3.2
REPORT OF THE SCIENTIFIC COMMITTEE WORKING GROUP ON THE ROLE OF MINKE WHALES, HARP SEALS AND HOODED SEALS IN NORTH ATLANTIC ECOSYSTEMS

1.-3. OPENING PROCEDURES

At its Sixth Meeting in Tromsø, March 1996, the Council requested that the Scientific Committee:

A...focus its attention on the food consumption of three predators in the North Atlantic: the minke whale, the harp seal and the hooded seals, with a particular emphasis on the study of the potential implications for commercially important fish stocks≅

As a result, the Scientific Committee decided to convene a special Working Group on the Role of Minke Whales, Harp Seals and Hooded Seals in the North Atlantic (SC/5/ME), during the 1997 Scientific Committee meeting. The Working Group was chaired by Gísli Víkingsson (Iceland) and included scientists from Canada, Denmark, Greenland, Iceland, and Norway. A list of participants is given in Appendix 1.

The Agenda for the Working Group as given in Appendix 2 was adopted. Pia Barner Neve (Greenland) and Garry Stenson (Canada) agreed to act as rapporteurs. A list of documents presented and references is given in Appendix 3.

4. FEEDING ECOLOGY IN THE NORTH ATLANTIC

4.1 North East Atlantic

4.1.1 Minke whale

SC/5/ME/4 presented current information on the energy requirements, diet composition, and stock size of minke whales *(Balaenoptera acutorostrata)* in northeast Atlantic waters. These were combined to estimate the consumption of various prey species by this stock.

The distribution pattern and abundance estimate were based on a survey conducted in 1995. A total of 85,000 minke whales that feed in coastal waters off northern Norway, in the Barents Sea and around Spitsbergen, were estimated to consume more than 1.8 million tons of prey biomass during the six months from mid-April to mid-October.

This biomass consumed by minke whales was composed of 602,000 tons of krill *(Thysanoessa* spp.), 633,000 tons of herring *(Clupea harengus)*, 142,000 tons of capelin *(Mallotus villosus)*, 256,000 tons of cod *(Gadus morhua)*, 128,000 tons of haddock *(Melanogrammus aeglefinus)*, and 55,000 tons of other fish species, including sand eel (*Ammodytes* sp.) and saithe *(Pollachius virens)*. It was also noted that minke whale diets are subject to year-to-year variations due to changes in the resource base in different feeding areas. Thus, relative distribution of consumption of different prey items is highly dynamic.

Consumption by minke whales may therefore represent an important cause of mortality for some of the prey species. This is indicated, for example, by the fact that the estimated minke whale consumption of herring corresponds to about 70% of the total fishery, or 16% of the estimated spawning stock biomass, of Norwegian spring-spawning herring in the northeast Atlantic in 1995. However, it should be noted that the diet assumed is based upon samples taken during a period (1992-1995) of high herring and low capelin abundance.

The estimate of minke whale consumption was based on an energy model including energy requirements for reproduction, feeding, growth and storage of energy in tissue. Also the energy density of prey species varied seasonally.

Major uncertainties in the model are related to assumptions of minke whale distribution throughout the feeding season. The main strength of the approach was a good abundance estimate and a reasonable assessment of the energy requirements.

4.1.2 Harp seals

Paper SC/5/ME/7 combined data collected in 1990-1996 on harp seal *(Phoca groenlandica)* diet compositions from various areas and seasons in the Barents Sea, with information on the energy density of various prey species. It was possible, under certain assumptions, to estimate the total consumption of various prey items required by harp seals to cover their energy demands. All diet composition data were based on reconstructed prey biomass, and adjustments were made for differences in digestibility of crustaceans and fish. The number of seals belonging to different age and sex groups was calculated, and then their monthly food requirements were modelled.

Under the assumptions of a variable basal metabolic rate (BMR) throughout the year, and a field metabolic rate (FMR) of 2 x BMR, the estimated consumption by harp seals of crustaceans was 428,200 tons, capelin 258,200 tons (in 1992 when capelin stocks were high), polar cod *(Boreogadus saida),* 212 500 tons, herring *(Clupea harengus)* 69,600 tons, cod *(Gadus morhua),* 32,200 tons and Avarious fish≅ 142,300 tons.

The total food consumption of the Barents Sea harp seal stock (assumed to comprise 700,000 seals, including 100,000 pups) was estimated to be in the range of 1.14 - 1.61 million tons (depending on choice of input parameters) when capelin *(Mallotus villosus)* is abundant in the Barents Sea ecosystem. When capelin stocks in the Barents Sea are low, the estimated total food consumption increased slightly, to values ranging between 1.25 - 1.74 million tons. According to the model the largest quantities of food were consumed in the period June-September.

When the capelin stock was at a very low level (as in the period 1993-1996), consumption of capelin seemed to be replaced by an increased consumption of other species, particularly polar cod (from 16.9-18.6 % to 25.5-26.1%), followed by other gadoids, Avarious fish≅, herring and crustaceans. Using the same assumptions as above, the harp seal consumption of polar cod increased by 113,900 tons, other gadoids (cod, saithe and haddock) by 80,200 tons, various fish by 76,500 tons, herring by 61,300 tons, and crustaceans by 29,100 tons.

