Operational Conflict between Seals and Fisheries: Recommendations for Approaching the Problem in Atlantic Canada

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Abstract

Conflicts between marine mammals and fisheries occur worldwide. Conflict can be separated into two categories: (i) operational conflict, involving direct physical interaction with fisheries, such as depredation and gear damage, and (ii) ecological conflict, involving indirect interaction, such as competition and transmission of parasites. Seals are perceived to be in both operational and ecological conflict with fisheries in Atlantic Canada, however research and management focuses mainly on the ecological aspect. Thus, the purpose of this project was to create a strategy for approaching the problem of operational conflict between seals and coastal fisheries in Atlantic Canada. To accomplish this, a comprehensive review of the nature and management of operational conflict between seals and fisheries worldwide was completed, which highlighted three case studies. This review showed that damage to fisheries varies both regionally and locally. Damage was not caused by entire populations, but rather a few specialized seals. Many mitigation attempts, such as gear modifications, have proven unsuccessful or have not been appropriately assessed. Overall, involvement of stakeholders, especially local fishermen, was shown to be crucial for development and successful implementation of management plans. As such, it was recommended that the Department of Fisheries and Oceans create a stakeholder forum to facilitate information sharing, fund research that engages fishermen and uses their local knowledge, and create a mitigation plan that focuses on improving the current nuisance seal policy to promote assessment and adaptability.

Keywords: seal, pinniped, fishery, operational conflict, operational interaction, depredation, gear damage

Abbreviations

DFO	Department of Fisheries and Oceans
FAO	Fisheries and Aquaculture Organization of the United Nations
AHD	Acoustic Harassment Device
GiK	Grey Seals in Kvarken
UK	United Kingdom
NQ	Not Quantified
IFMP	Integrated Fisheries Management Plan
NASRC	Northwest Atlantic Seal Research Consortium
US	United States

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Chapter 1: Introduction

Conflict between marine mammals and fisheries is a worldwide problem that has been recorded as far back as second century A.D. (Lavigne, 2003). Interaction between these two groups exists because they often overlap in their distribution, and both target the same resource. It is thought that conflict in recent decades may be increasing as growth of the human population and fisheries overexploitation are unprecedented, and as new conservation policies aid the recovery of some species of marine mammal (Gulland, 1986). These interactions are receiving growing attention, including at the international level where workshops and reviews have focused on the problem (e.g. IUCN, 1981; Northridge, 1984). However, few coordinated management plans have been developed.

Conflict can be harmful to both the marine mammal by endangering individuals or the entire population, and the fishery by causing economic losses and even threatening livelihoods. Interactions between marine mammals and fisheries can be grouped into two general categories: operational and ecological. Operational conflict involves direct conflict that occurs when marine mammals physically interact with the operation of fisheries, for example by removing or damaging fish from gear (depredation) or damaging nets. Ecological conflict involves indirect interaction, including competition by depletion of resources and transmission of parasites (Lavigne, 2003). Table 1 describes the different types of conflict between marine mammals and fisheries.

Table 1: Potential operational and ecological conflicts between marine mammals and fisheries, shown as either mammals cause harm to fisheries or fisheries cause harm to mammals. Modified from Lavigne, 2003 and Königson, 2011.

	Mammals → Fisheries	**Fisheries → Mammals**
Operational Conflict	-Damage to or loss of catches (depredation) -Damage to fishing gear -Disturbance of fish near fishing gear	-Accidental by-catch or entanglement -Harming, harassing or killing by fishermen
Ecological Conflict	-Competition for fish -Repression of threatened fish stock recovery -Dispersal of Parasites	-Food depletion through overfishing -Disturbance in sensitive areas (e.g. feeding and breeding grounds)

Seals are one of the most common marine mammals perceived to interact with fisheries. Operational interactions between seals and fisheries have long been experienced throughout the world (Wickens, 1995). Conflicts often occur with fixed gear coastal fisheries that overlap with seal habitat (Wickens, 1995). These conflicts seem to draw a wealth of stakeholder attention when harm is caused to the fishery, and this is arguably becoming more common in some areas of the world where seal populations are increasing. Operational conflict in which seals negatively impact fisheries will be the focus of this paper, and will hereafter be the type of conflict referred to by the term 'operational'.

Operational conflict with seals can harm fisheries by causing financial losses, both directly and indirectly (figure 1). Depredation and gear damage can cause observable losses when catch is damaged and nets are in need of repair. However, losses that cannot be directly observed by the fishermen, or 'hidden' losses, can also result. These can include things like fish removed completely from gear, fish scared from gear, and fish lost from the net due to gear damage (Königson, 2011).

