Northwest Atlantic Fisheries Organization

Serial No. N5401 **NAFO SCR Doc. 07/49**

SCIENTIFIC COUNCIL MEETING – JUNE 2007

Current Research on the Impact of Pinnipeds on Commercial Fish Stocks in the Northwest Atlantic

By

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Abstract

The impact of marine mammals, particularly seals, on the recovery of depleted fish stocks is a controversial issue and the focus of significant research efforts. Three species of seals are considered important predators in the northwest Atlantic, harp, hooded and grey seals. Harp and hooded seals are seasonal migrants that have shown little or no increase in abundance over the past decade. Grey seals are residents of temperate waters that, after a number of decades of exponential growth, are beginning to show signs of density dependent reductions in growth rates. Consumption of important prey species by seals Atlantic Canada has been estimated using bioenergetics models. Harp seals are important predators in Divisions 2J3KL and 4RS while grey seals are the most important pinniped predator in 4T and 4VsW. Hooded seals feed primarily in 2J3KL and 3M. Recent advances in methods of estimating diet have provided new insights into the importance of individual prey species that will require new estimates of consumption. A number of studies have attempted to determine the impact of seals on fish stocks in the northwest Atlantic, particularly the impact of harp and/or grey seals on Atlantic cod. In general, these studies have indicated that although seals consume substantial amounts of commercial fish species and important forage species, the impact of these removals on the current fish stocks is difficult to determine. Seals are important predators of both large and small cod and could be playing a role in the non-recovery of cod stocks, but seal predation can not account for a large component of mortality in most areas and therefore, the total impact of seal predation cannot be determined. Often, estimates of age specific cod consumption by seals are inconsistent with the high mortality observed among older age groups. Little is known about the functional response of seals to changes in abundance of prey, other sources of mortality, or possible ecosystem effects such as competition for forage fish and positive feedback through seal predation on piscivorous fish. Among other initiatives, the Canadian Department of Fisheries and Oceans and NAFO are organizing scientific meetings in the coming year to improve our understanding of the role seals are having on the population dynamics of their prey.

INTRODUCTION

The potential impact of marine mammals on fish stocks is an issue that has been debated for decades (e.g. see Malouf 1986). Over the years, bounty programs and culls to reduce predator populations have taken place in many areas, including Atlantic Canada. For example, harbour seals were subjected to a bounty from the 1940s through the late 1960s which resulted in a significant decrease on populations (Boulva and McLaren 1979), while Gulf of St. Lawrence grey seals were culled during the 1980s in an effort to reduce consumption of commercial fish stocks (Hammill et al. 1998). In recent years this debate has become more intense due to the large declines that have occurred in many important fish stocks. Although there was some speculation that harp seals contributed significantly to the collapse of cod stocks, this is not supported by more recent analyses (e.g. Mohn and Bowen 1996, Shelton and Lilly 2000, Fu et al. 2001, Trzcinski et al. 2006). However, there is concern that predation by

marine mammals, particularly seals, are impeding the recovery of depressed fish stocks. Predation is obviously an important component of natural mortality for many of these species, but the question remains as to degree to which predation by seals is contributing (directly or indirectly) to the continuing high levels of mortality observed, i.e. to what extent these populations are controlled by these top-down effects (e.g. Frank et al. 2007).

Over the past two decades, considerable research has been carried out to try to clarify the role seals have on the population dynamics of their prey. In 2006, the NAFO Scientific Council was asked to provide an overview of present knowledge related to role of seals in the marine ecosystem of the Northwest Atlantic and their impact on fish stocks in the NAFO area. The objective of this paper is to provide a review of recent studies that have attempted to address this issue.

IMPORTANT SEAL SPECIES IN THE NORTHWEST ATLANTIC

Harp seals

Harp seals (*Pagophilus groenlandicus*) are the most abundant marine mammal in the North Atlantic. Three putative populations, based upon the location of their pupping areas, are recognized: the White Sea/Barents Sea, the Greenland Sea and the Northwest Atlantic. In the northwest Atlantic, harp seals are seasonal migrants, summering in the waters of the eastern Canadian Arctic and along the west and southeast coasts of Greenland (Sergeant 1991; Stenson and Sjare 1997). In the fall and early winter, seals migrate southward along the continental shelf to Newfoundland, the Grand Banks and into the Gulf of St. Lawrence. Following pupping (March) and moulting (mid April – late May), harp seals migrate northward again.

Harp seals are the primary species taken in the commercial seal hunt in Atlantic Canada. After a decade of limited hunting, catches increased in the mid 1990s and between 1996 and 2002, an average of 237,900 harp seals was taken annually (Stenson 2005). In recent years, catches have increased to an annual average of 333,400 for the period 2003-2006. In 2007, the harp seal quota was reduced to 270,000. Although limited data are available on catches in the Canadian Arctic, they appear to be relatively low (generally <5,000); a recent study indicates that current catches average less than 1,000 per year. In addition to Canadian catches, harp seals are also taken in Greenland. Prior to 1980, catches in Greenland were consistently less than 20,000 animals. Since 1980, Greenland catches increased relatively steadily to a peak of over 100,000 in 2000. In recent years, catches have declined to just under 70,000 (Stenson 2005).