The food consumption estimates are sensitive to the model assumptions. The most critical parameter for the total consumption estimates examined in the model was the choice of the multiplier ("a") for predictions of field metabolic rate from basal metabolic rate FMR = a x BMR. When ≅a≅ was increased from 2 to 3, the estimated food consumption increased approximately 40%. Stenson et al. (1995) estimated an increased food consumption of 25% when they increased Aa≅ from 2 to 2.5. The consumption estimates based on the lowest FMR (Aa≅ = 2) in SC/5/ME/7 are similar to estimates based on the monitored energy expenditures of immature harp seals in captivity throughout the year (Nordøy et al. 1995). The consumption estimates showed little variation by changing procedure for calculating basal metabolic rate (BMR) in the model (annual average BMR or monthly changes in BMR).

4.1.3 Cod

SC/5/ME/11 describes the diet of cod in the Barents Sea in the period 1984-1995, based on consumption calculations made by Bogstad and Mehl (1996). The total annual consumption by cod in the Barents Sea varied between 5 and 7 million tons in the period 1992-1995, i.e. the consumption by cod is about twice that of harp seals and minke whales combined. The diet is dominated by fish, with capelin as the most important prey. The consumption estimates are based on stomach content data and a model of the gastric evacuation rate. Consumption is calculated separately for three areas, each half-year and cod age group. The composition of the diet varies considerably between years, corresponding to the fluctuations in the prey (particularly capelin) stock size. For some years and prey species, the calculated consumption is considerably higher than the prey stock estimate. The consumption per cod is also quite variable.

4.2 Central North Atlantic

4.2.1 Minke whales

Paper SC/5/ME/5 summarises the available data on stomach contents of minke whales in Icelandic waters. 58 animals, mostly from June/July 1977-78 were examined, of which 44.8 % contained fish only, 24.1 % krill only and 29.3 % a mixture of the two. The identified fish species were capelin, sand eel and Atlantic cod. Calculations based on a population estimate from the NASS-87 and NASS-89 surveys, migration patterns and estimated energy requirements indicate that minke whales consume around 391,000 tons in Icelandic and adjacent waters (approximately ICES 5a division), of which 198,000 tons are fish (Sigurjónsson and Víkingsson 1995) . The Working Group noted that the diet assumptions are based upon low sample sizes and a simple classifications system of the prey items found in the stomachs.

4.2.2 Harp seals

SC/5/ME/8 presented information on diet of harp seals from 1987-1992. The material was collected in the Greenland Sea pack ice (the West Ice) during spring and early summer. The majority of the harp seal stomachs were empty in all sampling periods, but intestinal contents were found in most of the seals. The harp seal diet was totally dominated by pelagic amphipods *(Themisto* sp.), but krill *(Thysanoessa* sp.) and polar cod *(Boreogadus saida)* were also eaten quite frequently.

Gray (1889) reported that stomachs of adult harp seals in the Greenland Sea contained *Themisto libellula* and krill, while Surkov (1960) reported *Themisto* sp. in harp seal stomachs and crustacean remains in faecal masses on the ice in the Jan Mayen area during spring and July. *Themisto* sp. was the dominant prey of young (< 1 year) harp seals in the Greenland Sea in April 1995 (Haug et al. 1996). Polar cod also occurred frequently in the harp seal intestines in some of the sampling periods in this study, which is consistent with previous observations made during spring and summer in coastal areas of eastern Greenland (Pedersen 1930; Rasmussen 1957).

Harp seals collected in the period February-May in coastal areas of northern Iceland had a diet comprised mainly of sandeels *Ammodytes* sp., codfishes (*Gadidae*), capelin *(Mallotus villosus)* and other fish species. Crustaceans (including amphipods and krill) and other invertebrates were also present (Hauksson and Bogason 1995a).

4.2.3 Hooded Seals

Paper SC/5/ME/8 presented information on the diet of hooded seals *(Cystophora cristata)* collected in May and June 1992 and 1994 during Soviet/Russian commercial sealing in Greenland Sea pack ice. The majority of the hooded seal stomachs were empty in all sampling periods, but intestinal contents were found in most of the seals. The hooded seals had mainly been feeding on squid *(Gonatus fabricii)*, which occurred most frequently in the intestines. It also dominated the biomass in the few stomachs with contents. Polar cod also occurred frequently in most of the periods, while crustaceans, such as amphipods and krill, occurred sporadically.

Little additional information is available concerning hooded seal diets in the Greenland Sea. Arsenjev et al. (1973) reported that the hooded seal diet in the Greenland Sea consisted mainly of squid and to a lesser extent fish, such as redfish, codfishes and others.

