Introduction

Harp seals (*Phoca groenlandica*), hooded seals (*Cystophora cristata*) and minke whales (*Balaenoptera acutorostrata*) are top predators in the North Atlantic Ocean. In late winter, harp and hooded seals migrate to geographically well defined pack ice areas to whelp, breed and moult. During the rest of the year they disperse widely in the North Atlantic between Canada, Greenland and North Europe in search of their prey of various fish and invertebrate species. The migration pattern of minke whales is poorly understood, although they are believed to migrate between high latitude summer feeding areas and breeding areas at lower latitudes in winter. These three species are among the most abundant marine mammals, in terms of numbers and biomass, in the North Atlantic and Arctic, and hence can be expected to play an important role as predators in this ecosystem.

Humans are also top predators in the North Atlantic ecosystem. They exploit the populations of fish and crustaceans of the North Atlantic extensively, and also exploit the harp seal, hooded seal and minke whale populations. The commercial exploitation of these three marine mammals was previously much more intense, which led to criticism and demands for tighter regulation. Quotas were introduced, and since the 1970's, a major research effort has been devoted to the assessment of the status and productivity of the stocks. It is evident that the stocks of these species are at or near historically high levels, and that some of them may still be expanding quite rapidly. This gives rise to a new concern: will these large and expanding stocks lead to increasing competition with man for other marine fisheries resources?

Since the mid 1980's, more research effort has been allocated to the examination of the role of marine mammals as predators in relation to fisheries interests. In addition to continued assessment of the status, composition and productivity of the stocks, quantitative studies of the diet as well as the energy density of the prey and the energy requirements of the marine mammals were intensified. During the same period, multispecies models were developed for studies of fisheries interactions as the shortcomings of single species fishery management became apparent. Significant advances have been made in this field in recent years, and initial steps in multispecies management of fisheries have been taken by some countries when making decisions on total allowable catch for certain fisheries. Some multispecies models have been expanded to include mammalian predators, or special models have been constructed to examine the role of marine mammals in the ecosystems.

In 1996, the Scientific Committee of NAMMCO was requested to *"focus its attention on the food consumption of three predators in the North Atlantic: the minke whale, the harp seal and the hooded seal, with a particular emphasis on the study of the potential implications for commercially important fish stocks"*. As a result, a special Working Group on the Role of Minke Whales, Harp Seals and Hooded Seals in the North Atlantic was convened in Tromsø, Norway, 10-14 March 1997. This volume presents updated versions of some of the contributions to that meeting, supplemented with a few additional papers.

The harp seal is probably the most abundant marine mammal in the North Atlantic. Their number is presently estimated to be in the order of 7-8 million seals, with the Northwest Atlantic stock being the largest (4-5 million), followed by the White Sea-Barents Sea stock (> 2 million) and the Greenland Sea stock (0.5 million).

Hooded seals number about half a million, based on estimates of pup production of about 100,000 in the Northwest Atlantic and 26,000 in the Greenland Sea.

The number of minke whales in the North Atlantic is estimated in excess of 200,000 animals. According to the most recent sightings survey conducted in 1995, the summer abundance of minke whales in the Northeast Atlantic was 184,000.

In this volume, four contributions summarize data on the diet of harp seals, but only one of them presents estimates of total consumption (Nilssen *et al.*). Combining data on harp seal

diet composition from various areas and seasons in the Barents Sea, with information on the energy density and digestability of different prey species, it was possible, under certain assumptions, to estimate the total consumption of all prey items required by harp seals to cover their energy demands. The number of seals belonging to different age and sex groups was calculated, and then their montly food requirements were modelled.

The total food consumption of the Barents Sea harp seal stock was estimated to be in the range of 2.76-5.07 million tonnes annually, depending on the choice of input parameters. When capelin (*Mallotus villosus*) were abundant, total consumption was estimated to be 3.35 million tonnes, of which the consumption of crustaceans was 1.22 million tonnes, capelin 0.81 million tonnes, polar cod (*Boreogadus saida*) 0.61 million tonnes, herring (*Clupea harengus*) 0.21 million tonnes, Atlantic cod (*Gadus morhua*) 0.1 million tonnes, and "other fish" 0.4 million tonnes.

When the capelin stock was at a very low level (as in the period 1993-1996), total consumption was estimated to be slightly higher (3.47 million tonnes), divided between various prey species as follows: crustaceans 1.20 million tonnes, polar cod 0.88 million tonnes, herring 0.39 million tonnes, various codfish 0.36 million tonnes, and "other fish" 0.62 million tonnes.

Data on the diet of harp seal pups collected at the Greenland Sea whelping patch in 1995-1997 demonstrated that independent feeding starts shortly after weaning (Haug *et al.*). The first food was dominated by pelagic amphipods of the genus *Parathemisto* sp., but sympagic amphipods (*Gammarus* sp.) or krill (*Thysanoëssa* sp.) were also found quite frequently.

The diet of subadult and adult harp seals was analyzed based on data collected in the Greenland Sea pack ice from March to June 1987-1997 (Potelov *et al.*). Most stomachs were empty but intestinal contents were found in most of the seals. The diet was dominated by amphipods (*Parathemisto* sp. and *Gammarus* sp.), but krill and polar cod were also eaten quite frequently.

Stomach content analyses of harp seals collected in West Greenland from 1986-1993 indicated that the diet is variable in this region, but consisted mainly of pelagic crustaceans (*Thysanoëssa* sp. and *Parathemisto libellula*) and small fish species such as capelin, sand eel (*Ammodytes* sp.), polar cod and Arctic cod (*Arctogadus glacialis*) (Kapel). Species of importance for commercial fisheries in Greenland, such as northern prawn (*Pandalus borealis*), Atlantic cod and Greenland halibut (*Reinhardtius hippoglossoides*) played a minor role in the diet of harp seals feeding in this region.