Abundance of harp seals is estimated using a population model that incorporated known levels of mortality and age specific reproductive rates with independent estimates of pup production. Using pup production estimates since the late 1970s, reproductive rates since 1960 and human induced mortality (catches, by-catch in fishing gear and struck and lost) since 1952, Hammill and Stenson (2005) estimate total abundance for the period 1960 - 2004. The harp seal population declined during the 1960s to a minimum of less than 2 million in the early 1970s, and then increased steadily to 1996. From 1996 - 2005 the population remained relatively stable at the highest values in the time series, and possibly its highest level since commercial exploitation began in the 1700s. The estimated total population size in 2005 was 5.82 million (95% CI= 4.1-7.6 million). Recently, Hammill and Stenson (unpublished data) updated this model to 2007. Their data indicate that the population has declined slightly to 5.43 million (95% CI= 3.3-7.5 million) due to the high level of catches in recent years and poor ice conditions that have resulted in increase pup mortality (Fig. 1).

Hooded Seals

Hooded seals (*Cystophora cristata*) are the second most abundance pinniped in the northwest Atlantic. Like harp seals, Northwest Atlantic hooded seals are also seasonal migrants wintering in the Gulf of St. Lawrence and off the east coast of Newfoundland and/or southern Labrador. However unlike harps, after pupping and breeding in March hooded seals spend the next 2 months feeding before eventually migrating to southeast Greenland where they moult in late June – July. Also unlike harp seals, hooded seals inhabit shelf edges and deep waters areas of the Labrador Sea and Baffin Bay. In southern areas, they are often found along the edge of the Grand Banks and Flemish Cap where they dive to depths of over 1500m (Stenson et al. unpublished data).

Hooded seals are killed during a subsistence harvest in Greenland and a commercial hunt in southern Canadian waters. Although over 12,000 were taken annually between 1974 and 1982, current Canadian harvests are very low being less than 100 per year (Stenson 2006). Only 5 hooded seals were reported taken in 2006. The majority of hooded seals are caught in Greenland; with the exception of three years (1996-98) annual catches in Greenland have averaged a little over 8,000 seals since 1982 (Stenson 2006).

Northwest Atlantic hooded seals pup in the southern Gulf of St. Lawrence, off Newfoundland and in the Davis Strait. Hammill and Stenson (2006) present a population model incorporating pup production estimates since the 1980s, reproductive rates and human induced mortality (catches, by-catch in fishing gear and struck and lost) to estimate total abundance for the period 1960 - 2005. Fitting to pup production estimates from all three whelping areas and making assumptions about numbers of hooded seals in the Davis Strait herd for years when this area was not surveyed resulted in an estimated total population of 475,400 (95% C.I.=344,500-606,300) in 1960. The population has remained fairly stable over the past 40 years, increasing to only 592,100 (95% C.I.= 404,400-779,800) by 2005 (Fig. 2). Unfortunately, there is considerable uncertainty associated with these estimates which results from a lack of understanding of the relationship between the three pupping areas, few surveys of all areas, limited reproductive data and uncertain harvest statistics.

Grey Seals

A third seal species that has been identified as having an impact of northwest Atlantic fish stocks is the grey seal (*Halichoerus grypus*). Unlike harp and hooded seals, grey seals do not undergo extensive migrations, remaining in southern Canadian waters throughout the year. The majority of northwest Atlantic grey seals pup on Sable Island or in the southern Gulf of St. Lawrence. Although they are large seals, only slightly smaller than hooded seals, they are mainly found in the relatively shallow water of the Gulf of St. Lawrence and on the Scotian Shelf were they feed on a range of pelagic and demersal fish (Austin et al. 2004; Trzcinski et al. 2006; Beck et al. 2007).

Although there is a commercial hunt for grey seals in Canada, catches are small. In 2006 reported catches were less than 1,000 although information from buyers and producers suggest that the catch was between 1,500 and 2,000. An unknown number of additional grey seals are taken annual through nuisance seal permits issued by DFO.

Although not independent populations, the Sable Island and Gulf of St. Lawrence components of the northwest Atlantic grey seal population show different population trajectories. Pup production in the Gulf was quite variable over time, likely due to changes in pup mortality related to ice conditions. Pup production on Sable Island, which now accounts for the majority of grey seal births, showed an exponential increase in pup production of 12.8% between the early 1960s and 1997 (Bowen et al. 2003). However, surveys in 2004 indicated that the rate of increase has slowed down and that grey seals may be showing density dependent reductions in reproductive rates (Bowen et al. 2006).
The total population of grey seal was estimated to be approximately 260,000 in 2006 (Fig, 3).