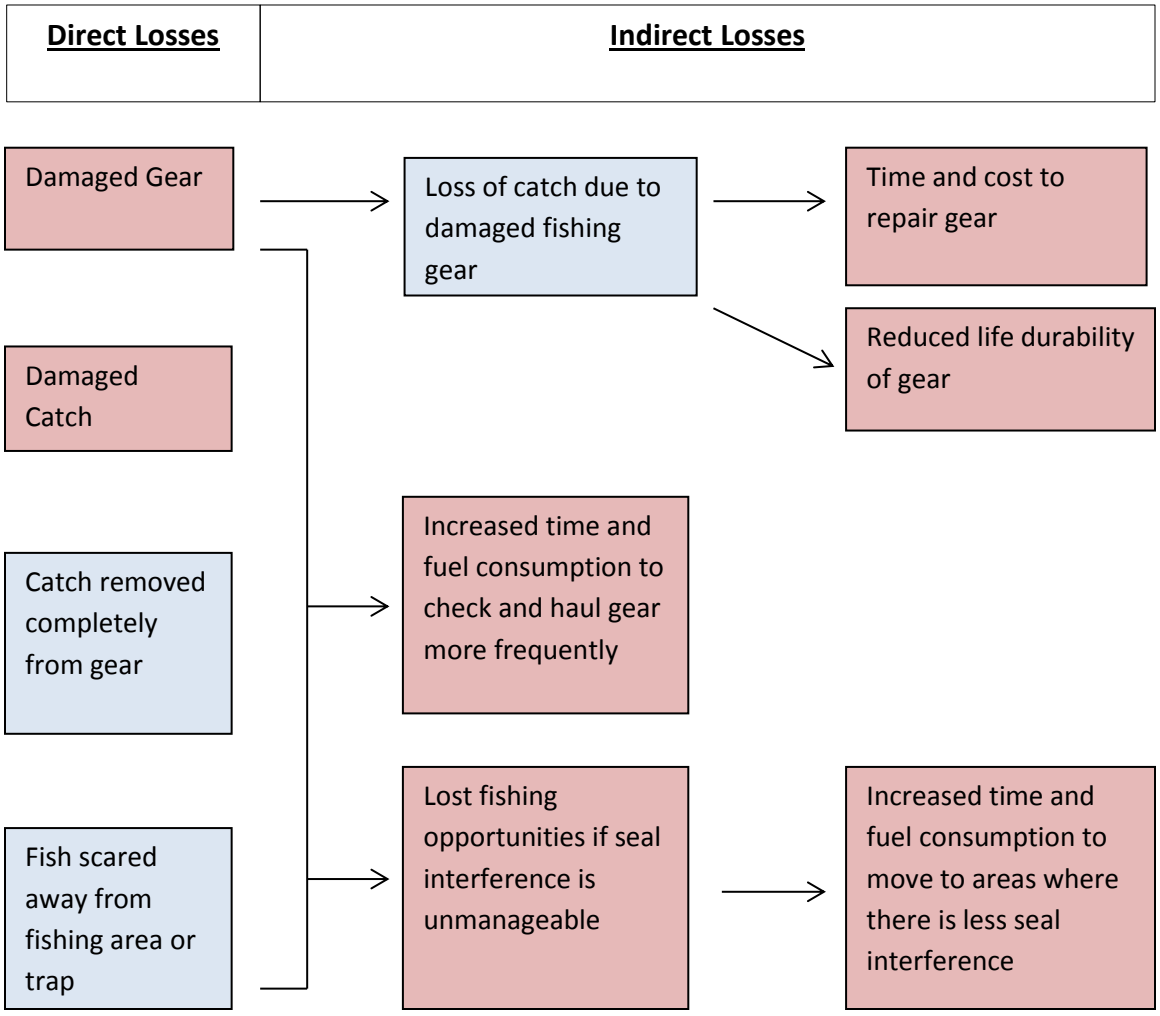

Figure 1: Diagram depicting the different sources of financial loss to fisheries when operational interaction with seals occurs. Direct and indirect losses are shown under the headings; visible losses are represented by pink boxes and hidden losses are represented by blue boxes. Arrows indicate a progressive relationship. Modified from a table in Königson, 2011.

As perceived losses increase for fisheries, efforts to understand operational interaction are increasing, as are efforts to manage conflict in some parts of the world. Management of this type of conflict is complicated, due to uncertainty surrounding potential solutions, and differing objectives of the many interested stakeholders (Gulland, 1986). Often the initial reaction of the fisheries stakeholders is to call for a targeted removal or 'cull' of seals, although they are often controversial, and the ability of a cull to reduce or eliminate operational conflict is highly uncertain (Lavigne, 2003). Innovative, effective ways to manage the conflict between seals and fisheries are needed. Few areas

of the world, including Sweden, Finland, and the Moray Firth region of Scotland, have already developed management plans that focus on mitigating or solving operational conflict between seals and fisheries (Brukmeier & Larsen, 2008; Butler, 2004; Varjopuro, 2011).

