sites in the Inner and Outer Hebrides, Orkney Islands, Fair Isle, Loch Erribol and Helmsdale on the northern Scottish mainland, Isle of May and Farne Islands and at Donna Nook on the English east coast. Stomach and large intestine samples were collected by stomach lavaging and rectal enema at the Farne Islands during summer 1992.

The methods of processing and analysis of the faecal samples and the subsequent estimation of the proportion of each species in the diet have been fully described in Prime and Hammond (1987; 1990). Hard parts were extracted by passing the samples through 0.4 mm sieves under running water. All fish otoliths and cephalopod beaks were identified to species (except sandeels (Ammodytidae) which were simply identified as such) using an extensive reference collection and identification guide (Härkönen 1986). Thickness, length and width of each otolith were measured to 0.01 mm. Thickness only was used for sandeels.

Species specific digestion coefficients obtained from a series of feeding trials (Prime & Hammond 1987) were used to estimate undigested otolith size. Fish weights were estimated using empirical fish weight to otolith dimension relationships (Prime & Hammond 1987). Digestion coefficients and fish length/weight to otolith thickness relationships for all species examined are given in Prime & Hammond (1990) and Hammond *et al.* 1994 (cited in SC/4/GS/9).

In Orkney and north-eastern Scotland sandeels were the most important item in the diet, accounting for almost half the fish consumed by weight except in the east of the region in February. The rest of the diet comprised mainly larger gadid species (particularly cod (*Gadus morhua*) and ling (*Molva molva*)) and flatfish (particularly plaice (*Pleuronectes platessa*)). Sandeels were more prevalent in February and in the summer than in November. No significant regional or seasonal differences were found in the number of cod, haddock (*Melanogrammus aeglefinus*) or saithe (*Pollachius virens*) consumed. Whiting (*Merlangius merlangus*) were important in November in the south of the region and ling were the dominant gadid in the north and west in February and in the west and east in November.

In the Inner and Outer Hebrides gadids predominated in the diet. They contributed approximately 40% or more of the diet by weight. The most abundant gadid species were ling, cod and whiting. The dominant gadid species varied by area and season. E.g. in the Monach Isles ling were important in January and June, cod were important in June and November, and whiting were important in August and November.

Flatfish were a major part of the diet, especially in the Outer Hebrides. Again the dominant species varied between areas and seasons. Sandeels were less important in the western isles than in any other region of the UK. Interestingly, pelagic schooling fish including mackerel (*Scomber scomberus*), herring (*Clupea harengus*) and horse mackerel (*Trachurus trachurus*) were more important than in other regions.

At the Isle of May the samples were restricted to the pupping season and February. Again cod and sandeels dominated the diet, accounting for over 70% of the prey consumed. Cod was the most important component of the diet, accounting for 35-64% of the November/December diet each year. There were large between year fluctuations in the importance of sandeels, from 0.6 to 40%.

At the Farne Islands the diet during the pupping season was also dominated by sandeels (mean=54.1%) and cod (29.9%). Unlike at the Isle of May there was little variation in the percentage of sandeels or cod between years. During the spring there was more variability, with sandeels (20%) and cod (34%) again being important, but whiting (23%) being the dominant species in 1983.

The summer diet at the Farne Islands has been assessed from gut contents of seals shot in 1981 and stomach and large intestine washout samples collected in 1992. Again sandeels and gadids were the predominant constituents of the diet, accounting for over 90% in both years. The large intestine samples in the two years were similar, 67-69% sandeels and 27-29% gadids.

In the south of the grey seal range in the North Sea, represented by samples from Donna Nook, the diet consisted mainly of sandeels (26.4%), gadids (particularly cod (17.6%)) and flatfish (particularly Dover sole (12.2%)).

The relative importance of each prey species varied through the year. Initially roundfish, especially cod and sandeels, predominated. During the spring flatfish were the dominant food items accounting for around 60% of the diet. During the summer and autumn sandeels dominated, with flatfish in early summer and roundfish in late summer-autumn. By December sandeels had disappeared and the diet was 70% flatfish.

These data show that a small number of species form the core of the diet of grey seals in British waters. In all areas sandeels and large gadids accounted for over 70% of the diet by weight, except at Donna Nook where they made up only 50%. At all the major grey seal concentrations a reduction in the sandeel percentage was compensated by an increase in the gadoid percentage. The dominant gadoid was cod except in the Hebrides where ling were important.

