NAMMCO SCIENTIFIC COMMITTEE

REPORT OF THE WORKING GROUP ON THE ECONOMIC ASPECTS OF MARINE MAMMAL - FISHERIES INTERACTIONS

16-17 February 2000, Copenhagen

North Atlantic Marine Mammal Commission
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The Working Group on the Economic Aspects of Marine Mammal – Fisheries Interactions met in Copenhagen 16-17 February, 2000. The participants in the Working Group are listed in Appendix 1.

1. CHAIRMAN'S WELCOME AND OPENING REMARKS

Aqqalu Rosing-Asvid welcomed the members to the meeting (Appendix 1), and noted his pleasure at the wide array of expertise brought to the meeting. He suggested that, since he was an ecologist and felt himself less than qualified to chair some portions of the meeting, a co-chair should be elected. This suggestion was accepted and Trond Bjørndal was selected as co-chair for the Working Group.

2. REVISION AND ADOPTION OF AGENDA

The draft agenda (Appendix 2) was adopted without change. Appendix 3 provides the list of documents for the meeting.

3. APPOINTMENT OF RAPPORTEUR

Daniel Pike, Scientific Secretary of NAMMCO, was appointed Rapporteur for the meeting.

4. HISTORICAL BACKGROUND AND THE REQUEST FROM NAMMCO COUNCIL

Grete Hovesrud-Broda, General Secretary of NAMMCO, presented SC/8/EC/19, which outlined the background and context of the present request before the Working Group.

The precursor to this Working Group was the Working Group on the Role of Minke Whales, Harp Seals and Hooded Seals in the North Atlantic Ecosystem, which met in 1996. The terms of reference of this Working Group were to report on present knowledge of the consumption by these three species in the North Atlantic, and the potential implications this might have for commercially important fish stocks.

The 1996 Working Group looked at the feeding ecology of the three species and estimated their consumption levels, cautioning to that there were many uncertainties involved in the estimates. It also considered the use of multispecies models to look at species interactions in the Barents Sea and in the central North Atlantic. The Scientific Committee, based on the results from the Working Group, concluded that minke whales, harp seals and hooded seals in the North Atlantic might have substantial direct and/or indirect effects on commercial fish stocks. The Council endorsed the Scientific Committee's recommendation that it was necessary to pursue this line of study in order to better understand these effects.

As a follow-up to the 1996 request and to the results presented by the Scientific Committee, the Council, at the annual meeting in 1997, requested the Scientific Committee to pay special attention to studies related to competition and the economic aspects of marine mammal- fisheries interactions. The Scientific Committee, in response, convened a Working Group on the Economic Aspects of Marine Mammal - Fisheries Interactions, the precursor to the present Working Group. This Working Group considered bio-economic models of varying complexity and ecosystems, and concluded "that many of the analyses were in a preliminary stage and should only be taken as first indications". They further concluded that despite the preliminary nature of the results, the emerging cost benefit figures warranted serious consideration, as the overall costs to the fishing, whaling and sealing industries incurred by not whaling and/or not sealing could be quite considerable, and that the effects due to predation could be an important part of the overall picture.

The Council responded, at the 1998 annual meeting, by forwarding a more specific request for advice to the Scientific Committee:

i) to identify the most important sources of uncertainty and gaps in knowledge with respect to the economic evaluation of harvesting marine mammals in different areas;
ii) to advise on research required to fill such gaps, both in terms of refinement of ecological and economic models, and collection of basic biological and economic data required as input for the models;
iii) to discuss specific cases where the present state of knowledge may allow quantification of the economic aspects of marine mammal-fisheries interactions;
    a) what could be the economic consequences of a total stop in harp seal exploitation, versus different levels of continued sustainable harvest?
    b) what could be the economic consequences of different levels of sustainable harvest vs. no exploitation of minke whales?

At the Seventh Meeting of the Scientific Committee in April 1999, the Committee decided to reactivate the Working Group on the Economic Aspects of Marine Mammal - Fisheries Interactions to deal with this request. It was agreed to separate the request into two sections. At the first Working Group meeting items i) and ii) were to be considered, while treatment of item iii) was to await the conclusions on the first two.

5. CONSUMPTION BY MARINE MAMMALS IN THE NORTH ATLANTIC-AVAILABLE DATA

Consumption estimates for marine mammals in various areas of the North Atlantic were presented in SC/8/EC/4-7. In addition, SC/8/EC/9, 13, 15 and 16 gave consumption estimates for specific periods and areas. The Working Group noted that in most cases, the consumption estimates were point estimates that represented the best approximations available based upon current information, without estimates of associated uncertainty (e.g. confidence intervals). Although the amount of uncertainty associated with these estimates has not been provided, it will result in a wide range of possible consumption values.

In order to estimate consumption of prey species, data on abundance, daily energy requirements, seasonal distribution and geographical and temporal variation in the diet are required. Unfortunately, the data required to estimate consumption by these species are limited and significant uncertainty exists.

Abundance data for large cetaceans in the Northeast Atlantic are available from the NASS surveys. Estimates of the abundance of small cetaceans are not available in most areas. Information on the abundance of seal species varies greatly among regions and species. For example, estimates of the abundance of harp seals in the Northwest Atlantic and White Sea are relatively recent and precise, while that for harp seals in the Greenland Sea is out of date. For some areas and species, for example grey seals in the Faroe Islands, no estimates of abundance are available.

Although the geographical distribution of some species at specific times of the year is available, information on the seasonal distribution of most species is not. Good data on the movements of North Atlantic harp and hooded seals have been obtained using satellite telemetry but even these data are limited seasonally and for some age groups. Given the spatial variation observed in diets, changes in assumptions related to seasonal distribution can result in significant changes in estimates of consumption (e.g. Northwest Atlantic harp seals SC/8/EC/16).

Diets of marine mammals vary greatly geographically and seasonally. Although the diets of some species in specific areas are well known (e.g. minke whales in the Barents Sea, pilot whales in the Faroes), little is known about diets of most species in the majority of areas. Diet also responds to the relative abundance of prey, which can change dramatically on seasonal, annual or decadal scales. SC/8/EC/13 showed extreme shifts in the consumption by Barents Sea harp seals in response to changes in the abundance of capelin, and similar shifts have been observed for minke whales in response to changes in the abundance of herring and capelin (SC/8/EC/9). Estimation of consumption by these mammals therefore requires either long-term monitoring of diet throughout the year and study area, and/ or the estimation of predation functions to predict consumption under various prey abundance scenarios.

The latter approach requires the simultaneous collection of prey abundance and marine mammal diet data.

Most consumption models assume that the daily energy requirements of an individual are met. The amount of energy required can be estimated using various methods. Depending upon the assumptions used, the estimated daily requirements can vary significantly. Also, many marine mammals exhibit seasonal changes in food requirements, undergoing periods of increased consumption to store energy and periods of decreased consumption during periods of fasting. Our understanding of these seasonal variations in feeding is lacking for many species.

The calculation of the consumption of individual prey species depends on knowledge of the energy value of the prey. However, the energy content of prey species can vary greatly both geographically and temporally (Mårtensson *et al.* 1996). For example, the energy content of most species is much higher immediately before spawning than immediately after. This can greatly affect the calculation of the mass and number of prey items consumed.

These limits to our knowledge result in significant uncertainty in the current estimates of consumption for virtually all species. In some instances (e.g. abundance data based on surveys) the degree of uncertainty can be quantified while for others (e.g. seasonal distribution, diet, energy requirement, energy density of prey) the level of uncertainty cannot be estimated at this time. The degree of uncertainty associated with estimates of consumption must be quantified before these estimates can be used in multispecies and/or economic models. The Working Group therefore recommends the uncertainty associated with estimates of consumption should be quantified, and that uncertainty should be integrated in future multispecies and multispecies-economic models.