IMPACT OF SEALS ON FISH STOCKS IN THE NORTHWEST ATLANTIC

Estimating diet and consumption

The first step in determining the impact of predation is to obtain accurate estimates of consumption with realistic estimates of uncertainty. Prey consumption can be estimated using a bioenergetics model that incorporates information on population size, energetic requirements, diet composition and energy density of the prey, as well as the seasonal distribution of feeding (Harwood and Croxall 1988; Harwood 1992; Hammill and Stenson 2000; Stenson and Hammill 2004, 2006). Using such a model, Hammill and Stenson (2000) estimated prey consumption by four species of seals (harp, hooded, grey and harbour) in Atlantic Canada (NAFO Divisions 2J3KLMNO4RSTVW). They found that harp seals were the most important predator (82% of total consumption), followed by hooded seals (10%), grey seals (7.8%), and harbour seals (0.2%). Regional differences existed with harp seals being most important in Divs. 2J3KL and 4RS, hooded seals were most important in Divs. 2J3KL and 3M and grey seals in the southern Gulf of St. Lawrence (Div. 4T) and on the Scotian Shelf (Divs. 4VsW). Of the 3.1 million tonnes of fish consumed by the four species of seals in 1996, only about 20% was accounted for by

commercial species such as Greenland halibut (7%), Atlantic cod (6%), redfish (4%), and Atlantic herring (3%). Most of the consumption of these commercial species consisted of juveniles. As new data have become available, the consumption estimates for specific areas have been updated (e.g. 2J3KL Stenson and Perry 2001; 4T Hammill and Stenson 2002; 4RS Hammill and Stenson 2004) although the focus of these latter study has been Atlantic cod.

Buren et al. (2006) analyzed stomach content data from harp seals collected off the coast of Newfoundland between 1992 and 2001. They found that year, age group (pups, juveniles, adults), zone (Divisions 2J3K, 3LMNO), area (inshore, offshore) and season (summer, winter) all had significant effects on the probability of a given prey to be dominant, by weight, in a stomach content. These results support the structure of the consumption model used by Hammill and Stenson (2000) and Stenson and Perry (2001). When the analysis was focused on the presence/absence of Atlantic cod, year and season (i.e. temporal variation) did not have a significant effect on the likelihood of eating cod, i.e. the proportion of seals eating cod did not significantly changed over time. However, the probability of Atlantic cod being a dominant prey increased over time. This can be explained by the observations that the size of the cod consumed has increased, possibly reflecting changes in the structure of the Atlantic cod population in the area.

Accurate estimates of diet are crucial for realistic estimates of prey consumption. However, all methods of diet analysis have inherent biases that limit our ability to obtain realistic estimates of diet. For example, diets obtained from the analysis of hard parts (HPA) found in stomachs or feces are affected by differential digestion and retention of hard parts; prey with large robust otoliths are often overestimated while prey with small, fragile otoliths are underestimated. Soft-bodied prey, or prey in which the heads are not eaten, can be missed completely. The development of new techniques such as the use of stable isotopes, fatty acid signatures or DNA PCR analysis (e.g. Beck et al. 2005, Hart 2007) provide new ways of viewing the diet of predators, often over longer time frames, that can supplement or replace traditional diet estimates. For example, using fatty acid signatures Beck et al. (2005) found significantly lower levels of cod in the diet of grey seals on the Scotian Shelf than previously assumed based on hard part analysis of feces (11.4 – 15.2% vs 0-4.5% for adults and 8.6% for young of year).

Because of their large, robust otoliths, Atlantic cod are likely to be overestimated in the diet of seals. The importance of a prey species is expressed as a proportion of the total biomass (or energy) consumed. Therefore faster digestion of smaller otoliths and lack of soft bodied prey will reduce the proportion of these species in the diet. This, along with the tendency for retention of robust otoliths within the stomachs, would result in a positive bias to the estimated proportion of cod in the diet. Comparing DNA PCR products from the stomach contents of harp seals to hard part analysis, Hart (2007) suggested that traditional methods overestimated the presence of Atlantic cod (i.e. otoliths remain when no DNA are present) while capelin, and to a lesser extent Arctic cod, are underestimated (i.e. DNA present with no otoliths).

The one potential exception to the direction of this bias occurs if seals eat only the soft parts of large fish (referred to as ‘belly biting’) in which case their presence (and size eaten) will be underestimated. Such behaviour has been proposed as an explanation for the apparent high mortality of older cod in areas where seal diet studies indicate that consumption is directed towards younger age classes (e.g. Shelton and Lilly 2000, Rice and Rivard 2003; Chouinard 2005). Harp seals have been observed taking only the soft parts of cod (e.g. Lilly and Murphy 2004), but these observations have been made mainly in areas where high numbers of cod are found in restricted areas. It is not clear how common, or even if, this behaviour occurs in open water areas. In a preliminary study, Hart (2007) did not find evidence of belly biting on cod by harp seals (i.e. DNA present but otoliths absent) but the sample size was limited and additional sampling is required to determine the degree to which this method of feeding may occur.