Hammond, Hall and Rothery (1995 - cited in SC/4/GS/9) carried out an assessment of the annual consumption of fish by the North Sea grey seal population and compared this to the commercial catch. Because the diet varies both geographically and seasonally it is appropriate to stratify estimates of consumption by area and season and to sum across seasons to estimate annual consumption for each area. For each area data on the percentage by weight of each prey species were combined with seasonal estimates of seal numbers, seal energy requirements and fish energy densities to estimate annual consumption of each major prey species.

Grey seals consume a wide range of prey sizes, including many small fish, so it is appropriate to consider consumption in relation to total stock biomass. A direct comparison shows that typically grey seals' consumption is around two orders of magnitude less than stock biomass for any species. In the worst case cod consumption upper 95% confidence limit is around 6% of the lowest cod stock biomass estimate in the last decade. Sandeels and cod are the two most important species by mass in the grey seal diet. The consumption over biomass (average biomass between 1983-92) was 36,130 tons/2,050,000 tons and 10,464 tons/428,000 tons for sandeel and cod, respectively.

Although annual removals of fish biomass by seals are small on a North Sea wide scale, there may be local areas where fish consumption by seals is more important. The concentration of seal foraging in small areas supports this suggestion (McConnell *et al.* 1992).

5.2 Recommendations

The Working Group underlined the significance of information on distribution of foraging activity in space and time when the role of marine mammals in the ecosystem is to be evaluated. In order to monitor the movements, the Working Group **recommended** further studies using satellite tags on grey seal. Where possible these should be combined with studies of diet and food availability. The Working Group further **recommended** that when diet studies are based entirely on either shot samples or fecal samples, attempts should be made to calibrate the method by comparing ingestion and excretion of identifiable prey in captive seals. The Working Group noted the limited data on population size, diet and foraging behaviour of grey seals in Norway and **recommended** that such studies be undertaken.

6. Grey seals as a source of nematodal infestation in fish

6.1 Review of parasitic nematodes transferred from seals to fish

Four species of anisakine nematodes with fish as intermediate hosts occur in the stomach or intestine of grey seals (e.g. Scott and Fisher 1958; Templeman 1990; SC/4/GS/5). The most abundant is *Pseudoterranova decipiens*, the cod worm, but *Anisakis simplex*, *Contracoecum osculatum*, *Phocascaris cystophora* are common in several areas. The three first species occur in the stomach cavity while *P. cystophorae* occurs in the pyloric caeca close to the junction to the stomach.

Recently, enzyme electrophoresis and other methods of molecular taxonomy have show that *A. simplex* is composed of two sibling species, *P. decipiens* of three and *C. osculatum* of three sibling species (Berland and Fagerholm 1994). The sibling species A of *P. decipiens* dominates in the Northwest Atlantic. In the Northeast Atlantic sibling species B dominates in grey seals while A dominates in harbour seals.

The larval stages of *P. decipiens* penetrate the intestine and infest the muscle of the fish. The easily visible, up to c. 50mm long worm strongly reduces the commercial value of fish fillets, is an important problem to fish industry in areas where infestation is high (e.g. Bjørge *et al.* 1981; Templeman 1990). The *P. decipiens* is therefore discussed in more detail below.

6.2 Population biology of the Pseudoterranova decipiens

The *Pseudoterranova decipiens* attain sexual maturity in the stomach of seals and in particular in grey seals (e.g. Templeman 1990; McClelland *et al.* 1990; Bjørge *et al.* 1981). The partly embryonated ova are passed with faeces into sea water. The embryonated ova have a slightly negative buoyancy and the freshly hatched, still ensheated small larvae adhere to the substrate by a caudal extremity. In the next step the small larvae are found in haemocoel of benthic copepods and in e.g. amphipods and isopods. Still small larvae then occur in body cavities and musculature of of benthophagus fish. Larger larvae occur in the body cavities and musculature of benthic piscivore fish. The final larval stage of the parasite then enters into the stomach of the final host i.e. piscivore mammals and the *P. decipiens* matures and completes the life cycle (Bjørge 1979; McClelland 1990; McClelland *et al.* 1990).