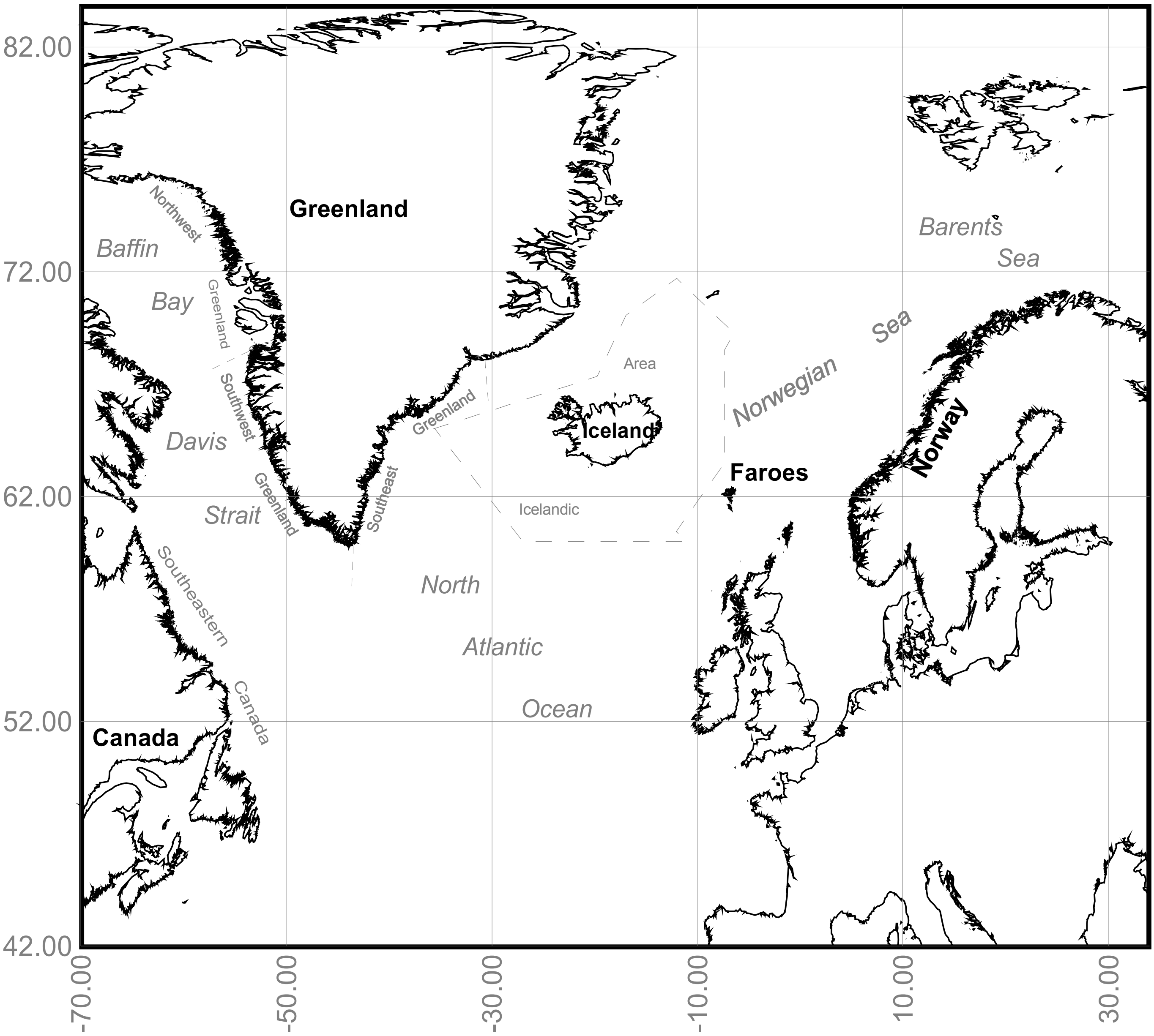
i. Northeast Atlantic- Barents and Norwegian Sea

The consumption by marine mammals in the Barents and Norwegian Seas was summarized in SC/8/EC/4 (Fig. 1). Harp seals and minke whales were clearly the most important marine mammal predators in the area, together accounting for about 70% of the total consumption by marine mammals. In addition, the quality of the available data was far better for these species than for any others. About 70% of the diet of minke whales was composed of finfish, with capelin, herring and cod being the most important species. For harp seals, about 65% of the diet was composed of finfish, with polar cod, capelin, herring and cod the most important species.

The diet composition of both minke whales and harp seals changed with fluctuations in the abundance of their major prey species. For harp seals, the disappearance of capelin was compensated for by an increase in the consumption of cod, polar cod and other fish. The occurrence of harp seal "invasions" of Norwegian coastal waters may be related to fluctuations in the abundance of capelin. During such invasions, the consumption of Norwegian coastal cod may be significant.

For other species, data quality was much lower and the consumption estimates were really only qualified guesses. Particularly lacking was information on seasonal distribution and diet composition for most species. Fin whales may be important consumers in the area, but finfish may comprise a minor part of their diet. Sperm whales were also identified as significant consumers, but there was no information available on their diet in this area. They consume mainly finfish around Iceland (SC/8/EC/15). Other potentially important consumers in the area included white-beaked dolphins, humpback whales and killer whales.

Fig. 1. North Atlantic Ocean, showing areas referred to in the text.



ii. Northeast Atlantic- Faroe Islands

The consumption by marine mammals in the area around the Faroe Islands was summarized in SC/8/EC/5. Point abundance values were available for only two species, fin whales and pilot whales. Abundance was estimated for other species by "best guesses" and by comparison with densities observed in Icelandic waters. It was noted that the abundance of several cetaceans and pinnipeds varied on a seasonal basis in Faroese waters, but no data were available to assess the magnitude of this seasonality. Consumption was calculated using methods similar to those used in SC/8/EC/6 and 15.

Bottlenose whales and pilot whales were likely the most important marine mammalian consumers in the area, feeding almost entirely on cephalopods. Pilot whales were also important consumers of finfish, as were minke whales, white-sided and bottlenose dolphins. Hooded seals may also be important consumers of finfish, perhaps even Atlantic salmon, in the area, but little is known about their seasonal abundance or diet in Faroese waters.

iii. Central Atlantic- Iceland

The estimates of consumption for cetaceans around Iceland (SC/8/EC/6) (Fig. 1) were based on previously published estimates (SC/8/EC/15), while those for seals were new. The Working Group noted that while the information on abundance and seasonal distribution was adequate for some species, information on diet was very limited for all species. It was also noted that there were significant discrepancies between the estimates of daily ration used in these calculations, and those used in SC/8/EC/4 and 5.

Minke whales were the most important marine mammalian consumers around Iceland, and their distribution overlapped with important Icelandic fisheries to a greater degree than most other species. Much of their consumption of finfish concentrated on capelin and sandeel while cod was also among the identified prey items. Fin whales, pilot whales and northern bottlenose whales were also important consumers, but most of their consumption was of crustaceans (fin whales) or cephalopods (northern bottlenose whale, pilot whale). Dolphins of the genus *Lagenorhynchus* were likely next in importance to minke whales in terms of their consumption of valuable fish species. It was also considered that their abundance, as that of other small cetaceans, has probably been considerably underestimated by previous surveys.

Consumption by pinnipeds was generally of far less magnitude than that by cetaceans in Icelandic waters. Consumption by harbour seals and grey seals was not of great magnitude, but they are likely of some importance in terms of their direct conflict with fishers. The seasonal distribution of hooded and harp seals in Icelandic waters is very poorly understood, so their consumption can only be very roughly estimated.

iv. Northwest Atlantic – Greenland

SC/8/EC/5 summarized consumption estimates in 3 areas around Greenland: Southwest, Northwest and Southeast Greenland (Fig. 1). The Working Group noted that information on abundance, seasonal distribution and diet was generally poor for all areas, and that the consumption estimates were generally qualified guesses that gave a qualitative indication of the relative importance of various species in terms of their consumption.

The marine ecosystem around Southwest Greenland is affected by dramatic environmental changes on a decadal scale, switching between a cold environment dominated by Arctic species to a warmer one dominated by boreal species. The area is presently dominated by Arctic species, with harp seals being far more abundant in the area than they were previously. Harp seals accounted for almost 80% of the consumption by marine mammals in the area, with most of this consumption consisting of capelin, polar cod and other small fish species. Hooded seals were of far less importance in terms of total consumption, but much of their diet is composed of valuable fish species such as cod, redfish and Greenland halibut. Minke whales were also of some importance, consuming mainly capelin in the area.

The marine ecosystem is more stable around Northwest Greenland, although fluctuations of lesser magnitude have been experienced. Once again harp seals are the most important consumers in the area, accounting for over 60% of the consumption by marine mammals in this area. Capelin, Arctic cod and other small fish species are important items in the diet, but invertebrates such as *Parathemisto* spp. and prawns may also be more important in this area. Ringed seals are next in importance in terms of consumption, with most of their diet consisting of invertebrates and Arctic cod. Hooded seals were potentially important consumers of valuable finfish such as Greenland halibut and redfish in this area, but little is known about their seasonal distribution. The area is an important wintering area for narwhal, which probably consume Arctic cod and Greenland halibut.