Pelagic amphipods *(Themisto libellula)* dominated the hooded seal pup diet after weaning (April) in the Greenland Sea (Haug et al. 1996). As in the present analyses (SC/5/ME/8), most hooded seal stomachs examined by local hunters in Southeast Greenland were empty in July and August (Kapel 1982;1995). In those with contents redfish *(Sebastes* sp.) dominated. The dominance of the squid *(G. fabricii)* and the frequent occurrence of polar cod in the hooded seal diet (SC/5/ME/8) resembles stomach content analysis of young hooded seals made in Southeast Greenland in September when squid dominated the diet, followed by shrimp *(Pandalus* sp.), polar cod and redfish (Kapel 1995).

In the coastal waters of northern Iceland from April to October, hooded seals were reported to feed mainly on redfish, cod and various other fishes. Shrimp and squid *(Todarodes sagittatus)* were also eaten (Hauksson and Bogason 1995b).

Recent satellite tracking data have shown that hooded seal migrate between breeding and moult from the pack ice areas off eastern Greenland to the continental shelf edges off the Faroe Islands and northern Ireland, and to areas in the Norwegian Sea (Folkow and Blix

1995; Folkow et al. 1996). After moult hooded seals perform excursions which last for approximately 3-7 weeks to the waters off the Faroe Islands, the Irminger Sea, north/northeast of Iceland, areas in the Norwegian Sea and along the continental shelf edge from Norway to Bear Island.

Evidence of hooded seal feeding habits in these areas are lacking. In order to improve current knowledge on the feeding habits of hooded seals, stomach and intestines should be sampled in the areas where the seals are observed to occur for longer periods.

4.3 Northwest Atlantic

4.3.1 Minke whales

SC/5/ME/15 presented a review of earlier published results on the diet of minke whales in Greenland together with information reported by local hunters in Greenland through the Greenland Home Rule reporting system. Previous information on the feeding of minke whales highlights the importance of capelin as the most important prey species, making up about 70 % of the items found in the stomachs. Other identified food items recorded are Atlantic cod (*Gadus morhua*), polar cod (*Boreogadaus saida*), Greenland cod (*Gadus ogac*), and Atlantic catfish (*Anarhichas lupus*), herring , sand eel (*Ammodytes* sp.). Amphipoda (*Themisto* sp.), euphausiacea (*Thysanoessa* sp.), decapoda (*Pandalus* sp.) and pteropods have also been reported. Minke whales in Greenland appear to have a flexible feeding pattern.

A review of the available information on the diet, distribution and abundance of minke whales in Atlantic Canada was presented in SC/5/ME/6. The most comprehensive information on diet was collected prior to 1972 and indicated that capelin was the primary prey. Other species such as squid (*Illex illecebrosus*), salmon (*Salmo salar*), herring, cod, euphausiids and copepods were also eaten. Examination of a small number (n=10) of stomachs from minkes caught in fishing nets indicate that the whales had been feeding exclusively on capelin. There is no information on the diet of minke whales in the Gulf of St. Lawrence.

A study of whales in one Newfoundland bay during the early 1980s (Piatt et al. 1989) estimated that humpback, fin and minke whales took less than 1% of the total capelin biomass in the area. Of this, minke whales accounted for approximately 10%.

There are no current estimates of minke whale abundance in Canadian waters and the seasonal distribution is unknown. However, a preliminary estimate of prey consumption assuming a population of 6,000 and seasonal movements between Newfoundland and the Gulf of St. Lawrence suggests that minke whale consumption is relatively low in comparison to harp seal consumption. The amount of capelin consumed may be greater than that taken by hooded, grey or harbour seals in the area, but this estimate was considered to be illustrative and not appropriate for detailed comparisons.

4.3.2 Harp Seals

Paper SC/5/ME/9 presented information on results of stomach contents analysis of material collected in West Greenland waters in the period 1986-93 compared with published data and information from local hunters. The diet of harp seals feeding in this region is available but consists mainly of pelagic crustaceans (*Thysanoessa* spp. and *Themisto libellula*) and small fish species like capelin (*Mallotus villosus*), sand eel (*Ammodytes* spp.), polar cod (*Boreogadus saida*) and Arctic cod (*Aectogadus glacialis*). Species of importance for commercial fisheries in Greenland, such as northern shrimp (*Pandalus borealis*), Atlantic cod (*Gadus morhua*), and Greenland halibut (*Reinhardtius hippoglossoides*) play a minor role in the diet of harp seals in this area.

Using information on distribution of catches and recoveries of tagged seals, an attempt to calculate the relative importance of various prey items of harp seals during their stay in coastal West Greenland was presented. It was concluded that about 1/3 of the food was capelin, 1/4 polar cod and 1/4 euphasiids or amphipods. Cod, shrimp and Greenland halibut each constituted 1-2 % of the food eaten. However, even at this low level, consumption by harp and hooded seals of these three prey species may well be of the same order as the commercial fishery in this region.

The estimates of consumption are sensitive to the assumed number of harp seals in West Greenland throughout the year.

Estimates of the consumption of Atlantic cod, capelin, and *Boreogadus* by harp seals off the coast of Newfoundland and in the Gulf of St. Lawrence were presented in Stenson et al. (1995). SC/5/ME/10 provides an update of the model used previously to estimate consumption of all prey species in Atlantic Canada from 1990-96. It also provides estimates of consumption by grey, harbour and hooded seals for comparison.