There are very few datasets that provide information on changes in seal diets over time. However, estimates of consumption are very sensitive to assumptions about how seals respond to changes in prey availability (i.e. the ‘functional response’). Trzcinski et al. (2006) estimated consumption of Atlantic cod by grey seals on the Eastern Scotian Shelf (Div. 4VsW) under the assumptions that either the proportion of cod in the diet was constant over time or that the proportion of cod in the diet decreased hyperbolically with cod abundance. Under the first assumption (constant ration model) cod consumption was estimated to be 5,369 (±9,529 se) tonnes while under the second (functional response model), consumption was estimated to be half (2,899 ± 4,888 se tonnes). Ausseberg (2005) attempted, unsuccessfully, to determine the functional response of harp seals to changes in prey abundance off Newfoundland due to a lack of concurrent high quality data on abundance and diets. Abundance data are poor, or

totally lacking, for important prey species in inshore areas of northeast Newfoundland which is the only area where a extensive time series of seal diets are available.

Updated data on abundance, diets and distribution of harp, hood and grey seals has been collected under the Atlantic Seal Research Program, carried out by DFO from 2002 – 2006. In addition to traditional HPA for diets, fatty acid signatures and stable isotopes are being analyzed to provide alternate descriptions of the diet of these three species. Although analysis of the surveys has been completed (see above), results of the diet and distributional data will not be available until later in the 2007. Once available, these data will improve our ability to provide accurate estimates of consumption by these three seal species.

Estimating impact and multispecies modelling

In order to determine the impact a predator is having on their prey species requires a substantial data on the predator, their prey and other components of the ecosystem. To date, the majority of research has been directed towards estimating the amount of prey consumed by predators. A few researchers have attempted to incorporate this mortality quantitatively into the population dynamics of the prey species, usually treating the predator as another 'fleet' (e.g. Mohn and Bowen 1996; Fue et al. 2001). However, this approach ignores the interactions that can occur within natural systems. Efforts to develop multispecies models either as part of an entire ecosystem (e.g. Ecopath and Ecosym models, e.g. Bundy et al. 2000; Bundy 2001, 2005; Pitcher et al. 2002, Heymans 2003, Morissette et al. 2006) or as a subset of 'critical' species (e.g. miminum realistic models (Koen-Alonso and Yodzis 2005, Punt and Butterworth 1995) have been limited by the lack of available data on most components of the ecosystem. Based on these ecosystem models, harp and hooded (likely grey) seals have been identified as key trophic species that are critical for maintaining ecosystem structure and function (Libralato et al. 2006; Koen-Alonso and Stenson 2006; Koen-Alonso unpublished data). Many of these studies were reviewed at the ICES workshop on the decline and recovery of cod stocks (ICES 2006).

McLaren et al. (2001) reviewed the available data on abundance, diets and consumption of fish by harp, hood and grey seals in Canada. They concluded that seals consume substantial amounts of commercial fish species as well as important forage species (e.g. capelin), but that the impact of these removals on the current fish stocks was difficult to determine. They also concluded that consumption of cod in the northern Gulf (4RS) and off Newfoundland (2J3KL) by harp seals is particularly large and may be contributing to the apparent high levels of mortality exhibited by these stocks. However, they pointed out that many of these fish stocks will probably take a long time to recover to exploitable levels even if all seal predation is removed. Finally, they concluded that a large reduction in harp seal numbers will probably result in a short term increase in cod stocks (and possibly decreases in shrimp and/or crab), but long term impacts are unknown.

In a review of the possible causes of the lack of recovery of cod stocks in Atlantic Canada, Rice and Rivard (2003) concluded that predation by seals is a factor contributing to the high total mortality of cod. However, this conclusion was based primarily on the large, and increasing, size of seal populations, data showing that seals eat Atlantic cod and the lack of information pointing to other factors rather than detailed analysis of the interactions (Lilly 2006).

While trying to account for the high mortality of cod that accompanied the collapse of the northern (2J3KL) cod stock, Shelton and Lilly (2000) concluded that unreported deaths caused by the offshore fishery was the most plausible explanation, but increasing mortality due to seal predation and changes in catchability may also have played a role. Harp seal predation is considered to be contributing to the high total mortality of cod in the offshore and the high natural mortality of adult cod inshore (DFO 2006) even though the available diet data (Lawson et al. 1995; Lawson and Stenson 1997; Stenson and Perry 2001; Buren et al. 2006) indicate that cod predation is primarily on young fish captured inshore.