The Greenland Sea stock of hooded seals has a breeding and moulting concentration off Southeast Greenland, and they are likely the most important marine mammal predator in the area. Little is known about their diet, but redfish appear to be an important prey item in this area. Harp seals occur in Southeast Greenland, but virtually nothing is known about their seasonal abundance or diet. Other species such as ringed seal are likely of lesser importance in the area.

v. Northwest Atlantic – Southeastern Canada

The consumption by harp, hooded, grey and harbour seals in southeastern Canadian waters was summarized in SC/8/EC/16. Good information on abundance, seasonal distribution, energy requirements and diet was available for harp seals and grey seal. Abundance estimates for hooded and harbour seals were dated and uncertain. Little information was available on the diet of hooded and harp seals in most areas. The seasonal distribution of hooded seals was also very uncertain.

Harp seals were by far the most important pinniped predator in southeastern Canadian waters, consuming about 8 and 10 times more than hooded and grey seals respectively. Harbour seals were of much less importance. However the seal species concentrated their consumption in different areas. Harp seals consumed most in northern areas, while hooded seals were more important in the offshore area. Consumption by grey seals was concentrated in the southern part of the area.

Fish accounted for 74% of the diet of harp seals, and capelin, sand lance and Arctic cod were the most important fish species in terms of consumption. Consumption of invertebrates, mainly shrimp, by harp seals was significant and probably underestimated due to poor preservation in the stomach. A higher proportion (88%) of the diet of hooded seals consisted of fish, and Greenland halibut and Atlantic cod were the most important fish species consumed. Grey seals consumed a still higher proportion of fish (97%), eating mainly Atlantic cod and herring.

The working group noted that cetaceans such as minke whales, pilot whales, humpback whales and fin whales were of unknown but significant abundance in this area, but their consumption could not be estimated with the information available at present.

6. CONSUMPTION BY MARINE MAMMALS IN THE NORTH ATLANTIC- MAJOR INFORMATION GAPS

SC/8/EC/5-8 and 16 present consumption estimates using the best available data for marine mammals in the North Atlantic. The Working Group concluded, however, that with few exceptions, the data were not of sufficient quality to warrant their use in multispecies or multispecies-economic models. In many cases, the final consumption estimates are really no more than "guestimates", with the magnitude of uncertainty unknown but certainly large. Table 1 presents an assessment of the quality of the data available to calculate the consumption by marine mammals in various areas of the North Atlantic.

Based on their assessment of the magnitude of consumption by marine mammals in various areas, and on the quality of the available data, the Working Group concluded that it would be most productive to focus on the consumption by minke whales, harp seals and *Lagenorhynchus* spp. (white-sided and white beaked dolphins) on capelin, cod, herring and shrimp. *Lagenorhynchus* spp. dolphins were included because of the magnitude of their consumption in some areas, however it was recognized that very little information was available about their abundance, distribution and diet.

i. Northeast Atlantic- Barents and Norwegian Sea

Table 2 shows the estimated consumption by minke whales and harp seals. Separate estimates are provided for the East Ice stock in periods of high and low capelin abundance. The Working Group concluded that there was insufficient information to calculate the consumption of West Ice harp seals and *Lagenorhynchus* spp. dolphins.

Harp seals are clearly the most important mammalian predators in these waters. Most of this predation is concentrated on capelin when it is available, but cod, herring and other species become more important in years when capelin stocks are at a low level. Minke whales prey primarily on herring, but also take significant quantities of cod and capelin.

Consumption by marine mammals is of the same order of magnitude as fishery landings. There has been no fishery for capelin in this area since 1993, however catches exceeded 1,000,000 tonnes before that time. Total landings of Norwegian Arctic Cod were between 187,000 – 771,000 tonnes from 1990-97 (Bogstad 1998), compared with total consumption by harp seals and minke whales of about 360,000-550,000 tonnes. Total landings of Norwegian Spring Spawning Herring were between 78,400 – 1,428,000 tonnes from 1990-97 (Røttingen 1998), while total consumption by harp seals and minke whales was about 800,000 – 1,000,000 tonnes

ii. Northeast Atlantic- Faroe Islands

While it was considered that consumption by minke whales and white-sided dolphins may be important in this area, there was simply too little data on abundance, seasonal distribution, energy requirements and diet to quantitatively assess consumption by these species. Consumption by harp seals is likely not significant in the area.

iii. Central Atlantic – Iceland

Consumption by minke whales and *Lagenorhynchus* spp. dolphins in Icelandic and adjacent waters is calculated in Table 3. The Working Group concluded that there was insufficient information to calculate the consumption of harp seals in Icelandic waters.

Minke whales are the most important mammalian predators in Icelandic waters in terms of ingested biomass. However the major part of their diet was made up of species other than those listed in Table 3, mainly euphausiids and sandeel (SC/8/EC/6). Minke whales also appear to consume a significant amount of capelin in Icelandic waters. While cod were a relatively minor component of the diet, preliminary assessment of multispecies interactions indicates that cod consumption by minke whales may significantly reduce the long-term yield of the Icelandic cod stock (Stefánsson et al. 1997). *Lagenorhynchus* spp. dolphins were far less important as predators than minke whales in Icelandic waters. However consumption by *Lagenorhynchus* spp. dolphins was concentrated on teleost fish, making them potentially important in terms of interactions with fisheries. Consumption of cod by *Lagenorhynchus* spp. dolphins slightly exceeded that by minke whales. Thus, according to the limited available data both minke whales and *Lagenorhynchus* spp dolphins appear to be significant consumers of cod in Icelandic waters and may be in direct competition with the fishery. In order to assess these effects with more certainty it is therefore of great importance to acquire more data on the feeding ecology of these species, in particular the diet of minke whales and the population size of the two dolphin species.

Consumption of cod and capelin by these three marine mammal predators was somewhat less than the fisheries landings for these fish species combined. Landings of Icelandic cod were between 169,000-335,000 tonnes from 1990-1998, while consumption by minke whales and *Lagenorhynchus* spp. dolphins was about 127,000 tonnes (Anonymous 1999). Landings of capelin by Iceland were between 258,000 – 1,561,000 tonnes from 1990-98, while consumption by the three mammalian predators totalled 585,000 tonnes. However other cetacean species, including humpback and sei whales, may also be important predators of capelin in these waters, so the total consumption by marine mammals might be considerably more than this (SC/8/EC/6). Landings of herring, between 65,000 – 134,000 tonnes from 1990-98, were considerably more than the estimated consumption by the three marine mammal species. However, killer whales have been estimated to consume over 100,000 tonnes of herring annually in Icelandic waters (SC/8/EC/6).

iv. Northwest Atlantic – Greenland

Consumption by minke whales in inshore and offshore areas of West Greenland is calculated in Table 4. Although harp seals are seasonally abundant in the area and their consumption is likely several times that of minke whales, there was insufficient data on seasonal abundance and diet in Greenlandic waters to estimate consumption with any degree of certainty. Consumption by *Lagenorhychus* spp. dolphins is likely not significant in the area.

Minke whales consume mainly capelin in the area, while consumption of cod, herring and shrimp is not significant. There is presently a very small fishery for capelin and cod in Greenland, and no fishery for herring. Therefore interactions between minke whales and commercial fisheries are likely of no importance in this area. However, the abundance of, and fishery for cod varies dramatically in Greenland, so such interactions may be important in the future.

7. EXISTING MULTISPECIES MODELS FOR THE NORTH ATLANTIC

i. Description of models

MULTSPEC

MULTSPEC is a simulation model for the Barents Sea that includes capelin, herring, cod, harp seal and minke whale (Tjelmeland and Bogstad 1998). Within the model, the Barents Sea and surrounding area is divided into 7 areas. In general the model is aggregated temporally on a monthly basis, with discontinuous processes such as reproduction handled annually. Recruitment of cod and capelin is modelled using a Beverton-Holt function, while a special function is used for herring. Migration follows a fixed pattern for all species except mature capelin, for which migration is modelled based on the observed distribution in cod stomachs.

Predation by the fish species depends on their size distributions, the relative abundance of prey, and temperature. The predation by harp seals and minke whales is modelled based on their energy requirements and their observed diets.

The model requires input data on the relative abundance and distribution of cod by size and age, and the absolute abundance and distribution by size and age for capelin and herring. Predation by cod and seasonal distribution of capelin are determined from annual sampling of cod stomachs throughout the area. The abundance and distribution of the marine mammals is based on the latest available survey data, and their seasonal distribution is modelled qualitatively. Sea temperature affects growth, maturation and predation by fish, and annual synoptic measurements are included in the model.