Harp seals were the most important pinniped predator in the northern Gulf and NAFO areas 2J3KL. They were estimated to have consumed over 150,000 tons of Atlantic cod, 1.1 million tons of capelin, 600,000 tons of *Boreogadus*, 130,000 tons of Greenland halibut, 107,000 tons of redfish and 104.000 tons of herring in 1996.The amount of cod consumed was not sensitive to the assumption concerning the proportion of time spent in near shore or offshore areas of Newfoundland, but changes in this assumption will affect estimates of the other species, particularly capelin, herring and *Boreogadus*. Although the total amount of prey consumed by harp seals in Atlantic Canada is large, most are not commercial species or taken prior to recruitment to the fishery.

There were several differences in the model presented in SC/5/ME/10 when compared with that found in Stenson et al. (1995). The major differences were related to the use of a population model which assumes that pup mortality is greater than that of older seals and incorporating seasonal and geographic variation in the diet of seals off Newfoundland. The proportion of time spent in the Gulf of St. Lawrence and off Newfoundland was also corrected from the earlier model. The resulting estimates were similar to those presented in Stenson et al. (1995) for the same time period, although the proportion taken off Newfoundland is greater while that taken in the Gulf is less.
There is a considerable amount of information available on harp seals in the Northwest Atlantic, particularly on population size, and energy requirements. There is also extensive data on geographical and seasonal variations in the diet of harp seals off Newfoundland although there is less information for offshore areas and in the Gulf. The greatest source of uncertainty in the estimates of consumption are related to the limited information

available on the seasonal distribution of harp seals and potential spacial and temporal variations in the diet. Current studies on the movements of seals using satellite telemetry will increase our understanding of the distribution of harp seals and improve the estimates of consumption.

4.3.2 Hooded Seals

Paper SC/5/ME/9 also presented information on the results of stomach contents analysis of material from hooded seals collected in Greenland waters in the period 1986-93 and information from hunters from 1970-83. Variation in the diet of hooded seals is less well documented than the harp seal, but in addition to the species also taken by harp seals, larger demersal fishes such as Greenland halibut, redfish (*Sebastes* spp.), cod and wolffish (*Anarhichas minor*) are apparently important prey items.

SC/5/ME/10 presents estimates of prey consumption of hooded seals in Atlantic Canada. Total abundance was estimated using a Leslie matrix model and recent data on reproductive rates. Based on estimates of pup production off Newfoundland and in the Gulf of St. Lawrence, the population was assumed to be increasing at 5% per year in this area. Greenland halibut was the major prey of hooded seals in offshore areas, followed by witch flounder, squid (*Gonatus*), and Atlantic cod. Greenland halibut and redfish were the main prey in inshore areas. No information was available on the diet in the Gulf and it was assumed that it was the same as that observed in near shore areas of Newfoundland. Considering the small population present in the Gulf, changes in this assumption will affect the estimates of consumption in the northern Gulf but will have little influence on the estimates of total consumption.

Hooded seals were estimated to have consumed approximately 129,000 tons of Greenland halibut, 36,000 tons of Atlantic cod and 19,000 tons of redfish in 1996. Almost all of the prey consumed were from NAFO division 2J3KL. However, these estimates are based upon a limited number of samples of hooded seal diet.

The greatest sources of uncertainty in the consumption estimates are associated with the estimates of abundance and seasonal distribution. The model assumes that the change in pup production between 1984 and 1990 represents an actual increase in the area and not a temporary influx of females from Davis Strait. It is also assumed that Davis Strait hooded seals do not enter the area. There is also uncertainty associated with the seasonal distribution of hooded seals. While satellite telemetry has provided information on the movements of seals during the spring, little is known about their distribution during the fall and winter.

5. INTERACTIONS BETWEEN MARINE MAMMALS (MINKE WHALES, HARP AND HOODED SEALS) AND COMMERCIALLY IMPORTANT FISH STOCKS - MULTISPECIES MODELLING

5.1 Northeast Atlantic

Two papers describing multispecies models incorporating fish and marine mammal stocks in Northeast Atlantic were presented.

SC/5/ME/11 describes how multispecies interactions between minke whales, harp seals, herring, capelin and cod in the Barents Sea are modelled in the multispecies model MULTSPEC (Bogstad et al. in press). The model is divided into seven areas, and the species included are also structured by age, sex and length (fish only). A one-month time step is used. In the model, minke whales and harp seals are predators on cod, capelin and herring. Cod prey on capelin, herring and young cod (cannibalism), while herring is a predator on capelin larvae. The feeding, growth, fertility and natural mortality rates of minke whales and harp seals all assumed to be constant. The feeding and growth rates of cod are affected by the abundance of prey, while the growth of herring and capelin depends on the abundance of these two species combined.

MULTSPEC was used to study the effects of varying:

i) the stock size of harp seals and minke whales;
ii) the food preferences of harp seals and minke whales; and
iii) the food preferences of cod.