Three of the above mentioned contributions also contain information on the diet of hooded seals. The initial diet of hooded seal pups in the Greenland Sea appeared to be identical to that of harp seal pups, which suggests the possibility of interspecific competition between pups of the two species (Haug *et al.*).

As in the case of harp seals, most stomachs of subadult and adult hooded seals collected in the Greenland Sea in May-June 1992 and 1994 were empty, but food remains were found in most of the intestines (Potelov *et al.*). The food was dominated by the squid *Gonatus fabricii*, but polar cod also occurred frequently, while amphipods and krill occurred only sporadically.

According to information from hunters in Southeast Greenland, most stomachs of hooded seals caught in July-August were empty. Redfish (*Sebastes* sp.) was the food item found most frequently. Stomach analysis of young hooded seals caught in this area in September 1991 showed, however, *Gonatus* to be the predominant food, followed by *Pandalus*, polar cod and redfish (Kapel).

In West Greenland, the diet of hooded seals appeared to be dominated by larger demersal fish species such as Greenland halibut, redfish, cod and wolffish (*Anarhichas minor*), but capelin and polar cod occured quite frequently in the stomachs, while crustaceans and squid were only found sporadically (Kapel).

Data on the diet of minke whales are presented in three contributions, one of which also contains estimates of total consumption.

Information on stock size, diet composition and energy requirements of minke whales in north-east Atlantic waters were combined to estimate the consumption of various prey species (Folkow *et al.*). The estimate was based on diet data collected during the period 1992-1995, an energy model including data on energy requirements for reproduction, feeding, growth and storage of energy in tissue, as well as seasonal variation in the energy density of prey species.

The estimate of minke whale distribution and abundance was based on a survey conducted in 1995, indicating a total of 85,000 whales feeding in the coastal waters of northern Norway, in the Barents Sea and around Spitsbergen during summer.

The total consumption of these whales during the six months from mid-April to mid-October was estimated to be 1.8 million tonnes of prey, of which 0.60 million tonnes were krill, 0.63 million tonnes herring, 0.14 million tonnes capelin, 0.26 milion tonnes cod, 0.13 million tonnes haddock (*Melanogrammus aeglefinus*), and 0.06 million tonnes other fish species. It was noted that minke whale diet was subject to year-to-year variation, and that the above estimate of consumption was based on diet data from a period of low capelin abundance.

In coastal Iceland, 52% of the minke whale stomachs examined contained fish, 22% krill, and 25% both fish and krill (Sigurjónsson *et al.*). Fish species identified were capelin, sandeel, cod and herring, and two species of krill were found (*Thysanoëssa raschii* and *Meganyctiphanes norvegia*). Sandeel was the dominant prey species in the western and south-western areas, while capelin and krill were more frequently found in northern Iceland. Because of small sample size a large degree of uncertainty is associated with the analysis of the diet and hence with the assessment of the potentially large impact of minke whales on different fish stocks in Icelandic waters.

Available information on the diet of minke whales in Greenland waters indicated that capelin is the predominant prey species, particularly in coastal areas, while sandeel is consumed quite frequently in offshore areas, and krill is also important in some areas or periods (Neve).

The two last contributions in this volume touch upon different aspects of multispecies modelling for the Barents and Norwegian Seas. Estimates of consumption of commercially important fish stocks in the Barents Sea by the most important predators (including man) are generally consistent with estimates of abundance of the prey species and removal through natural mortality (Bogstad *et al.*). However, some inconsistencies are encountered in periods of low capelin biomass or high herring biomass. Multispecies models are currently used in assessment and management of some fish stocks in the Barents Sea, but the estimates of consumption by marine mammals are at present only used to assess the values of natural mortality used and for making long-term predictions of the development of the fish stocks.

Schweder *et al.* investigated theoretically the direct and indirect effects on the stocks of cod and herring in the Greater Barents Sea (Barents and Norwegian Seas) of varying minke whale abundance over a broad range. According to this model the relationship between whale abundance and fish quotas targeting fixed fishing mortalities is mainly linear, the quotas for each species decreasing by around five tonnes for each minke whale added. The authors stress, however, that no systematic evaluation of total uncertainty has been attempted, and the conclusions are conditional on the model used and its parameterisation.

We hope that the contributions presented in this volume serve to illustrate the state of art of studies aimed at evaluating the role of minke whales, harp and hooded seals in the North Atlantic ecosystem. From evidence presented in these contributions, and at the special Working Group meeting in Tromsø in March 1997, it is evident that the predation by these marine mammal species may have substantial direct and/or indirect effects on other elements of the ecosystem, including commercially important fish stocks. It is, however, also obvious that there is an urgent need for further research in this field to better understand these effects, in order to integrate such knowledge into assessment and management plans.

At their fifth meeting in March 1997, the Scientific Committee of NAMMCO recom-

mended that future research in this area should focus on:

1) Improving the knowledge of seasonal, annual and spatial variation in abundance, distribution, diet, energy requirements, and prey abundance;

2) Understanding prey selectivity and responses to changes in prey abundance by these predators;

3) Estimating consumption by other important predators, and assessing the degree of potential competition; and

4) Constructing multispecies models for all regions of the North Atlantic and improving these by: incorporating uncertainty in the parameters to provide a realistic estimate of the total uncertainty; incorporating variations in migration and prey selection; and constructing models on the appropriate spatial and temporal scale for the various components."

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