MULTSPEC has been used to study the effects of varying the stock size of minke whales and harp seals in the area (Bogstad *et al.* 1997). The stock of herring was found to be negatively associated with the abundance of minke whales, while the capelin stock had a negative association with the abundance of harp seals. Capelin had a positive association with the abundance of minke whales, as their abundance was strongly influenced by predation by maturing herring. The cod stock had a negative association with the abundance of both minke whales and harp seals. However, because of the aforementioned minke whale – herring – capelin interaction, the association between the cod stock and minke whale abundance was weaker than that between cod and harp seals.

It is unlikely that the MULTSPEC model will be maintained in its present form due to lack of resources. It is planned to convert the model into the same code used in BORMICON, however it is not certain when this will be completed.

Table: 1. Quality of data used to derive consumption estimates for marine mammals in the North Atlantic. Species are listed in order of the magnitude of their consumption of finfish in the area, and only those species accounting for 90% of the consumption of finfish by marine mammals in the area are listed. Quality is assessed based on the statements below:

- Estimate is biased and the direction of known bias is not known.
- Estimate does not apply directly to the entire area and/or species in question.
- Variance not available directly.
- Plausible range cannot be inferred.
- For factors subject to short-term, temporal change (e.g. abundance), estimate is not recent (<6 yrs).

**** None true.
*** 1 true
** 2 true
* 3 or more true.

Species	Abundance	Residence Time	Energy Require-ment	Diet
Barents and Norwegian Seas				
Harp Seal, East Ice	****	***	***	**
Minke whale	****	**	***	***
Harp Seal, West Ice	*	*	***	*
Sperm whale	**	*	*	*
White Beaked Dolphin	*	*	*	*
Southwest Greenland				
Harp seal, NW Atlantic	*	*	*	**
Hooded seal, NW Atlantic	*	*	*	**
Minke whale, W Greenland	*	*	**	**
Northwest Greenland				
Harp seal, NW Atlantic	*	*	*	*
Hooded seal, NW Atlantic	*	*	*	*
Ringed seal	**	*	*	**
Narwhal	**	*	*	*
Southeast Greenland				
Hooded seal	*	*	*	*
Iceland and Adjacent Waters				
Minke whale	****	***	*	**
Lagenorhynchus spp.	*	*	*	**
Pilot whale	****	**	*	*
Killer whale	***	**	*	*
Humpback whale	***	***	*	*
Sperm whale	**	***	*	**

Species	Abundance	Residence Time	Energy Require-ment	Diet
Faroe Islands				
Pilot whale	****	**	*	***
Minke whale	*	*	*	*
White-sided dolphin	*	**	*	*
Bottlenose dolphin	*	**	*	*
Hooded seal	**	**	**	*
Southeastern Canada				
Harp seal	****	***	***	***
Hooded seal	**	**	***	**
Grey seal	****	***	***	***
Harbour seal	*	***	***	**

Table 2. Consumption by minke whales and harp seals in the Barents and Norwegian Seas (Fig. 1). CV – Coefficient of Variation, NA – Not available.

Abundance [CV]	**Residence Time (mean days/year) [CV]**	**Energy Requirement (kJ/day/ind) [CV]**	**Diet (% mass)**		**Diet (tonnes/year) [CV]**	
Minke whale North East Atlantic stock Barents and Norwegian Seas April 15 to October 15 Low Capelin, high herring abundance period (1992-1995[1])						
84,761[2] [0.131]	180[3] [NA]	618,170[4] [NA]	Cod	14	Cod	255,622
			Capelin	8	Capelin	142,408
			Herring	35	Herring	633,361
			Shrimp	0	Shrimp	0
			Others	43	Others	781,723
				[All NA]	**TOTAL**	**1,813,114[5]** [All NA]
Harp Seals East Ice stock Barents Sea All year Capelin abundant (period 1990-1992)[6]						
2.19 mill[7] [0.09]	365[8] [NA]	25,600[9] [NA]	Cod	3.0	Cod	100,500
			Capelin	24.1	Capelin	807,800
			Herring	6.3	Herring	212,400
			Shrimp	NA	Shrimp	NA
			Others	66.6	Others	2,233,300
				[All NA]	**TOTAL**	**3,354,000[10]** [All NA]
Harp Seals East Ice stock Barents Sea All year Capelin depleted (period 1992-1996)[11]						
2.19 mill[12] [0.09]	365[13] [NA]	25,600[14] [NA]	Cod	8.5	Cod	296,300
			Capelin	0.7	Capelin	22,900
			Herring	11.3	Herring	392,500
			Shrimp	NA	Shrimp	NA
			Others	79.5	Others	2,762,400
				[All NA]	**TOTAL**	**3,474,100[15]** [All NA]

The estimated diet composition is based on stomach contents analyses of 223 minke whales sampled in Norwegian scientific whaling operations in 1992-1995.This period was characterised by low abundance of Barents Sea capelin and the highest abundance levels of herring since the late 1960'es. After a peak in the early 1990'es, most of the Barents Sea capelin stock died after spawning in 1992. Only whales sampled well after the spawning period of capelin in 1992 were included in the diet composition and energy requirement analyses in SC/8/EC/9, which is the source of information for this table.

[2] The abundance covers the three management areas EB, ES, EC ("the Greater Barents Sea"). The population estimate is based on data from dedicated shipboard surveys in 1989 and 1995 (for details see, Schweder *et al.* (1997)).

[3] The migration pattern of northeastern Atlantic Minke whales is very poorly known , but recent estimates of consumption are based on a presumed minimum residence time of 180 days in the Greater Barents Sea.

[4]This estimate is an average value based on the total energy requirements of northeastern Atlantic Minke whales from mid April to mid October calculated in SC/8/EC/9. The original estimate was stratified with respect to season and reproductive classes.
[5] As no CV's are available on energy requirements, diet composition and energy density of prey, no overall CV could be calculated for the estimated total annual consumption. However, the CV of the abundance estimate alone suggests a confidence range of the consumption estimate between 1.4-2.1 million tonnes.
[6] The consumption estimates are based on Nilssen et al (2000). 655 Stomachs collected from September 1990 to April 1992 were used for estimating relative diet composition in a period with high abundance of Barents Sea capelin (see fig.2a).
[7] The abundance estimate used in SC/8/EC/13 is based on an estimate of total population size given in Anonymous (1999b) corrected for a 30% pup mortality.
The calculation of total population size is based on a high quality aerial survey of pup production performed in 1998 (Anonymous 1999b).
[8] According to Haug et al (1994) and unpublished satellite telemetry data (Erling Nordøy, pers. comm.) the migrations of East Ice harp seals are largely confined to the Barents Sea, West Spitsbergen and the North Norwegian coast. In the consumption model, it is assumed, that the East Ice population stays in the Barents Sea all year round.
[9] In SC/8/EC/13, energy requirements are modelled separately for different length groups in different seasons. This is in contrast to earlier and simpler studies in which an avarage individual daily energy requirement s were estimated and scaled up by the total population size and residence time to give total annual consumption. The value given here is taken from Nordøy et al (1995) and is based on average daily energy requirements of 4 bedlamers measured in captivity for 1 year. The resulting estimate of total annual consumption for the East Ice harp seal stock was 3.51 mill tonnes (No CV given).
[10]The total consumption estimate is taken from SC/8/EC/13 and is based on monthly averages for energy requirements and a multiplication factor of 2 from basal metabolic rate to field metabolic rates. No overall CV is given, since CV's for energy requirements, diet composition or energy density of prey were not available. However, a confidence range based on the CV of the abundance estimate alone was estimated at 2.69-3.96 million tonnes, when capelin is abundant. Based on different assumptions regarding activity levels and prey availability scenarios SC/8/EC/13 suggested a range of possible annual consumption estimates between 3.35 and 5.05 mill. tonnes for East Ice harp seals .
[11] The consumption estimates are based on SC/8/EC/13. 491 Stomachs collected from October 1992 to August 1996 were used for estimating relative diet composition in a period with low abundance of Barents Sea capelin (see fig.2a).
[12] See note [8]
[13] See note [9]
[14] See note [10]
[15] See note [11]

Table 3 Consumption by minke whales and *Lagenorhychus* spp. dolphins in Icelandic and adjacent waters (Fig. 1). CV – Coefficient of Variation, NA – Not available.