This was done by running the model for a period of 20 years. A reference run, resulting in variations in the biomass of cod, herring and capelin within the range observed for the period where stock estimates are available, was decided upon. A fixed harvesting rate for fish and marine mammals was assumed throughout the period. In the reference run, the catches of marine mammals are set so that the marine mammal populations stay approximately constant.

The main effects can be summarized as follows:

The herring stock increased as predation from marine mammals decreased. With prey preference as in the reference run, the herring stock was much more sensitive to changes in the minke whale stock than to changes in the harp seal stock. The quantity of herring consumed by whales and seals in the Barents Sea was moderate or negligible compared to the total herring stock biomass. The reason why the herring stock was so sensitive to changes in the whale stock is that predation reduced the number of recruits to the mature stock by an amount which is not negligible, and this had both an immediate effect on the total stock and a long-term effect through the spawning stock-recruitment relationship.

The development of the capelin stock was mainly determined by changes in the herring and cod stocks. The effect of changes in these stocks on capelin generally went in the opposite direction to effects from changes in marine mammal predation on capelin. This resulted in an increase in the capelin stock when the minke whale stock increased, and *vice versa.* Since herring was less sensitive to changes in the seal stock than to changes in the minke whale stock, and since predation on capelin from seals was high, an increase in the seal stock lead to a decrease in the capelin stock, and *vice versa.*

Generally, the cod stock increased or decreased when marine mammal stocks decreased or increased, as expected. However, because of the strong cod-capelin interactions, resulting in a tendency to cyclic variations in the two stock trajectories, the changes in the cod stock in some years was in a direction opposite to the one expected when compared to the reference run.

Decreasing the preference herring by cod had much greater effects than changing some of the marine mammal preferences, and even more dramatic effects than removing both marine mammal stocks from the system. In these runs, the herring stock increased above historical levels, with resulting detrimental effects on the capelin stock. The cod stock also decreased due to low capelin stock. An increasing minke whale stock had the greatest affect on the herring stock, while an increased harp seal stock mainly affected the capelin and herring stocks.

Considering the importance of polar cod to harp seals and possibly cod, including polar cod into the model may affect the interactions observed. It was also noted that the prey preferences in the model remained constant throughout the year. Given the reported changes in the prey selection by harp seals in the Barents Sea, it is important to consider the potential effect seasonal differences in prey selection may have on the model.

The MULTSPEC model was designed to describe fish/fish interactions. Although marine mammals have been included, their impact is through removal of fish. The model allows for the inclusion of an impact of fish stock size on the reproductive rates and growth of marine mammals, but such runs have not been made. Inclusion of such effects may provide a more realistic view of interactions among the species.

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SC/5/ME/12 investigated the effect of tuning the Revised Management Procedure (RMP) for minke whales from the current level (with a stock target of 72% of carrying capacity - k) to one with a lower abundance (60% of k) on fish stocks in the Barents and Norwegian Seas. A number of scenarios were simulated and the results analysed by regression methods. Four species were included in the model: cod, capelin, herring and minke whales. The fish populations were age and length distributed, while the minke whale was age and sex distributed. The time step was one month, and two areas (Barents and Norwegian Sea) were included.

The model assumes a food-web with minke whales as the apex predator, consuming herring, capelin and cod. Cod consume cod, herring and capelin, while herring prey on capelin. A non-linear function for minke whale prey preference is used. Minke whales may forage on plankton and fish other than cod, capelin or herring, and are thus modelled as having carrying capacity and demographic parameters independent of the status of the fish stocks in the model.

A constant fishery model was assumed for cod and herring, while capelin was managed using a fixed target spawning stock. Minke whales were managed according to the RMP. Fish recruitment and survey indices of minke whales were modelled stochastically. The model, run over a 100 year period, simulated 27 scenarios spanning 9 experimental factors, at three levels each. The primary study variable was the tuning level of the RMP, and the response variables are cod and herring catches and mortality caused by whale predation. The response variables were average over the last 90 years of the period.

Assuming 100,000 minke whales and MSYR between 1% and 2%, the main effect of changing the RMP target from 72 % to 60 % was an increase of some 14% in the cod catches. Mean mortality rate for cod caused by minke whales decreased from 0.2 to 0.1 and the mean yearly catch of whales was increased from approximately 270 animals to around 490 animals. For herring, no clear main effect was found on catch or mortality rate.

It was difficult for the Working Group to interpret the results of the model because of questions concerning the validity of the parameters used. The carrying capacity for the minke whale appears to have been set too high and the reproductive capacity (MSYR) too low. More relevant results might have been obtained with a lower carrying capacity and higher reproductive capacity.

Although indirect effects on the stock size of capelin and herring due to changes in marine mammal abundance were observed in the MULTSPEC model of the Barents Sea (SC/5/ME/11) and the model presented for Iceland (SC/5/ME/13), they were not observed in the model presented in SC/5/ME/12. This may be due to the different methods used or a result of the parameters chosen. The model should be run using a different set of parameters to determine if indirect effects are present.

In this model, the population dynamics of minke whales were assumed to be independent of prey availability. If prey availability is a limiting factor, the consumption might not be independent of stock level, as modelled.