In general, attempts to incorporate seal predation into cod population models have resulted in inconsistent results. Chouinard et al. (2005) correlated changes in natural mortality (M) estimates with changes in grey seal population in the southern Gulf of St. Lawrence. He concluded that seal predation may be a cause of increase M. However, as in 2J3KL, the seal diet data suggests seals consume mainly juveniles whereas evidence for an increase in M is for larger cod. Also, the estimated amount of cod consumed by seals (Hammill and Stenson 2000, 2002) is lower than required to account for the increase in M. To account for this discrepancy, Choiunard et al. (2005) assumed that the consumption estimates are incorrect due to sampling biases and that seals frequently do not consume the heads of

larger seals. Using an inverse mass-balance model of the southern Gulf, Savenkoff et al. (2007) found that predation by marine mammals on fish increase from the mid 1980s to the mid 1990s while predation by large fish, on fish, decrease. Predation by seals was the main identified source of morality for many species. However, a high proportion (47%) of the total mortality of large cod could not be explained by either fishing or predation which suggests that mortality due to other predators (e.g. cetaceans or large sharks) may be underestimated. They concluded that seals could be playing a role in the non-recovery of cod, but since much of the mortality of large cod cannot be accounted for, the total impact cannot be determined.

Morissette et al. (2006) constructed an Ecopath model of the northern Gulf of St. Lawrence ecosystem in the mid 1980s. They found that harp seals were the third most important predator on vertebrate prey following large Atlantic cod and redfish. They concluded that both marine mammals and fisheries had an impact on the trophic structure during this period which is prior to the collapse of commercially exploited demersal fish stocks.

Early studies of the eastern Scotian Shelf (4VsW) suggested that grey seal predation was impeding cod recovery (Fu et al. 2001) while a subsequent study using a similar cod population dynamics model (Trzcinski et al. 2006) found that grey seals account for only a small, although perhaps significant, fraction of natural mortality. Bundy and Fanning (2005) constructed an ecosystem mass-balance model (Ecopath) of the eastern Scotian shelf to compare ecosystem structure before and after the cod collapse. They found that although grey seals are important predators of both large and small cod, there was a large component of mortality that could not be explained. They also suggested that small cod may compete with sand lance, herring and capelin for food (large zooplankton). As all three of these species are also consumed by seals, it would be difficult to predict even the direction of the change in cod numbers if seal populations change. Using a similar model, Bundy (2005) also found that the majority of mortality on large cod cannot be explained by the model and that the available data do not substantially support the hypothesis that grey seals are a major source of cod mortality. However, she also points out that there is considerable uncertainty in these models due to a lack of data on many important components.

Cetaceans have been identified as important predators in a number of ecosystems (e.g. Laidre et al. 2004; Tjelmeland and Lindstrøm 2005; Witteveen et al. 2006; Kock et al. 2006). Overholtz and Link (2007) estimated that marine mammals, primarily cetaceans, consumed substantial amounts of Atlantic herring in the Gulf of Maine-Georges Bank area, second only to demersal fish. Studies on fin whales, humpback whales, minke whales and harbour porpoise indicate that they consumed primarily sandlance during the 1970s and 1980s, but fed heavily on Atlantic herring once herring stocks improved during the 1990s. Preliminary data indicates Atlantic cod are an important prey of harbour porpoise in the Gulf of St. Lawrence (Lawson and Stenson unpublished data). Based upon mass balance models of the Newfoundland ecosystem, Libralato et al. (2006) and Koen-Alonso (personal communication) identified cetaceans as key tropic species. Unfortunately, due to the lack of recent data, estimates of consumption by cetaceans in the northwest Atlantic are based primarily upon assumptions about abundance and/or diets (e.g. Pitcher et al. 2002; Heymans 2003; Overholtz and Link 2007). Therefore, until new data are available it will not be possible to estimate the true impact of cetaceans on fish stocks or how their consumption relates to that of seals.

Research to identify the impact of marine mammals on fish stocks in other areas are also ongoing. The North Atlantic Marine Mammal Commission (NAMMCO) established a working group to identify data gaps and develop models that can be used to determine the economic aspects of marine mammal-fisheries interactions. The working group has met a number of times to review methods of estimating diet and consumption (including their uncertainty), identify appropriate modelling methods and then to review progress on the modelling. They concluded that better data on diet and consumption were needed before marine mammals could be adequately represented in models and recommended that a general modelling approach involving the use of “minimum realistic” models be used. The most recent meeting was held in 2004 when they reviewed recent developments on diets, consumption, energy requirements and multispecies modelling. Although they recognized substantial improvements in diet data, energy requirements and methods of estimating consumption, the working group noted that available musltispecies models were preliminary and not sufficiently developed for identifying impacts on fish stocks or making management decisions (NAMMCO 2003, 2004).