Abundance [CV]	Residence Time (mean days/year) [CV]	Energy Requirement (kJ/day) [CV]	Diet (% mass) [CV]		Diet (tonnes/year) [CV]	
Minke whale North Atlantic Central stock (part) Icelandic and adjacent waters (Fig. 1). All year, most abundant during summer						
62,507[1] [0.28]	219[2] [NA]	710,042 (mean) 1,793,720 (summer)[3] 168,201 (winter) [NA]	Cod	3[4]	Cod	62,430
			Capelin	23	Capelin	478,630
			Herring	0	Herring	0
			Shrimp	0	Shrimp	0
			Others	73	Others	1,539,940
				[All NA]	**TOTAL**	**2,081,000** [All NA]
***Lagenorhynchus* spp. Icelandic and adjacent waters (Fig.1). Throughout the year.**						
76,635[5] [NA]	365 [NA]	L. acutus: 51,297 Unidentified: 68,619[7] L. albirostris: 86,192 [NA]	Cod	20[6]	Cod	64,739
			Capelin	33	Capelin	106,820
			Herring	0	Herring	0
			Shrimp	0	Shrimp	0
			Others	47	Others	152,137
				[All NA]	**TOTAL**	323,696 [All NA]

[1] From SC/8/EC/15.
[2] Calculated from migration curves given in SC/8/EC/15.
[3] Different summer and winter feeding rates (SC/8/EC/15).
[4] Based on a small sample size (n=68), no CV available.
[5] These calculations are based on SC/8/EC/15 except that lower body weight has been applied to *L. acutsus* (Bloch pers. communication).
[6] Around 1/3 of gadoids assumed to be cod. A guestimate.
[7] Unidentified dolphins assumed to be equal numbers of *L acutus* and *L.albirostris*.

Table 4. Consumption by minke whales in Greenlandic waters (Fig. 1).

Abundance[1] [CV]	Residence Time[2] (mean days/year) [CV]	Energy Requirement[3] (kJ/day) [CV]	Diet[4] (% mass) [CV]		Diet[5] (tonnes/year) [CV]	
Minke Whale West Greenland stock West Greenland May - October 1987/88						
3266	180	1,227	Cod	1	Cod	1,434
			Capelin	70	Capelin	100,409
[.31]	[NA]	[NA]	Herring	0	Herring	0
			Shrimp	0	Shrimp	0
95% CI			Others	29	Others	41,598
1702-5718				[All NA]	**TOTAL**	143,441 [All NA]
Minke Whale West Greenland stock (inshore) West Greenland May - October 1993						
5619	180 days/year	1,227	Cod	1	Cod	2,468
			Capelin	70	Capelin	172,751
[.36]	[NA]	[NA]	Herring	0	Herring	0
			Shrimp	0	Shrimp	0
95 % CI:			Others	29	Others	71,568
2815-11214				[All NA]	**TOTAL**	246,787 [All NA]

[1] Minke whale abundance surveys Off West Greenland hav been carried out during ten summers (1982-85, 1987-89, 1991-93) by the Greenland Fisheries Research Institute in co-operation with foreign research agencies (Born 1999). The first two attempts were ship-borne surveys, while the remaining surveys were airborne. Of the ten attempts only two were relatively successful (1987/89 & 1993) (Born 1999). The abundance estimates used in the following two tables are from Hedley *et al.* (1997) and they are based on cue counting with a surfacing rate of 53 surfacing per hour. In 1993 an estimate of 5619 minke whales was found in the coastal area (CV 36% and 95% CI 2815-11214) whereas an estimate of 6385 was found when an offshore block was included (CV 41%, 95% CI 2942-13855). Only the coastal estimate is used here because no new data on prey selection in offshore waters are available.

[2] Residence time is estimated as 180 day (from May to October). Catch records shows that the first minke whales are caught in April, but the number of catches and probably also the number of whales increases until June. From early October the catch-number starts to decrease, but some whales are caught until December.

[3] Energy requirement is estimated as four month of summer and two month of winter energy consumption, using the consumption rates from SC/8/EC/15. This gives a mean of 299.2 Kcal / day (1,227 KJ) in the 6 month period.

[4] Diet (% mass / day) is data from hunter's reports (n = 563) from the period 1992-96 (Neve 2000). The distribution of the samples is not adjusted to match the distribution of the whales, which only is known at the time of the survey. Capelin is the dominant prey species and this was also the case in a similar dataset from 1955-79, although krill seemed to be more important by then (Larsen and Kapel 1981). Greenlanders kill their minke whales close to the coast and the diet data therefore only represents the consumption in coastal waters. Data from the Norwegian whaling in the offshore area during 1979-81 found sand eel to be the most important prey item here (Larsen and Kapel 1981, 1982).

[5] Diet kg / year is found with the assumption that 80% was fish with the conversion factor 1.3 kcal/g (Steimle and Terranova 1985) and that the rest was crustaceans with a conversion factor of 0.93 kcal/g (Lockyer 1987). This gives mean food consumption with a conversion factor of 1.226 kcal/g and a mean daily consumption of 244 kg.

AGGMULT

AGGMULT is a simplified and highly aggregated version of MULTSPEC that has been used in combination with the economic model ECONMULT to study the economics of Barents Sea fisheries under various management regimes. However, the interactions with marine mammals have not yet been considered in these models.

BORMICON

Bormicon (Boreal migration and consumption model) was developed at the Marine Research Institute in Iceland as an assessment tool in which species interactions and spatial effects could be taken into account. The modeled species are divided according to area, age and length. The formulation of both biological processes and likelihood functions are rather flexible, allowing for a wide range of models to be described. Bormicon has been implemented for Icelandic waters and is also being implemented for the Barents Sea and Bering Sea ecosystems. A new assessment tool for Northeast Arctic cod developed at Institute of Marine Research in Bergen also builds to a large extent on the Bormicon code. Mammals have not been included in the model yet in either of the three ecosystems for which it is being implemented.

Bormicon is at present the most advanced analysis tool for boreal ecosystems. However, the high level of disaggregation and the need for specifying and estimating a migration model puts high demands on skill, manpower and knowledge of the ecosystem for effective use of the model.

Scenario Barents Sea

This model is described in SC/8/EC/14 and in Schweder *et al.* 1998. It differs from some other models in that it does not attempt to predict the actual future state of the ecosystem; rather, it is a tool for investigating management regimes for fish and marine mammals. The model therefore incorporates a probabilistic model for the dynamics of the ecosystem and of the catches determined by the catch rules for fisheries, and investigates the effects of changing various parameters in the catch rule. Variability is incorporated explicitly through stochasticity in fish recruitment and abundance estimates fed to the catch rule. Other uncertainty due to lack of information is handled through multiple simulation over a grid of plausible values for the uncertain parameters.

The model is aggregated spatially into Barents Sea and Norwegian Sea areas. Recruitment in cod, herring and capelin are modelled through a Beverton-Holt functions, and cod and herring are set to produce exceptionally good year classes once every 10 years on average. Predation by minke whales is based on predation functions derived from observations of minke whale stomach contents in relation to prey abundance. Predation by cod is dependent on fish size and relative abundance of prey items. In years with an abundance of herring in the Barents Sea, recruitment of capelin is impaired because of predation by herring.

SC/8/EC/14 demonstrated the use of this model to investigate the effect on cod, herring and capelin fisheries of varying the stock size of minke whales in the Barents and Norwegian Seas. The effects on catch quotas were modelled through the management regimes and catch rules presently in place for the three fisheries. Catches of cod, herring and capelin declined linearly with increasing whale abundance, by about 5 tonnes/whale for cod and herring, and 2.5 tonnes/whale for capelin. For cod, the direct effect on the catches of an extra minke whale in the system is a direct loss of some 2.5 tonnes due to minke whale consumption of cod, and an additional loss of some 2.5 tonnes due to predation on capelin and herring. For herring, the indirect effects seem to be positive, probably due to decreased predation on herring by cod. The direct negative effect from predation is, however, stronger.

The effect on cod and herring fisheries of retuning the Revised Management Procedure of the IWC has also been investigated by Scenario Barents Sea experiments (Schweder *et al* 1998). The result suggests that Northeast Atlantic cod catches will be increased by some 100 thousand tonnes annually by retuning from a target carrying capacity for minke whales of 72% to one of 60%.

Icelandic bioeconomic model

This model is described in detail in Baldursson *et al.* (1996) and Danielsson *et al.* (1998). The biological component has a Beverton and Holt model of the cod stock and a Ricker recruitment function. The shrimp stock is estimated using a stock-production model, CPUE data and the estimated biomass of juvenile cod. The capelin stock is modelled using random recruitment and a random stock collapse occurring on average once every seventh year. All biological relationships are modeled using stochastic variables representing the uncertainty of these relationships.