The fish-fish interactions are not well estimated, particularly predation of herring on capelin and cannibalism in cod. The net effect of increased whaling on cod catches may be less clear-cut, particularly when the whale stock is at lower levels, if predation of capelin by herring in the Barents Sea or the amount of cannibalism by cod is greater than assumed in the current model.

In the general discussion that followed on the two models presented for the Northeast Atlantic it was noted that neither model included size selectivity in terms of the amount of fish taken by marine mammals. Both models assumed a constant size selection pattern. Data exists to estimate the age selectivity from the diet samples and it was felt that these data should be incorporated into the models. It was also noted that different models of the cod/capelin/herring dynamics are used and it is therefore difficult to determine whether the differences in estimates with varying marine mammal abundance are due to the way in which the fish species are modelled rather than how the marine mammals are included.

5.2 Central North Atlantic

A model which explores potential interactions between several marine mammal species off Iceland and commercially important stocks that constitute their principal prey was presented in SC/5/ME/13. The analysis included three whale species - fin whale (*Balaenoptera physalus)*, minke whale (*Balaenoptera acutorostrata)* and humpback whale (*Megaptera novaeangliae*), two seal species - harbour seal (*Phoca vitulina)* and grey seal (*Halichoerus grypus)*, two fish species - Atlantic cod and capelin, and shrimp (*Pandalus borealis*). The inclusion of seals in the computations is a new and important addition to earlier models (Stefánsson et al., 1994; Stefánsson et al., 1995; Baldursson et al., 1996) for the area. In this model, cod act as both prey for the marine mammals, and as predator on capelin, shrimp, and young cod (cannibalism).

A single-species model of different harvest regimes of the Icelandic cod stock has been combined with a crude multispecies model to study the potential impacts of various developments of the marine mammal stocks on capelin and cod stocks. The model was run using a variety of assumptions regarding stock sizes, food preference, potential rates of increase and harvesting strategies. Simple aggregate population models were used to describe the marine mammal stocks, and the population and fisheries dynamics for shrimp and capelin were modelled using simple biomass-production models. Thus, only aggregates such as total, recruiting or adult numbers or biomass were considered for these species, as opposed to the fully age-class based cod model.

The impact of the five species of marine mammals on the development of the cod stock is uncertain. However, in the base run natural mortality from predation was estimated to be about twice that due to cannibalism and thus may be a major portion of natural mortality on the younger ages. Given the limited data on which the estimates of marine mammal consumption are based, it is important to improve understanding of the feeding habits of whales and seals in the area.

The main advantage of the approach used is model simplicity and thus clarity in terms of which factors affect which results. The simplicity comes at the expense of a lack of internal consistency, since each species group is modelled according to its own simplified approach and there is no possibility of examining the importance of spacial and temporal effects.

In the discussions that followed it was noted that although the residual natural mortality is unknown, it would have to be extremely large to change the effect of reducing whales on cod yield. However, the decrease in predation mortality which may be expected by reducing the numbers of marine mammal predators was compensated, to some extent, by increased cannibalism.

Recent information obtained from satellite telemetry and observed catches indicate that harp and hooded seals are seasonal migrants to Icelandic waters. They may provide an additional source of mortality on cod. It will be possible to estimate the level of predation by harp and hooded seals when more information on their movements and diet are obtained.

Paper SC/5/ME/14 described a statistically-based multispecies model framework, based on defining many stock components corresponding to areas, maturity stages, length and age groups. This approach allows for the possibility of using many different data sources in order to obtain a consistent set of parameters describing e.g. growth, migration, consumption and fishing. The main drawback of the methodology lies in the complexity and inherent difficulty in obtaining the adequately disaggregated data. The main advantage lies in the possibility of evaluating the effects of including spatial information and overlap as well as comparing information in different data sources.

This approach is similar to that described SC/5/ME/11. Although they provide a better understanding of the interactions between the components of the ecosystem, they are difficult to parameterize. The Working Group encourages this approach.

5.3 Northwest Atlantic

No models designed to assess the impact of the estimated harp or hooded seal consumption on commercial fish stocks in the Northwest Atlantic were presented. However, the Working Group was informed that work is currently underway to incorporate harp seal consumption into a sequential population analysis for NAFO Division 2J3KL cod (>Northern Cod=). The approach will be similar to that described in Mohn and Bowen (in press), which presents a two-species model (grey seals and Atlantic cod) describing the potential impact of seals on Eastern Scotian Shelf cod.

The difficulty of constructing multispecies models for the Northwest Atlantic was addressed by the Workshop on Interactions between Harp Seals and Commercial Fish in the Northwest Atlantic (see 5.4 below)..

5.4 Report of the Workshop on Harp Seal-Fishery Interactions in the Northwest Atlantic

Paper SC/5/13 presented the report from the Workshop on Harp Seal- Fishery Interactions held at Memorial University, St. Johns, Canada from 24 to 27 February 1997. The following is a summary of the main conclusions of the Workshop.

Population Size and Trends

The Workshop concluded that harp seal numbers in the Northwest Atlantic have increased since 1978, and that the best estimate of the 1994 total population size is around 4.5 million animals (although the precise size depends on what is assumed about the mortality of young animals). Animals are now growing more slowly, and the pregnancy rate is lower, than in the 1980s. These effects are expected when food becomes more difficult to find.