FUTURE RESEARCH

Although substantial progress has been made in the past decade to improve our understanding of seal fisheries interactions, considerable research is still required. New estimates of abundance are available (Hammill and Stenson 2005, 2006; Trzcinski et al. 2006; Hammill et al. in press) and additional data have been collected on the diet of seals which are currently being analyzed using traditional and new approach such as fatty acid signatures and DNA PCR. Once completed, consumption models can be updated to provide more accurate estimates of prey consumption. Also, the use of fatty acid signatures and DNA analysis of stomach contents will provide data that can be used to determine to what extent 'belly biting' occurs.

Unfortunately, significant data gaps remain that hinder our ability to understand the feeding behaviour of seals. Additional sampling is required to estimate the offshore diets of harp seals, seasonal changes in the diet of grey seals and the diets of hooded seals. Also, the relationship between prey availability and selection by predators (i.e. the functional response) which is critical for predicting the amount of prey consumed and if prey switching may occur, is poorly understood. Concurrent data on diets and prey abundance, over a range of prey levels, are required to quantify these relationships.

Cetaceans have been identified as important predators in many ecosystems. However, we have very little data with which to evaluate the impact of cetaceans on fish stocks; there is limited information on diets, distribution or abundance for most species. An international effort to estimate abundance of cetaceans across the north Atlantic is scheduled for this coming summer. Along with improved data on diets obtained from fatty acid signatures, it will provide valuable data on distribution and abundance of cetaceans that can be used to estimate consumption.

Most importantly, there are significant gaps in our understanding of the prey population dynamics and ecological interactions among the various biological and biological components of the ecosystem. In particular, any estimate of the impact of seals on commercial fish stocks is extremely sensitive to estimates of numbers at age and assumptions about natural mortality and other sources of predation. A common factor to many of the models used to examine this question concluded that cod stocks exhibit high levels of unexplained mortality (eg. Shelton and Lilly 2000; Chouinard et al. 2005; Bundy and Fanning 2005; Savenkoff et al. 2007). Directed research toward explaining this mortality is critical for estimating the impact of seals on these stocks.

To date, most of the research on impacts of seal predation has focused on interactions with Atlantic cod. These approach need to be applied to other prey species that may be impacted. Also, current research has examined direct predation mortality. However, trophic interactions that involve competition between important fish stocks and high level predators may be more important (e.g. Bundy and Fanning 2005; Lilly 2006; Koen-Alonso pers. comm.). Improved multispecies models (either mass-balance or dynamic models) are required to address this issue as well as the potential for positive feedback on the target fish species by seal predation on other fish predators.

Research to address these questions is continuing in many arenas. Scientists are collecting the required data and developing appropriate models to determine the impact of marine mammals on fisheries, as well as the impact of fisheries on marine mammals, in ocean systems around the world (e.g. Alaska Witteveen et al. 2006, Hennen 2006; Norwegian and Barents Seas Nilssen et al. 2000, Tjelmeland and Linstrøm 2005, Sivertsen et al. 2006; North Sea Hansen and Harding 2006; Scotland Butler et al. 2006, Thompson et al. 2007; Namibia Mecenero et al. 2006; Chile Hückstädt and Krautz 2004; Argentina Koen-Alonso and Yodzis; Southern Ocean Kock et al. 2006). The continued development of multispecies models is a priority of the North Atlantic Marine Mammal Commission (NAMMCO 2003, 2004) although the working group has not met recently.

In Canada, the Department of Fisheries and Oceans is hosting a two-part international workshop to review the impacts of seals on Atlantic cod stocks in eastern Canadian waters. The objectives of the workshop are:

1. to review research on the trophic interactions (e.g., impacts of predation) between seals and Atlantic cod stocks in eastern Canada, with a focus on grey and harp seals,
2. to review similar research conducted elsewhere that may provide insight into the effects of grey and harp seal predation on Atlantic cod stocks,
3. to review research on the effects of seal-transmitted parasites as a source of fish mortality,

4. to review research on the negative non-trophic indirect effects of seals on spawning success and feeding behaviour of fish,
5. to review available information on the impact of reductions in seal population size on fish population size and exploitable biomass, and the economics of seal management
6. to consider the design of experimental or other research that would clarify the impact of seals on the dynamics of cod stocks.

The first Workshop, scheduled for November 2007, will review research results and identify data analyses and modelling studies that could be carried out with existing data to more fully address the Workshop objectives. The second Workshop, approximately 9-12 months later, would review these new analyses and modelling results.

In 1995 NAFO and ICES sponsored a symposium on the ecological role of marine mammals. NAFO has proposed to hold a second symposium in the fall of 2008 on the same topic with the objective to bring together oceanographers, marine mammalogists, theoretical modelers, and fisheries biologists, to present and discuss the advances over the past 13 years in understanding the role of marine mammals in the ecosystem. A draft symposium announcement is presented in Figure 4. Together with the Canadian workshop, this symposium will provide an opportunity to ensure that the data gaps that have been identified are being addressed and to review the results of models designed to estimate the impact of seals and other marine mammals on commercial fish stocks.