The economic component of the model is rather crude, as is the estimation of costs and revenues. Efforts were made to estimate the price elasticity on the basis of the price of cod on the world market, but the price of shrimp and capelin was assumed to be constant. The wages of the seamen at the time (1993) were assumed to reflect accurately the opportunity cost of their labour, but this cost was assumed to remain constant during the simulation period of 25 years. This means that the sharing rule for renumerating seamen was assumed away and that technological progress in the fisheries and in the rest of the economy was assumed to be equal and equal to the increase in real wages. No uncertainties were included in the economic part of the model, although this has been done to some extent in unpublished work.

Simulation models of this kind need catch rules for the stocks involved. The catch rule for capelin in Iceland is to leave 400,000 tonnes of mature capelin to spawn each spring. The catch rule devised for shrimp was to increase or decrease the catch of shrimp as the cod decreased or increased their consumption of shrimp. This has since been improved by introducing a catch rule that aims at catching the increment in shrimp biomass less the consumption by cod and including uncertainty into the rule.

The main object of the project was to devise a catch rule for cod which was reasonably close to giving optimal economic benefits from the exploitation of these stocks. The catch rules considered expressed the catch of cod as a function of the cod stock biomass only. As the model included stochastic variables, efforts were made to measure economic benefits in terms of aversion to fluctuations in income and maintaining the present value of profits. As Iceland was experiencing some unemployment at the time, the model was used to analyze economic benefits from the fishery assuming that the opportunity cost of labour was zero for an 11 year adjustment period. The model showed that economic benefits (resource rents) were maximized by allowing the cod stock to grow, which increased profits as the cost of catching cod decreased.

CAPSEX

Capsex is an age distributed model for Barents Sea capelin, where the maturation is modelled by maturity ogives calculated from yearly age-length estimates using a length-dependent maturation model. The model also includes a dynamic sub-model for cod and the influence of herring on capelin recruitment. Capsex generates input to the spreadsheet model CapTool, which is used in the management of the capelin stock. At present, work is being undertaken to include harp seals in the model, which would make it a possible tool for studying the economics of harvesting in the cod-capelin-seal system of the Barents Sea.

ii. Limitations of models

The Working Group noted that multispecies models, while useful and informative, suffered from several limitations:

- Some models (MULTSPEC, BORMICON) have very high input data requirements, requiring costly annual surveys of fish abundance, distribution and stomach contents.
- Updating and maintenance of some models is costly and time consuming.
- Such models have not yet proven to be predictive for most fish species in the medium or long term.
- Multispecies models are dependent on the quality of the input data, and in the case of consumption by marine mammals, these data are not very good.
- Uncertainties are not always fully incorporated into the models.

- The levels of spatial and temporal aggregation are not always appropriate for use with marine mammals, or for linkage with economic models.
- In order to be linked with economic models, multispecies models must incorporate fixed “catch rules” for fisheries, and cannot deal with variable or other management strategies. However the assumption of a fixed catch rule over a long period is probably not realistic.

iii. Future directions in multispecies modelling

Multispecies models have multiple uses. In the present context, their use as testbeds for proposed management strategies are particularly important. When used as a testbed, the model should capture the main dynamics and interactions in the biology/economy in the system under various management strategies, and also the main stochasticity. It is not necessary for the model to give a very detailed representation of the system. A rough and flexible model that is cheap enough to be run in hundreds of replicates might be more useful than a more detailed and realistic model that is expensive to run and maintain and for which input data may not exist. The more realistic the model is the better, however.

As a testbed, the model must have an adequate representation of the interplay between the fishermen and the resources. It is important that the fishing-related mortality and catch rates resulting from a given management strategy in a given situation are reasonably modelled. The fishing mortality, and collateral mortality associated with fishing, are the main interactions between fishermen and the resource. In some contexts, habitat impacts like destruction of coral reefs might also be of interest. In the present NAMMCO context where the issue is the indirect effect on finfish fisheries of a change in sealing or whaling, it is vital that the predation structure of the model is realistic. It is mainly through predation and competition for food that a change in marine mammal populations leads to changes in fishery performance.

For the North Atlantic, the following species seem to be natural candidates in a scenario model: minke whales, harp seals, cod, capelin, herring and shrimp. We have inadequate knowledge of diet preferences for several of these species. The situation is perhaps worst for harp seals. Stomach contents have been sampled, but only in areas where the seals are hunted, which is only a small part of their range. Only through behavioural studies may it be possible at present to learn about diet preferences in harp seals. In recent years, A.S. Blix and his colleagues in Tromsø have obtained extensive telemetric data on harp seals from satellite tagged individuals. By correlating the distribution in time and space of harp seals and various prey items, one might obtain valid estimates of the predation function of the harp seal. The same approach might be taken for minke whales, but for this species the sampled stomach data represents a more unbiased picture. There is thus a need to obtain temporal/spatial abundance data for the various potential predator and prey species. The statistical work involved in estimating predation functions might well be done outside the multispecies model. The same is true for other statistical work necessary to obtain a satisfactory model for recruitment and other biological processes. Much of this work is already done or is underway, and need not be replicated.

The model should incorporate important economic relationships to realistically translate management strategies to realised mortalities and catches. There is insufficient knowledge concerning how fishermen, whalers and sealers adapt to a given situation with respect to resources, management decisions and other economic realities. Substantial work is needed to obtain good data and to estimate production functions, cost functions, investment behaviour and other related activity.

Uncertainty and stochastic variability are key terms in marine resource management. Fluctuation in the resource must be modelled in stochastic terms. Statistical uncertainty in abundance estimates and other estimates that feed into the management strategy and **influences** management decisions are also most naturally represented stochastically. However, in addition to uncertainties surrounding the scenario model itself, both in its structure and its parameterisation that can be represented stochastically, there are often more profound and unquantified uncertainties due to lack of data or even lack of theory. Whether a Bayesian approach is taken with replicate runs of the model based on drawings from a subjective prior distribution, or whether a less formal approach is taken with replicate runs chosen according to an experimental design representing plausible scenarios, is a matter of choice and of convenience.

8. ECONOMIC EVALUATION OF MARINE MAMMAL FISHERIES

i. The harp seal fishery

Northwest Atlantic

SC/8/EC/20 used a simple bioeconomic model to measure the loss to a fishery from the reduced harvesting of economically important species resulting from an increase in the stock of a mammalian predator, using the example of the harp seal – cod – capelin interaction in the Northwest Atlantic. As well as direct losses, when the economically important species is the prey, there may be indirect losses when the mammal and a fish predator compete for prey. The economic losses depend critically on the management of the predator and prey fisheries. However, when both predator and prey fisheries are managed so as to maximize the combined fishery rents, a simple formula for the cost of predation can be developed. Using recent data on seal predation developed by the Canadian Department of Fisheries and Oceans, it was estimated that, including compensation to sealers, the permanent cost to the capelin and cod fisheries from a renewed ban on sealing upon recovery of these fisheries is in the range $10-19 million, 3-7 percent of the 1990 value of the cod and capelin harvests. An additional loss of $1.4 to $3.6 million applies for each year that seal predation delays the recovery of the stocks in question.

This model was considered by the Working Group to be a useful first step in evaluating the economic impacts of predation and competition in a fishery. However, the Working Group noted that uncertainties were not incorporated explicitly into the model and that these were likely considerable. To calculate economic losses, it is assumed that the fisheries are managed optimally to maximize economic benefits. Although this is never realized in practice it is an important benchmark. Finally, the valuation of the harp seal fishery itself was questioned, as there have been several estimates published, some of which differed by orders of magnitude (see below). It was suggested that it may have been undervalued in this case.

Economic value of the Canadian seal hunt

There were several estimates of the net economic benefit of the Canadian seal hunt during and subsequent to the 1982 seal product boycott. The 1986 Canadian Royal Commission on Seals and Sealing, for example, estimated a net economic benefit to Newfoundland of $2.3 million (Canadian dollars) and to the Canadian Atlantic region of $3.2 million (all values given are nominal for the given year). An important assumption underlying these estimates was that the opportunity cost of labour for sealers was zero; meaning that if they weren't sealing there was no alternative occupation of any value (even leisure or education).