Seal populations in Atlantic Canada are some of the largest in the world, making interaction with lucrative Atlantic Canadian fisheries inevitable (DFO, 2006). Ecological conflict, especially grey seals limiting recovery of endangered and commercially valuable Atlantic cod, is perceived by fishermen as a major problem in the region (Matte, 2007). This conflict has received a wealth of attention in the media and political realm, and has become the recipient of much research and management focus. Controversial requests for a seal cull have made this a politically contentious issue in Atlantic Canada. Fishermen also perceive operational interaction with their fishing operations as a serious problem; however this issue has not yet received similar attention (Matte, 2007). Thus, the purpose of this paper is to examine the perceived problem of operational interaction between seals and coastal fixed gear fisheries in Atlantic Canada, and outline recommendations that can be used in a management plan. These recommendations are informed by case studies from other regions of the world that have already made an effort to research and manage operational conflict.

Chapter 2: Methods

A review of the relevant information pertaining to operational interactions between seals and fisheries in Atlantic Canada was completed. This review allowed for a better understanding of the causes of the problem, the status of research, and the management structure in which recommendations must be framed. First, an introduction to seal biology, population status, and the management of seals in Atlantic Canada was given. Review of fishing focused on commercial fisheries as these are most common in the region, and specifically coastal fixed-gear fisheries as these are most likely to experience operational conflict with seals. The potential and perceived interactions were discussed, as well as existing research and management initiatives and outstanding questions. Relevant stakeholders were identified.

A thorough desktop literature review was conducted to gather information on operational interactions with seals in other parts of the world. A review completed for the Fisheries and Aquaculture Organization of the United Nations (FAO) by Wickens (1995) was used to summarize existing research prior to the mid-1990s, allowing this study to focus on more recent information. From the literature review, three regions that experienced operational interactions with similar seal species as Atlantic Canada, and had made at least preliminary attempts to research and manage these conflicts, were identified. These case studies were: the Baltic Sea, the United Kingdom, and the New England region of the United States.

Several aspects of each of these case studies were reviewed: the status of fisheries and seals in the region, research methods and findings, and current management efforts. Personal insights from participation in research efforts in the Cape Cod weir fishery were included in the case study of New England. Advantages and disadvantages of the different research methods and mitigation tools used in the case studies were compiled in the discussion, and were used to guide recommendations for creating a management plan in Atlantic Canada.

Chapter 3: Seals and Fisheries in Atlantic Canada

Seals

Canada's Northwest Atlantic waters hold the largest populations of harp (*Pagophilus groenlandicus*), hooded (*Cystophora cristata*) and grey (*Halichoerus gypus*) seals in the world (DFO, 2006). Although all of these species were depleted due to hunting in the 19th and 20th century, the herds have shown substantial recovery and are now at some of their highest abundances on record (DFO, 2006). Smaller numbers of harbour seals (*Phoca vitulina*) also frequent Atlantic Canada. All of these seal species consume a wide variety of fish, many which are also harvested commercially, creating an interaction with fisheries (DFO, 2013). Seals are generalist predators that often change their diet seasonally and in response to prey abundance (Bowen & Siniff, 1999). Thus, they can take advantage of the variety of prey readily available in fishing nets and traps.

The Northwest Atlantic harp seal population, which consists of over 7 million animals, summers in the Canadian Arctic and migrates to areas off Southern Labrador and the Gulf of St. Lawrence in the fall. These seals feed on a variety of prey at several different trophic levels, including large quantities of groundfish. However, they mostly consume small fish that are prerecruits to the fishery (DFO, 2011). The Northwest Atlantic hooded seal population is approximately 600 000 animals which pup in areas off Southern Labrador, the Gulf of St. Lawrence and the Davis Strait in the winter, and migrate to Greenland to moult in July (DFO, 2011; DFO, 2013).

Harbour seals are the most widely distributed pinnipeds, found in temperate and arctic areas of the Northern Hemisphere. Western North Atlantic harbour seals are found year-round off all provinces in Atlantic Canada, as well as the East coast of the United States. Although there are only an estimated 20 000 – 30 000 animals found in Atlantic Canada, they are known to cause damage to aquaculture operations (Baird, 2001; DFO, 2013).