6.3 Abundance of Pseudoterranova decipiens in grey seals and other mammals

Although there are four species of pinnipeds found throughout Atlantic Canada, the grey seal is the most important as a vector for the nematode *P. decipiens*, known also as codworm or sealworm (Mansfield and Beck 1977). Sexually mature worms have been found in grey seals as young as 3-4 months of age. Worm burdens are linked to size with males carrying heavier burdens than females owing to their larger size (Stobo *et al.* 1990). Seasonal changes in sealworm burdens have been observed, with declines

observed during the breeding season, probably as a result of animals fasting and a second decline observed in late summer. This decline may be linked to a change in diet as grey seals switch to prey with lower infection levels (Stobo *et al.* 1990).

In Iceland, the prevalence of *P. decipiens* in grey seals was 100% in all areas and seasons, but the mean abundance varied from 160 worms (n=15, se=57) at the south coast in October, to 3,972 worms (n=24, se=974) at the northwest coast in October. At the northwest coast the abundance of codworm in summer numbers some hundred worms per seal, and the increase in abundance in October may be linked to a change in diet. During the breeding season in October the grey seals feed on heavily infested sculpins (38% frequency of occurrence) (SC/4/GS/5).

6.4 Abundance and prevalence of Pseudoterranova decipiens in fish

Although codworm is considered to be mildly pathogenic if consumed in raw or poorly cooked fish, the major impact is considered to be a cosmetic one, with high infections rendering fish unappealing to consumers. The cost of removing larvae from cod fillets alone were estimated to be in excess of $29 million in Atlantic Canada in 1982 (Bowen 1990).

Surveys conducted during the 1950s indicated that sealworm was found in the fillets of groundfish throughout Atlantic Canada, but the heaviest infections were limited to cod from the southern Gulf of St Lawrence, and inshore areas of southwestern Newfoundland, Nova Scotia and the Bay of Fundy (McClelland *et al.* 1985). Surveys conducted during the mid 1980s indicated that sealworm levels had increased in many regions throughout the Gulf of St Lawrence and Nova Scotia, particularly in the Miramichi area of the Gulf of St Lawrence and the Sable Island area of the Scotian Shelf (McClelland *et al.* 1985). Further increases in worm burdens have been observed in the Gulf of St Lawrence between the 1983 samples from McClelland *et al.* (1985) and samples collected in 1990 (Boily and Marcogliese 1995). These increases are believed to be linked to increases in the grey seal population that has been observed since the 1970s. However, high geographical and temporal variability in sealworm levels may be linked not only to the distribution of definitive hosts such as seals, but also to other factors such as variability in water temperatures (Boily and Marcogliese 1995). Surveys completed to determine nematode abundance among grey seals have shown that mean burdens have increased from 158-700 nematodes per seal between 1948-1956 (Scott and Fisher 1958 in Marcogliese and Boily submitted) to >1000 in 1990 (Marcogliese and Boily submitted). However, a decline in sealworm abundance and an increase in the abundance of the nematode *Contracaecum osculatum* have been observed in samples collected in the Gulf between 1988 and 1992 and it has been suggested that the recent cooling in the cold intermediate layer of the Gulf of St Lawrence may have had a positive effect on the abundance of *C. osculatum* at the expense of sealworm (Marcogliese and Boily submitted).

No significant change has been observed in *P. decipiens* abundance in cod from coastal waters of Iceland between 1980 and 1990 (SC/4/GS/5). The highest abundance of *P. decipiens* was recorded in sculpins at the west coast (n=71, 95.2 worms per fish, range 9-448). In this sample there were an average of 34 worms per 100 g fish (SC/4/GS/5).

In Norway, however, considerable variations between areas and years were observed for *P. decipiens* burden in cod (Haug *et al.* 1991). The abundance ranged from 0 to 70 parasites per fish. Close to a major grey seal haul-out mean abundance of 21 worms per fish was recorded (n=43, sd=18.6).

6.5 Recommendations

The complex life cycle of sealworm will complicate any attempt to control infestation levels in fish. Seven major areas requiring further research have been identified (Marcogliese and McClelland 1994). Based on this list and further discussions in the Working Group, the Working Group **recommended** that the following topics be given priority:

1) Establish time series of data on seal diet and levels of sealworm infestation in fish populations in the same areas;

2) Determine whether worm size and/or worm fecundity in seals are dependent on parasite densities;

3) Determine the importance of small benthophagus fish in the life cycle of the parasite, with special emphasis on sculpins;

4) Determine the longevity of sealworm and host response in important seal prey species;

5) Determine distribution and abundance of the sealworm in the macro invertebrate hosts;

6) Investigate further the role of temperature on sealworm transmission and development;

7) Determine whether infection of sealworm in fish produces behavioural modifications which facilitate transmission to seals.