With the recent increase of the harp seal quota to 275,000 animals, the issue of the net benefit of sealing has resurfaced. The Canadian Department of Fisheries and Oceans (DFO) prepared benefit estimates relating to the 1996 and 1997 seasons. They found that $10.8 million was spent by the harvesting, processing and transportation sectors in respect of the 1996 seal hunt, of which $9.1 million was the final processed value, rising to $11.9 million in 1997. The processing sector spent $9.0 million in 1996 on labour, transport and operating expenses. Although there is no explicit net benefit figure given, the study implies that the 1996 benefit to Canada was at least $9 million. This relates only to the direct benefits of hunt itself, and does not include any indirect benefits for fishing communities.

An alternative (and much lower) estimate of 1996 seal hunt benefits has been prepared by Clive Southey of the University of Guelph in Canada (Southey MS 1999). His $8.96 million processed value compares with the $9.1 million from DFO, but he correctly subtracts $2.65 million in purchases from the rest of the economy on the part of the harvesting, transport and processing sectors to get value added of $6.31 million, which represents the gross returns for labour and capital in all three activities. He does this because value added represents the true contribution of each sector to the economy, avoiding the double-counting involved with inter-sectoral purchases. He then subtracts $1.72 million in meat subsidies and $1.67 million in government expenditures directly related to sealing (both items paid by taxpayers) to get net value added of $2.91 million, which compares with the Royal Commission estimate above.

Value added is not, however, an estimate of true net economic benefit because the latter subtracts the opportunity cost of keeping the labour and capital in the sealing industry. If labour and capital could earn more than $2.91 million in another occupation, then this is preferred to sealing and the NEB of sealing would be zero. Southey does not attempt to estimate the opportunity cost of labour and capital, except to point out that the NEB from sealing would be zero if people could earn at least 46% of their sealing income somewhere else. If the value of seal organs (penises) is subtracted from value added on ethical grounds, then the cut-off opportunity cost is 31% of value added. However, he also shows that entry into the sealing industry is open, which implies low economic returns. Southey's net benefit estimate for the 1996 seal hunt is thus somewhere below $2.91 million, depending on assumptions about the alternatives for sealers and the true social value of the trade in seal organs.

Northeast Atlantic
There was no economic information available to the Working Group on the harp seal fisheries in the Northeast Atlantic.

ii. The minke whale fishery
SC/8/EC/17 described the economics of the Norwegian minke whale hunt, while SC/8/EC/21 updated that report to the year 1999. The hunt has been generally profitable for participants since its resumption in 1993. However, gross revenue per whale in the traditional fishery has declined from a high of over NOK 90,000 in 1993 to NOK 41,000 in 1999, mainly due to a decline in the price of whale meat as a consequence of increased quotas, and a lack of market for other whale products. This decline in revenue per whale has been partially offset by higher vessel quotas. In 1999, the average number of whales harvested per vessel was 17.32 as compared to 5.7 in the traditional hunt in 1993. Net revenue per vessel has remained at a reasonable level.

iii. Identification of information gaps
The most important information gap identified was the lack of data on the economic status of the Northeast Atlantic harp seal fisheries, both from Norway and Russia. It is likely that price data would be available from both jurisdictions, but that information on costs would be more difficult to obtain.

9. Development of a predictive model

i. Modelling framework and specifications
The Working Group considered that it was possible to incorporate consumption by marine mammals in an existing multispecies model, and to link it to an economic component describing the performance of fisheries. Indeed, this had already been done in some limited cases. However, the utility of the model would be limited by the quality of the input data, and this was problematic especially for the estimates of marine mammal consumption in most areas.

It was noted that the multispecies and economic models generally operated on different time scales: monthly for the ecological models, and annually for the economic models. However, it was considered that there would be little loss in aggregating the time scale of the ecological models to facilitate linkage.

The issue of incorporating the behaviour of fishers as "profit maximizing agents" was discussed briefly by the Working Group. Fishery regulations, catch rules, international agreements and codes of conduct influence and modify the behaviour of fishermen. At present it will be of interest to incorporate different management strategies into economic models.

The Working Group noted that reliable consumption data was available only for minke whales and harp seals, and then only in certain areas. The main fish species for which significant fishery interactions are likely to occur with these species of marine mammals, are herring, capelin, cod and shrimp. It was therefore decided to limit consideration of multispecies-economic models to these species only.

ii. Data needs

The Working Group noted that the following types of economic data were needed to define the economic components of a multispecies-economic model:

- Prices for fish and marine mammal products
- Catch rates/time series for fish and marine mammals over as many years as feasible
- Costs, including:
    - input prices- trip costs
    - days fished, fuel, bait, etc
    - allocation of costs to various fisheries, by season length, days fished, fuel consumption or other
    - the above costs should consider vessel size as a co-variate if relevant
- Catch rates and costs should be expressed by vessel for as many vessels and years as feasible
- Management regime, quota structure, ITQ's, and catch rules for relevant fisheries
- Information on relevant subsidies
- Other data relevant to the economic evaluation of marine mammal - fisheries interactions.

The availability and accessibility of these data for each jurisdiction is described below.

Northeast Atlantic – Norway

Sealing

The sealing industry has been in decline for many years. In the last few years, only two-three boats have participated annually. It has been indicated that new licences may be given to shrimp trawlers, which would involve a change in technology. Up-to-date cost data are not available for Norway, however price data and information on subsidies to sealers are available.

Whaling.

”Traditional” whaling was resumed in 1993. For the subsequent period, price data are available. Cost data are available for a small annual sample of boats; however, it is not possible to separate costs from whaling from costs from other fisheries. Whale blubber is currently mainly put into storage. A future export of blubber (and also whale meat) to, for example, Japan would imply a substantial outward shift in the total demand curve facing the whaling industry, resulting in an increase in prices and values. It should be possible to provide some assessment of these effects.

Shrimp, cod and capelin.

Price data are available both for primary and secondary product forms.

Different technologies are represented in these fisheries. Furthermore, boats will generally be harvesting several species. The Directorate of Fisheries collects data on an annual basis for a sample of boats (different technologies) in different fisheries. For each individual boat there is data on variables such as

-total harvest and harvest by species (quantities as well as revenues)
-costs (fuel, labour, capital, maintenance etc.) and
-some technical attributes (boat size, engine hp etc.).

The Centre for Fisheries Economics has used data of this kind to estimate cost functions for other fisheries. There are some problems with the data set:

- no information is available on quantities of inputs (ie. there is information about fuel expenditures, but not quantity of fuel used)
- the costs are annual costs and not seasonal, which makes it difficult to distinguish between fisheries for different species.

These constraints need to be taken into consideration when it comes to estimating cost functions.

Northeast Atlantic – Faroes

No information was available from the Faroe Islands.

Central Atlantic – Iceland
Very detailed and recent data were available from Icelandic fisheries. Catch, effort, costs and earnings data, sorted by fleet sector, were available up to the year 1997. Information on the Icelandic management regime for each species was also readily accessible.

Northwest Atlantic – Greenland
Data on the Greenlandic fishing fleet, sorted by region and vessel size, were available up to and including 1997. The data included harvest, prices and gross income to participants. Catch/effort data were also available for some of the main shrimp and finfish fisheries. However, no data on operating costs or the allocation of effort to various fisheries were available.

Northwest Atlantic – Canada
Prices for fish and marine mammal products are available from the Department of Fisheries and Oceans and/or Statistics Canada.

Fishing cost data are old for many of the major fisheries. There have not been recent surveys because many Atlantic fisheries such as that for Northern cod have been closed for a decade.

Catch rates for fish and marine mammals are available from the Department of Fisheries and Oceans, as are season length and days fished. Information on management regime, quota structure, ITQ's, catch rules and subsidies are also readily available. However, there is a major problem for the bioeconomic modelling of the major Canadian Atlantic fisheries in the lack of consistent stock size information. This problem must be solved before modelling of these fisheries is possible.

iii. Pilot project
Having reviewed the available information on consumption by marine mammals, multispecies models and the availability of economic data for fish and marine mammal fisheries, the Working Group concluded that the most efficient way to proceed would be to develop a pilot project limited to a specific area and a few species/fisheries. The specifications for the pilot study could be developed by a sub-committee of the Working Group, and the results evaluated at the next meeting of the Working Group.