Harp Seal Diet

The diet of harp seals in the near shore waters of the Labrador-Newfoundland shelf is dominated by Arctic cod (*Boreogadus saida)*, with some capelin and herring. In offshore waters the most important species are capelin and flatfish (mostly Greenland halibut). In both areas, Atlantic cod is a small, but apparently consistent, part of the diet. The proportion of Atlantic cod in the diet of harp seals does not appear to have declined in recent years, but this needs to be examined more carefully.

Effects on Commercial Fisheries

The Workshop could not assess whether or not harp seals were affecting commercial fish stocks - and Atlantic cod, in particular - on the Labrador-Newfoundland shelf. This was because there is an urgent need for an estimate of the size of the cod stock in both inshore and offshore areas, and for an assessment of the amounts of cod which are being taken by the other important predators (such as Greenland halibut, whales, and seabirds). When this information is available, it will be possible to analyse the effect of predation on the Atlantic cod stock.

Recommendations

A number of specific recommendations were made by the Workshop. The more general recommendations, summarised in order of priority, were:

1. There is an urgent need for an accurate estimate of the distribution and absolute abundance of young cod, in age-classes 0,1 and 2, in the inshore and offshore waters of NAFO divisions 2J, 3K and 3L.

2. The consumption of fish by harp seals in NAFO divisions 2J, 3K and 3L needs to be placed in context. There is therefore an urgent need for better estimates of the diet and consumption of fish by other predators in this ecosystem.

3. If the impact of higher predators on cod stocks is to be assessed, there is a need to extend the single species models which have been used to assess the status of cod stocks to include the effects of other predators.

4. Monitoring of the diet and pregnancy rate of harp seals should continue. More studies of the distribution of adult and young harp seals in NAFO divisions 2J, 3K and 3L using satellite transmitters are needed to refine the existing estimates of how much time is spent in the inshore and offshore waters of these divisions. Results from these studies should then be used to direct the sampling of harp seals for diet studies.

5. Existing information on the proportion of cod in the diet of harp seals in NAFO divisions 2J, 3K and 3L should be reanalysed to determine the statistical power of these data to detect trends over time, and to estimate the probability that this proportion has fallen to lower levels in recent years.

6. The model used to estimate abundance, trends in abundance, and replacement yields for harp seals in the Northwest Atlantic should explicitly incorporate variance in all of the inputs (i.e., catch at age, age-specific pregnancy, and pup production), by maximizing the combined likelihood over all available data. The sensitivity of this model to assumptions regarding longevity should also be investigated. The Workshop also recognized the fundamental importance of capelin in the Newfoundland-Labrador shelf ecosystem.

5.5 Theoretical consideration of multispecies models

In a discussion of the theoretical aspects of multispecies models, the Working Group noted that when ICES takes into account the results of multispecies models they usually only incorporate interactions among fish species. Marine mammal consumption is usually considered part of natural mortality in the normal assessments. However, in Iceland marine mammals have recently been incorporated into models used to understand the impact of long-term management strategies.

Because marine mammal stocks vary slowly, they have little effect on short term management goals which are more likely to be affected by fish/fish interactions. For long-term strategies, however, models should attempt to include long-term effects such as marine mammals.

Report of the Scientific Committee Working Group on the Role of Minke Whales, Harp Seals and Hooded Seals in North Atlantic Ecosystems

A number of specific questions were considered by the Working Group.

i) What are the potential uses of multispecies models?
Multispecies models provide insight into a number of aspects of the ecosystem and the way in which various components may interact. As such they can be used to:

- improve our understanding of how different factors influence the ecosystem;
- identify gaps in knowledge;
- identify which uncertainties are important to answer the questions we pose and which are not;
- provide an indication of where research efforts should be directed to improve management advice;
- assess the possible effects of a given management strategy.

ii) What is the current state of multispecies modelling in the North Atlantic?
There are efforts to model multispecies interactions in the Barents and Norwegian Seas and Icelandic areas. The output of these models incorporating fish/fish interactions are being used in management. However, models explicitly incorporating marine mammals are not routinely used. The available models provide a general impression of interactions and illustrate the range of effects which may occur. However, it should be realised that the models are designed to answer questions concerning the impact of various components of the ecosystem on fish, particularly cod. They do not include marine mammal/marine mammal interactions nor the potential effect of the prey on the apex predator. The models described in SC/5/ME/11 and SC/5/ME /14 will, in theory, allow this to be modelled but there is presently a lack of the appropriate data.

iii) What conclusions can be drawn from the results of the available models?
It must be remembered that models are designed to answer specific questions and extreme care should be taken before extending the interpretations to answer questions that were not specifically posed when constructing the model. For example, comparing the yield in two runs with different scenarios of whale abundance is not quite the same as estimating the impact of changing the abundance of whales with the associated uncertainties. This may be addressed if the model is constructed with the question in mind. One approach may be to include a wide range of scenarios similar to that outlined in SC/5/ME/12.