List of documents

SC/4/GS/3 A. Bjørge, Grey seals in Scandinavian and adjacent waters

SC/4/GS/5 E. Hauksson, Studies on the Icelandic grey seal; population status, food preference, interactions with fisheries and a source for nematode infection in fish

SC/4/GS/6 B. Mikkelsen, Summer diet of grey seals (*Halichoerus grypus*) in the Faroe Islands

SC/4/GS/7 M. Hammill, The Status of the Grey Seal in the Northwest Atlantic

SC/4/GS/8 D. Thompson. Size and status of the British grey seal population

SC/4/GS/9 D. Thompson. Diet of grey seals in British waters

References

Anon. 1994. State of the marine stocks in Icelandic waters 1993/94. *Fisheries Prospects 1994/95.* Marine Research Institute, Reykjavik.

Anon. 1996. Report of the ICES Study Group on seals and small cetaceans in European Seas. Cambridge, UK, 4-6 December 1995. ICES CM 1996/N:1. 20 pp + tables 33 pp.

Baker, S.R., Barrette, C. and Hammill, M.O. 1995. Mass transfer during lactation of an ice-breeding Pinniped, the grey seal (*Halichoerus grypus*), in Nova Scotia, *Canada. J. Zool.* 236: 531-542.

Benoit, D. and Bowen, W.D. 1990a. Seasonal and geographical variation in the diet of grey seals (*Halichoerus grypus*) in Eastern Canada. Pp 215-226 in W.D. Bowen (ed). Population biology of sealworm (*Pseudoterranova decipiens*) in relation to its intermediate and seal hosts. *Can. Bull. Fish.Aquat. Sci.* No 222. 306 pp.

Benoit, D. and Bowen, W.D. 1990b. Summer diet of grey seals (*Halichoerus grypus*) at Anticosti Island, Gulf of St Lawrence, Canada. Pp 227-242 in W.D. Bowen (ed). Population biology of sealworm (*Pseudoterranova decipiens*) in relation to its intermediate and seal hosts. *Can. Bull. Fish. Aquat. Sci.* No 222. 306 pp.

Berland, B. and Fagerholm, H.P. 1994. Thirthy years of anisakid research, and future trend. *Bull. Scand. Parasitol.* 4 (2): 40-46.

Bjørge, A.J. 1979. An isopod as intermediate host of cod-worm. *Fisk Dir. Skr. Ser. Hav Unders.* 16: 561-565.

Bjørge, A. 1995. Comparative habitat use and foraging behaviour of harbour seals and grey seals in western Norway. ICES C.M. 1995/ N:1. 13 pp.

Bjørge, A., Christensen, I. and Øritsland, T. 1981. Current problems and research related to interactions between marine mammals and fisheries in Norwegian coastal and adjacent waters. ICES C.M. 1981/N:18.

Bjørge, A, and McConnell, B. 1986. Recoveries in Norway of grey seals, *Halichoerus grypus*, tagged in Great Britain. *Fisken Hav.*, 1986(2): 1-8.

Boily, F. and Marcogliese, D.J. 1995. Geographical variations in abundance of larval anisakine nematodes in Atlantic cod (*Gadus morhua*) and American plaice (*Hippoglossoides platessoides*) from the Gulf of St Lawrence. *Can J. Fish. Aquat. Sci.* 52: 105-115.

Boskovic, R., Kovacs, K.M., Hammill, M.O., and White, B.N. (in manuscript). Geographic distribution of mitochondrial DNA haplotypes in grey seals (*Halichoerus grypus*). Submitted, *Can. J. Zool.*

Bowen, W.D. 1990. General intoduction. Pp vii-viii in W.D. Bowen (ed). Population biology of sealworm (*Pseudoterranova decipiens*) in relation to its intermediate and seal hosts. *Can. Bull. Fish. Aquat. Sci.* No 222. 306 pp.

Bowen, W.D., Lawson, J.W. and Beck, B. 1993. Seasonal and geographic variation in the species composition and size of prey consumed by grey seals (*Halichoerus grypus*) on the Scotian Shelf. *Can. J. Fish. Aquat. Sci.* 50: 1768-1778.