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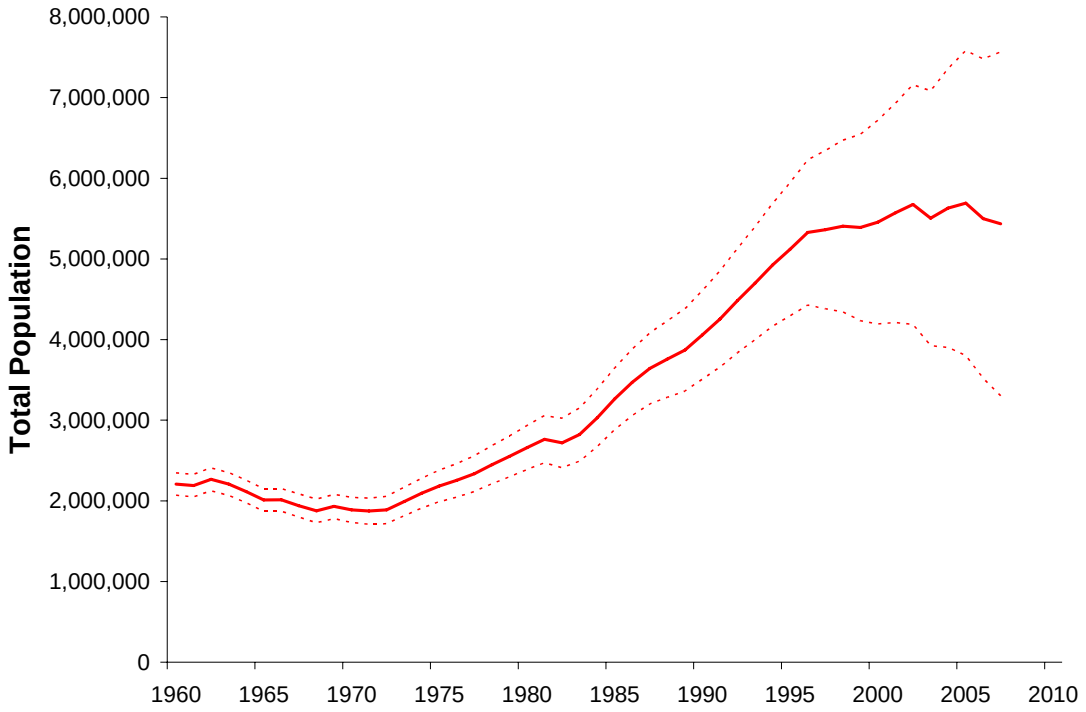

Figure 1. Estimated population size (and 95% C.I.) of northwest Atlantic harp seals 1960 – 2007. From Hammill and Stenson (unpublished data)

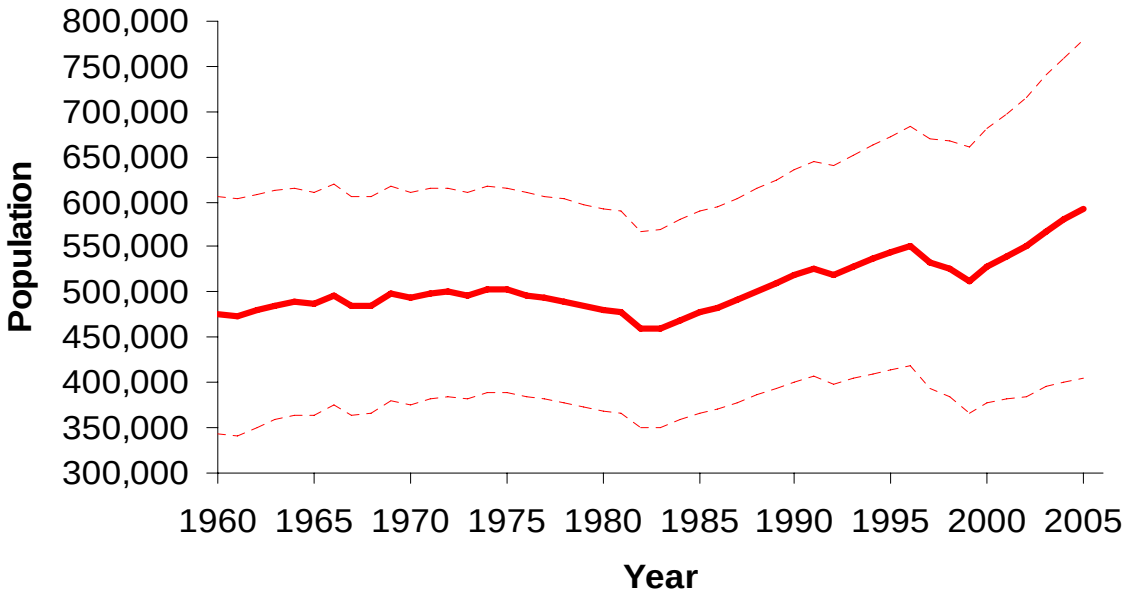

Figure 2. Changes in estimated total population (and 95% CI) of Northwest Atlantic hooded seals between 1960 and 2005 (from Hammill and Stenson 2006).