Including marine mammals in the current multispecies models provides a more realistic estimate of the uncertainty in predictions of fish abundance.

iv) What should be done to improve the models?
Uncertainty in the parameters (e.g. stock estimates, food preferences, migration) should be included in the models to provide a realistic estimate of total uncertainty.

The factors influencing migration or prey selection are poorly understood. A good understanding of these processes is important and should be incorporated into the models.

Models should be constructed on the appropriate spatial and temporal scale for the various components.

6. FUTURE WORK - RECOMMENDATIONS

The results of studies presented to the Working Group indicate that minke whales, harp and hooded seals may have substantial direct and/or indirect effects on commercial fish stocks. To better under-
stand these effects, the Working Group **recommended** the following:

1) For each species, knowledge should be improved on seasonal, annual and spatial variations in:
- abundance
- distribution
- diet
- energy requirements
- prey abundance

Knowledge on each of these factors varies for areas and species. The degree of knowledge for each has been noted within the report and should be considered when developing specific research plans.

2) The understanding of prey selectivity and responses to changes in prey abundance by these predators should be improved. Little is known about these processes at the present time.

3) Estimates of consumption by other important predators should be obtained and the degree of potential competition assessed.

4) Multispecies models should be improved by:
- incorporating uncertainty in the parameters (e.g. stock estimates, food preferences,
  migration) to provide a realistic estimate of the total uncertainty;
- incorporating variations in migration and prey selection. An understanding of these processes is important, but they are not understood at present;
- constructing them on the appropriate spacial and temporal scale for the various components.

5) Efforts to construct multispecies models in the Northwest Atlantic should be encouraged.

7. ADOPTION OF REPORT

The report was adopted on 13 March 1997.

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Appendix 2

AGENDA

1. Opening remarks

2. Adoption of Agenda

3. Appointment of rapporteur

4. Feeding ecology of minke whales, harp seals and hooded seals in the North Atlantic

   4.1 NE-Atlantic
      4.1.1 Minke whales
      4.1.2 Harp seals
      4.1.3 Cod

   4.2 Central N-Atlantic
      4.2.1 Minke whales
      4.2.2 Harp seals
      4.2.3 Hooded seals

   4.3 NW-Atlantic
      4.3.1 Minke whales
      4.3.2 Harp seals
      4.3.3 Hooded seals

5. Interactions between marine mammals (minke whales, harp and hooded seals) and commercially important fish stocks - Multispecies modelling

   5.1 NE-Atlantic
   5.2 Central N-Atlantic
   5.3 NW-Atlantic
   5.4 Report of the Workshop on Harp Seal/Fisheries Interactions, St. John=s, February 1997.
   5.5 Theoretical consideration of multispecies models

6. Future work - Recommendations

7. Any other business

8. Adoption of report

Appendix 3

LIST OF DOCUMENTS

Working Group documents

SC/5/ME/4	Lars P. Folkow, Tore Haug, Kjell.T. Nilssen, and Erling S. Nordøy, Estimated food consumption of minke whales in Northeast Atlantic waters in 1992-1995
SC/5/ME/5	Jóhann Sigurjónsson and Anton Galan, Some information on stomach contents of minke whales (*Balaenoptera acutorostrata*) in Icelandic waters.
SC/5/ME/6	J. Lien, B. Sjare, M.O. Hammill and G. Stenson, Diet and Prey Consumption by Minke Whales in the Northwest Atlantic: A Review
SC/5/ME/7	Kjell.T. Nilssen, Ole Petter Pedersen, Lars P. Folkow & Tore Haug. Food consumption of Barents Sea harp seals.
SC/5/ME/8	Vladimir Potelov, Kjell T.Nilssen, Vladislav Svetochev & Tore Haug, Feeding habits of harp (*Phoca groenlandica*) and hooded seals (*Cystophora cristata*) during moult (April-June) in the Greenland Sea
SC/5/ME/9	Finn O. Kapel, Feeding habits of harp and hooded seals in Greenland waters
SC/5/ME/10	M.O. Hammill and G.B. Stenson, Estimated prey consumption by Harp seals (*Phoca groenlandica*), Grey seals (*Halichoerus grypus*), Harbour seals (*Phoca vitulina*) and hooded seals (*Cystophora cristata*) in the Northwest Atlantic.
SC/5/ME/11	Bjarte Bogstad, Multispecies interactions between minke whales, harp seals, herring, capelin and cod in the Barents Sea
SC/5/ME/12	Tore Schweder, Einar Hatlebakk and Gro S. Hagen, On the effect of whaling on other fisheries: Scenario experiments of the Barents- and Norwegian Sea
SC/5/ME/13	Gunnar Stefánsson, Erlingur Hauksson, Valur Bógason, Jóhann Sigurjónsson, and Gísli Víkingsson, Multispecies interactions in the C Atlantic
SC/5/ME/14	Gunnar Stefánsson and Ólafur K. Pálsson, A framework for multispecies modelling of Boreal systems

SC/5/ME/15 Pia Barner Neve, The diet of minke whales in West Greenland - a short review

Scientific Committee documents

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