Bowen, W.D. and Harrison, G.D. 1994. Offshore diet of grey seal *Halichoerus grypus* near Sable Island, *Canada. Mar. Ecol. Prog. Ser.* 112: 1-11.

Bowen, W.D., Stobo, W.T. and Smith, S.J. 1992. Mass changes of grey seal *Halichoerus grypus* on Sable Island: Differential maternal investment reconsidered. *J. Zool.* 227: 607-622.

Boyd, I.L. 1985. Pregnancy and ovulation rates in grey seals (*Halichoerus grypus*) on the British coast. *J. Zool.* 205: 265-272.

Clay, D. and Nielsen, G. 1985. Grey seal (*Halichoerus grypus*) distribution during 1983/84 in the Gulf of St Lawrence as observed by arial survey. *Can. Ms. Rep. Fish. Aquat. Sci.* No 1836. 8pp.

Godsell, J. 1991. The relative influence of age and weight on the reproductive behaviour of male grey seals, *Halichoerus grypus. J. Zool.*224: 537-551.

Hammill, M.O. and Mohn, B.O. 1994. A model of grey seal predation on Atlantic cod on the Scotian Shelf and Gulf of St Lawrence. DFO Atl. Fish. Res. Doc 94/75. 25 pp.

Hammill, M.O., Ryg, M.S. and Mohn, B. 1995. Consumption of cod by the Northwest Atlantic grey seal in eastern Canada in A.S. Blix, L. Walløe and Ø. Ulltang (eds). *Whales, seals, fish and man.* Elsevier, Amsterdam: 337-349..

Hammill, M.O. and Gosselin, J.F. (in press). Female reproductive rates, age at first birth, and age of maturity in male grey seals (*Halichoerus grypus*) from the northwest Atlantic. *Can. J. Fish. Aquat. Sci.*

Hammill, M.O., Stenson, G., Myers, R.A. and Stobo. W. (in manuscript). Population trends of the grey seal (*Halichoerus grypus*) in the Gulf of St Lawrence. Submitted, *Can. J. Fish. Aquat. Sci.*

Härkönen, T. 1986. *Guide to the otoliths of bony fishes of the northeast Atlantic.* Danbiu ApS, Hellerup. 256 pp.

Harwood, J., Anderson, S.S. and Curry, M.G. 1976. Branded grey seals (*Halichoerus grypus*) at the Monach Isles, Outer Hebrides. *J. Zool.* 180: 506-508.

Harwood, J. and Prime, J. 1978. Some factors affecting the size of British grey seal populations. *J. appl. Ecol.* 15: 401-411.

Haug, T., Henriksen, G., Kondakov, A., Mishin,V., Nilssen, K.T. and Røv, N. 1994. The status of grey seals *Halichoerus grypus* in North Norway and on the Murman coast, *Russia. Biol. Conserv.* 70: 59-67.

Haug, T., Henriksen, G., Nilssen, K.T. and Ørjebu, A. 1991. Recent studies of the distribution and abundance of grey seal *Halichoerus grypus* in North Norway, and their possible influence on parasitic infestations in fish.ICES CM 1991/N:2.21 pp.

Hiby, L. 1995. The use of automated pattern matching in a demographic study of grey seals. Abstract, Eleventh Biennial Conference on the Biology of Marine Mammals. Orlando, Dec. 1995.

Hiby, L., Duck, C. and Thompson, D. (in manuscript). The use of aerial photography to monitor pup production of grey seals (*Halichoerus grypus*) in Scotland. Submitted, *J. Appl. Ecol.*

Hiby, A.R., Thompson, D. and Ward, A.J. 1988. Census of grey seals by aerial photographs. *Photogram. Rec.* 12: 589-594.

Iverson, S.J., Bowen, W.D., Boness, D.J. and Oftedal, O.T. 1993. The effect of maternal size and milk energy output on pup growth in grey seals (*Halichoerus grypus*). *Physiol. Zool.* 66: 61-88.

Johannesen, Ó.G. 1976. Kópaveiða i Dali. *Mondul* 1976(2): 7-9.

Katona, S.K., Rough, V. and Richardson, D.T. 1993. *A field guide to whales, porpoises and seals from Cape Cod to Newfoundland.* Smithsonian Institute, Washington DC. 316 pp.

Landt, J. 1800. Om Sælhundefangst.in *Forsøk til en beskrivelse over Færøerne.* Tidsjob Forlag, Københavh:214-16.