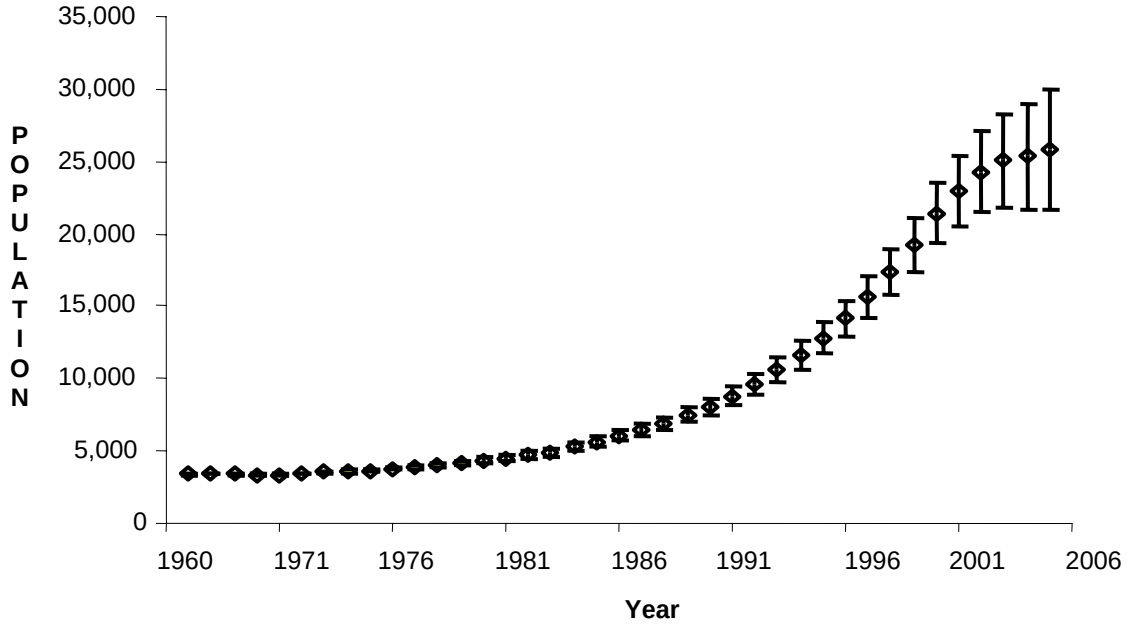

Figure 3. Changes in estimated total population (and 95% CI) of Northwest Atlantic grey seals between 1960 and 2006 (from Trzcinski et al. 2006).

SYMPOSIUM

The Role of Marine Mammals in the Ecosystem in the 21st Century

Hosted by the Scientific Council of the
Northwest Atlantic Fisheries Organization (NAFO)
and
International Council for the Exploration of the Sea (ICES)

29 September – 1 October 2008
venue to be decided

The Northwest Atlantic Fisheries Organization (NAFO) and the International Council for the Exploration of the Sea (ICES), announce a joint symposium on "The Role of Marine Mammals in the Ecosystem in the 21st Century", to be held on 29 September – 1 October 2008, at a venue to be decided.

In 1995 NAFO and ICES sponsored a very successful symposium on the ecological role of marine mammals. Since that time, significant new research has been carried out to address many of the knowledge gaps. The objective of this Symposium is to bring together oceanographers, marine mammalogists, theoretical modelers, and fisheries biologists, to present and discuss the advances over the past 13 years in understanding the role of marine mammals in the ecosystem.

The Symposium will be divided into four theme sessions. Session will begin with invited keynote speakers followed by oral and poster presentations.

- *Environmental, spatial and temporal influences on life history traits*
- *Foraging strategies and energetic considerations*
- *Multispecies models and theoretical considerations on the role of apex predators*
- *Marine mammal-fisheries interactions*

Presentations will focus upon methods to synthesize information from one or several ecosystem components and/or present new approaches to such studies. Papers describing biological and physical components of the environment or methods for species other than marine mammals that are relevant to the theme sessions are included.

Contributed oral and poster presentations are welcome. Abstracts should be submitted by **30 June 2008**. Final papers should be submitted by **31 October 2008** and will follow a scientific review process for publication in a peer reviewed journal. Participants who are not giving presentations must register by **1 September 2008**.

For further information or to express interest in participating please contact one of the following. Program and practical information will be available at www.nafo.int.

Co-conveners

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Figure 4. A draft announcement for a symposium on the role of marine mammals in the ecosystem sponsored by the NAFO Scientific Council and ICES proposed for September 2008.