The following candidates for a pilot study were considered, based on data availability, model availability and the likelihood of significant marine mammal – fishery interactions:
1. Consumption by minke whales and harp seals in the Barents and Norwegian Seas. Likely fishery interactions are with capelin, herring and cod. The major information gap identified is likely the lack of predation functions applicable under various conditions of prey availability.
2. Consumption by minke whales around Iceland. Likely fishery interactions are with capelin and cod. The major data gaps identified were a lack of area- and season- specific diet data for minke whales, and a lack of data on energy consumption by minke whales. However, this last could likely be addressed with data from other areas.
3. Consumption by harp seals around southeastern Canada. Likely fishery interactions are with capelin and cod. The major data gap identified was the apparent unreliability of recent fishery assessment data for this area, and the lack of multispecies fishery models for this area.

The Working Group concluded that candidates 1. and 2. offered the best chance of providing meaningful and important information on marine mammal-fisheries interactions.

10. Conclusions
The Working Group concluded that significant uncertainties remained in the calculation of consumption by marine mammals, and that this uncertainty was the most important factor hindering the development of models linking consumption with fishery economics. Data quality was highest for minke whales and harp seals in the Barents and Norwegian Seas, pilot whales around the Faroes and for harp, hooded and grey seals off southeastern Canada.

Harp seals and minke whales are the most important marine mammalian consumers of finfish in the Barents and Norwegian Seas. Minke whales are likely the most important consumers around Iceland although the data on diet composition are very limited. Dolphins of genus *Lagenorhynchus* are likely of importance also, but there are too few data on abundance, distribution and diet to assess this quantitatively. Pilot whales are the most important consumers around the Faroes, but here again white-sided dolphins and bottlenose dolphins are probably important consumers. The harp seal was the most important consumer in most areas of Greenland, but here data were too sparse to express data quantitatively. Harp seals were the most important pinniped predator off southeastern Canada, but the importance of cetaceans in this area has not been assessed.

In addition to these species that undoubtedly are important because of their large consumption, there are also species that might be in more direct conflict with fisheries, because of their consumption of valuable fish species of commercial size. The hooded seal is known to be in this category, but both narwhal and sperm whales are also known to eat commercially interesting fish. This potentially makes narwhal important consumers in the Baffin Bay, and sperm whales so in the Norwegian Sea, but no data on their diets are available from these areas. Killer whales appear to be important predators on herring in Icelandic and adjacent waters and humpback, pilot and sperm whales may also be important consumers of commercial fish species.

Consumption by marine mammals was similar to fisheries landings in some areas. While this does indicate that there is at least a potential for interaction between marine mammal predation and fisheries, the magnitude of marine mammal predation must be put into the context of total natural mortality for the target species. For example, while minke whales and harp seals may be important predators on cod and capelin in some areas, cod are likely of far greater importance as predators for both species (SC/8/EC/8).

Multispecies models presently in use or under development in Norway and Iceland offer a means of assessing the impact of marine mammal predation on fish stocks, and preliminary investigations in this area have already been conducted (e.g. SC/8/EC/14, Stefánsson *et al.* 1997). Furthermore, such models can be linked to fisheries economic models to assess the impact on fisheries. The Working Group concluded that, for certain selected areas and species, there was sufficient data on marine mammal consumption, stock dynamics of prey species, and the economics of the fisheries themselves, to make this a realistic proposition.

The Working Group therefore recommended that the next logical step in addressing the request from NAMMCO Council should be for NAMMCO to lead or assist in the development of a multispecies-economic model for a candidate area. A subcommittee of the Working Group could be tasked with developing the specifications for such a model. The candidate species/areas identified, in order of preference, were:

1. Consumption by minke whales and harp seals in the Barents and Norwegian Seas. Likely fishery interactions are with capelin, herring and cod. The major information gap identified is likely the lack of predation functions applicable under various conditions of prey availability.
2. Consumption by minke whales around Iceland. Likely fishery interactions are with capelin and cod. The major data gaps identified were a lack of area- and season- specific diet data for minke whales, and a lack of data on energy consumption by minke whales. However, this last could likely be addressed with data from other areas.

11. Adoption of report

The Report was adopted by correspondence on May 9, 2000.

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Appendix 2

Working Group On The Economic Aspects Of Marine Mammal - Fisheries Interactions

Agenda

1. Chairman's welcome and opening remarks.
2. Revision and adoption of Agenda
3. Appointment of Rapporteur
4. Historical background and the request from NAMMCO Council

Part 1 – Who eats whom in the North Atlantic?

5. Consumption by marine mammals in the North Atlantic- Available data
   i. Northeast Atlantic- Barents and Norwegian Sea
   ii. Northeast Atlantic- Faroe Islands
   iii. Central Atlantic- Iceland
   iv. Northwest Atlantic
6. Consumption by marine mammals in the North Atlantic- Major information gaps.
7. Existing multispecies models for the North Atlantic
   i. Description of models
   ii. Limitations of models
   iii. Future directions in multispecies modelling.

Part 2 – Linking the ecology with the economy

8. Economic evaluation of marine mammal fisheries
   i. The harp seal fishery
   ii. The minke whale fishery
   iii. Identification of information gaps.
9. Development of a predictive model
   i. Modelling framework and specifications
   ii. Data needs
   iii. Pilot project
10. Conclusions
11. Adoption of report.

Appendix 3

Working Group On The Economic Aspects Of Marine Mammal - Fisheries Interactions

List of Documents

SC/8/EC/1	List of Participants
SC/8/EC/2	Draft Annotated Agenda
SC/8/EC/3	Draft List of Relevant Documents
SC/8/EC/4	Frie, A.K. Consumption tables for the Barents and Norwegian Seas.
SC/8/EC/5	Rosing-Asvid, A. Consumption tables for Greenland waters (Year 2000).
SC/8/EC/6	Víkingsson, G.V. and Þórðarson, G. Consumption tables for Icelandic waters.
SC/8/EC/7	Bloch, D. and Mikkelsen, B. Consumption tables for Faroese waters.
SC/8/EC/8	Bogstad, B., Haug, T. and Mehl, S. 2000. Who eats whom in the Barents Sea? *NAMMCO Sci. Publ.* 2: In Press.
SC/8/EC/9	Folkow, L.P., Haug, T., Nilssen, K.T. and Nordøy, E.S. 2000. Estimated food consumption of minke whales *Balaenoptera acutorostrata* in Northeast Atlantic waters in 1992-1995. *NAMMCO Sci. Publ.* 2: In Press.
SC/8/EC/10	ICES International Council for the Exploration of the Sea. 1999. Report of the Working Group on Marine Mammal Population Dynamics and Trophic Interactions. ICES CM 1999/G:3
SC/8/EC/11	NAMMCO. 1997. Report of the Fifth Meeting of the Scientific Committee. In: NAMMCO Annual Report 1997, NAMMCO, Tromsø, 1999. pp. 85-202. [Excerpts]
SC/8/EC/12	NAMMCO. 1999. Report of the Sixth Meeting of the Scientific Committee. In: NAMMCO Annual Report 1998, NAMMCO, Tromsø, 1999. pp. 89-131. [Excerpts]
SC/8/EC/13	Nilssen, K.T., Pedersen, O.P., Folkow, L.P. and Haug, T. 2000. Food consumption estimates of Barents Sea harp seals. *NAMMCO Sci. Publ.* 2: In Press.
SC/8/EC/14	Schweder, T., Hagen, G.S. and Hatlebakk, E. 2000. Direct and indirect effects of minke whale abundance on cod and herring fisheries: A scenario experiment for the Greater Barents Sea. *NAMMCO Sci. Publ.* 2: In Press.
SC/8/EC/15	Sigurjónsson, J. and Víkingsson, G.A. 1997. Seasonal abundance and estimated food consumption by cetaceans in Icelandic and adjacent waters. *J. Northw. Atl. Fish. Sci.* 22:271-287.
SC/8/EC/16	Hammill, M.O. and Stenson, G.B. Estimated prey consumption by

harp seals (*Phoca groenlandica*), hooded seals (*Cystophora cristata*), grey seals (*Halichoerus grypus*) and harbour seals (*Phoca vitulina*) in Atlantic Canada.

SC/8/EC/17 Bjørndal, T. and Conrad, J.M. 1998. A report on the Norwegian minke whale hunt. *Mar. Pol.* 22:161-74. (With update)

SC/8/EC/18 Flaaten, O. and Stollery, K. 1996. The economic costs of biological predation. *Environmental and Resource Economics* 8:75-95.

SC/8/EC/19 Hovelsrud-Broda, G. Re. Agenda Item 4: Background and request from NAMMCO Council.

SC/8/EC/20 Stollery, K. The economic costs of predatory competition: Theory and application to the case of harp seal (*Phoca groenlandica*) predation on fish Stocks in the North-West Atlantic

Other References:

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