Lavigueur, L. and Hammill, M.O. 1993. Distribution and seasonal movements of grey seals, *Halichoerus grypus*, born in the Gulf of St Lawrence and eastern Nova Scotia shore. *Can. Field Nat.* 107: 329-340.

Marcogliese, D.J. and Boily, F. (in manuscript). Distribution and abundance of stomach nematodes among grey seals (*Halichoerus grypus*) in the Gulf of St Lawrence. Submitted, *Can. J. Fish. Aquat. Sci.*

McClelland, G., Misra, R.K. and Martell, D.J. 1985. Variations in abundance of larval Anisakines, sealworm (*Pseudoterranova decipiens*) and related species in eastern Canadian cod and flatfish. *Can. Tech. Rep. Fish. Aquat. Sci.* No 1392. 57 pp.

McClelland, G., Misra, R.K. and Martell, D.J. 1990. Larval anisakine nematodes in various fish species from Sable Island Bank and vicinity, in W.D. Bowen (ed). Population biology of sealworm (Pseudoterranova decipiens) in relation to its intermediate and seal hosts. *Can. Bull. Fish. Aquat. Sci.* No 222:83-118.

McConnell, B.J., Chambers, C., Nicholas, K.S. and Fedak, M.A. 1992. Satellite tracking of grey seals (*Halichoerus grypus*). *J. Zool.* 226:271-282.

Mansfield, A.W. and Beck, B. 1977. Grey seals in eastern Canada. *Fish. Mar. Serv. Tech. Rep.* No 704. 81 pp.

Marcogliese, D.J. and McClelland, G. 1994. The status of biological research on sealworm (*Pseudoterranova decipiens*) in eastern Canada. *Can. Ms. Rep. Aquat. Sci.* 2260. viii + 26 pp.

Mohn, R. and Bowen, W.D. 1994. A model of grey seal predation on 4VSW cod and its effects on the dynamics and potential yield of cod. DFO Atl. Fish.Res. Doc.94/75. 25 pp.

Murie, D.J. and Lavigne, D.M. 1992. Growth and feeding habits of grey seals (*Halichoerus grypus*) in the northwestern Gulf of St Lawrence, Canada. *Can.J. Zool.* 70: 1604-1613.

Nicholas, K.S., Fedak, M.A. and Hammond, P.S. 1992. An automatic recording station for detecting and storing radio signals from free ranging animals. In I.G. Priede & S.M. Swift (eds). *Wildlife Telemetry: remote monitoring and tracking of animals.* Ellis Horwood. Chichester:76-78

Pomeroy, P.P., Anderson, S.S., Twiss, S.D. and MocConnell, B.J. 1994. Dispersion and site fidelity of breeding female grey seals (*Halichoerus grypus*) on North Rona, Scotland. *J. Zool.* 233: 429-447.

Preust, F. 1996. Composition du regime alimebtaire du phoque gris (Halichoerus grypus) dans le Golfe du Saint-Laurent, Quebec, Canada. Memoire de Maitrise Presente a l'UniversitÚ du Quebec a Rimouski.

Prime, J.H. and Hammond, P.S. 1987. Quantitative assessment of grey seal diet from faecal analysis. In A.C. Huntley, D.P. Costa, G.A.J. Worthy and M.A. Castellini (eds). *Approaches to Marine Mammal Energetics.* Society of Marine Mammalogy, Special Publication No 1. Allen Press, Lawrence:161-181

Prime, J.H. and Hammond, P.S. 1990. The diet of grey seals from the southwestern North Sea assessed from analyses of hard parts found in faeces. *J. appl. Ecol.* 27: 435-447.

Reinert, A. 1982. Havert omkring Færøerne. In A. Nørrevang and J. Lundø (eds). *Danmarks Natur. Færøerne*, 12: 55-58

Scott, D.M. and Fisher, H.D. 1958. Incidence of the ascarid *Porrocaecum decipiens* in the stomachs of three species of seals along the southern Canadian Atlantic mainland. *J. Fish. Res. Bd Can.* 15: 495-516.

Sjøberg, M., Hunter, C., McConnell, B.J. and Fedak, M.A. 1993. Movements, diving behavior of grey seal (*Halichoerus grypus*) in the Baltic. Abstract, Tenth Biennial Conference on the Biology of Marine Mammals. Galveston, Texas, Nov. 1993.

Stobo. W.T., Beck, B. and Fanning, L. 1990. Seasonal sealworm (*Pseudoterranova decipiens*) abundance in grey seals (*Halichoerus grypus*). In W.D. Bowen (ed). Population biology of sealworm (*Pseudoterranova decipiens*) in relation to its intermediate and seal hosts. *Can. Bull. Fish. Aquat. Sci.* No 222: 147-162

Stobo, W.T. and Zwaneneburg, K.C.T. 1990. Grey seal (*Halichoerus grypus*) pup production on Sable Island and estimates of recent production in the northwest Atlantic. In W.D. Bowen (ed). Population biology of sealworm (*Pseudoterranova decipiens*) in relation to its intermediate and seal hosts. *Can. Bull. Fish. Aquat. Sci.* No 222: 171-184

Stobo, W.T., Beck, B. and Horne, J.K. 1990. Seasonal movements of grey seals (*Halichoerus grypus*) in the northwest Atlantic. In W.D. Bowen (ed). Population biology of sealworm (*Pseudoterranova decipiens*) in relation to its intermediate and seal hosts. *Can. Bull. Fish. Aquat. Sci.* No 222: 199-213

Templeman, W. 1990. Historical background to the sealworm problem in eastern Canadian waters. In W.D. Bowen (ed). Population biology of sealworm (*Pseudoterranova decipiens*) in relation to its intermediate and seal hosts. *Can. Bull. Fish. Aquat. Sci.* No 222: 1-16.

Twiss, S.D., Pomeroy, P.P. and Anderson, S.S. 1994. Dispersion and site fidelity of breeding male grey seals (*Halichoerus grypus*) on North Rona, Scotland. *J. Zool.* 233: 683-693.

Wiig, Ø. and Øien, N. 1987. Recoveries of grey seal *Halichoerus grypus (Fabricius)* tagged along the Norwegian coast. *Fauna norv.*, Ser. A, 8: 39-42.

Zwanenburg, K.C.T. and Bowen, W.D. 1990. Population trends of the grey seal (*Halichoerus grypus*) in Eastern Canada. In W.D. Bowen (ed). Population biology of sealworm (*Pseudoterranova decipiens*) in relation to its intermediate and seal hosts. *Can. Bull. Fish. Aquat. Sci.* No 222: 185-197.

Appendix 1

List of Participants

Dorete Bloch
Museum of Natural History
Fútalág 40
FR-100 Tórshavn, Faroe Islands
Tel.: +298 18588
Fax: +298 18589
Email: doreteb@ngs.fo

Arne Bjørge (Chairman)
NINA, P.O.Box 736, sentrum
N-0315 Oslo, Norway
Tel.: +47 22 94 03 71
Fax: +47 22 94 03 01
Email: arne.bjørge@bio.uio.no

Mike Hammill
Department of Fisheries & Oceans
P.O. Box 1000, Mont Joli (Quebec)
G5H 3Z4 Canada
Tel.: +1 418 775 0580
Fax: +1 418 775 0542
Email: m_hammill@am.qc.dfo.ca

Tore Haug
Norwegian Institute of
Fisheries and Aquaculture
P.O.Box 2511,
N-9037 Tromsø, Norwau
Tel.: 77 62 92 20
Fax: 77 62 91 00
Email: toreh@fiskforsk.norut.no

Erlingur Hauksson
Icelandic Fisheries Laboratories
Skúlagata 4
IS-101 Reykjavik, Iceland
Tel.: +354 56 20240
Fax: +354 56 20740
Email: erlingur@rfisk.is

Bjarni Mikkelsen
Norwegian Institute of
Fisheries and Aquaculture
P.O.Box 2511,
N-9037 Tromsø, Norwau
Tel.: 77 62 92 20
Fax: 77 62 91 00

Nils Øien
Institute of Marine Research
P.O.Box 1870,
N-5024 Nordnes, Bergen
Tel.: +47 55 23 86 05
Fax: +47 55 23 83 87
Email: nils@imr.no

Jóhann Sigurjónsson
Marine Research Institute
P.O.Box 1390
IS-121 Reykjavik, Iceland
Tel.: +354 55 20240
Fax: +354 5 623790
Email: johann@hafro.is

David Thompson
Sea Mammal Research Unit
c/- British Antarctic Survey
High Cross, Madingley Road
Cambridge, CB3 0ET
UK
Tel.: +44 1223 311354
Fax: +44 1223 328927
Email: DTH@wpo.nerc.ac.uk