The species that seems to be causing greatest concern to the fishing industry in Atlantic Canada is the Northwest Atlantic Grey seal population. These seals in particular have demonstrated recent rapid population increases, with estimated numbers rising from 13 000 animals in 1960 to over 330 000 in 2010 (DFO, 2011). These year-round residents are found off the shores of all Atlantic Provinces, and are subdivided for management purposes into three herds of breeding animals: Sable Island, Gulf of St. Lawrence and Eastern Shore (DFO, 2011). This population of grey seals can also be found on the U.S. coast, extending as far South as New York (NOAA, 2012a).

Seals are afforded protection under the *Marine Mammal Regulations*, which were created under the Fisheries Act in 1993. Seal management in Canada falls under the responsibility of the Department of Fisheries and Oceans (DFO). Commercial sealing has existed in Canada as early as the 1700's (DFO, 2011). Beginning in the 1960's, Canada's seal hunt fell under intense national and international criticism fueled by animal welfare and conservation organizations concern that the hunt was inhumane (Barry, 2005). Since then, new regulations have been established to control the hunt, ban the killing of white-coated seal pups and make the killing of seals as humane as possible (Barry, 2005). Total allowable catches (TAC) for harp and hooded seals, and a very small TAC for grey seals are currently hunted. However, TAC's have not been fully harvested in recent years, due in part to diminished international markets caused by the sealing controversy (DFO, 2011). Abundant seal populations can also be considered a tourist attraction for Canada's marine mammal tourism industry.

Management plans are also created by DFO; the current plan is called the Integrated Fisheries Management Plan (IFMP) for Atlantic seals and is effective from 2011 to 2015 (DFO, 2011). Development of the management plans use occasional seal forums to include input from relevant stakeholders, such as seal harvesters, fishermen's organizations, the processing and marketing sector and animal rights and conservation activists (DFO, 2005). The plan overviews the knowledge of Atlantic seal populations of commercial importance (harp, grey and hooded) including limited Aboriginal Traditional Knowledge, provides stock assessments, discusses ecosystem interactions and management issues, established quotas and allocations, sets management objectives and

provides a compliance and enforcement strategy for meeting those objectives. The plan does mention the fishing industry's concern regarding interaction with grey seals, and suggests exploring an ecosystem based management approach to seals in the future. However, the plan focuses strongly on the management and development of sealing, not the interaction between seals and fisheries.

Fisheries

Canada is home to some of the world's most productive marine systems, which have supported lucrative fisheries on both the Atlantic and Pacific coasts (OECD, 2004). The Atlantic fisheries account for over 80% of the total landed value, which was over 2 billion dollars in 2011 (DFO, 2013b). Despite being a small proportion of the Canadian gross domestic product (GDP), Atlantic Canadian fisheries play an important role in the economy of coastal regions, where sub-areas are highly dependent on fisheries for employment and livelihoods (OECD, 2004). Commercial fishermen dominate Atlantic Canadian fisheries; however they share the resource with aboriginal food fisheries, recreational fishers and aquaculture interests (DFO, 2004). The structure of commercial fisheries is characterized by many small-scale operators and few large ventures (OECD, 2004).

Atlantic Canadian fisheries have faced many challenges in recent decades. Declining stocks of some species, most notably Atlantic cod, have led to fisheries closures and consequent restructuring (DFO, 2004). Many of these stocks do not appear to be recovering. Overcapacity in the industry combined with a lack of alternative economic opportunities in some coastal areas lead communities to be highly sensitive to any reduction in fishery resources, and thus some of these fisheries have become dependent on government subsidies. Conflict between resource users and managers has also been prevalent due to limited participation in the decision making process. To respond to some of these challenges, the Department of Fisheries and Oceans has adopted objectives of conservation and self-reliance in Atlantic Canadian fisheries policy (DFO, 2004). All of these challenges can exacerbate the effects of increased interactions with seals, and will influence how potential problems are managed.

Seal and Fishery Interactions

Depredation and gear damage due to seals tends to be most common in coastal fisheries using passive gear, in which capture of fish is based on movement of the target species toward the fishing gear, although interactions can occur with active gear types as well (FAO, 2002; Wickens, 1995). Several Atlantic Canadian fisheries take place inshore using passive gear types and overlap with seal distributions, making them susceptible to interactions with seals. These gear types are also often environmentally benign compared to larger scale active gear types.

Since the collapse of the cod stocks in the early 1990's, Atlantic Canada has relied heavily on invertebrate species, such as lobster and crab, to maintain coastal fisheries (Fuller et al., 2008). Inshore lobster fishing takes place along the entire Atlantic coast, and is highly active in the Gulf of St. Lawrence and coastal Nova Scotia, areas which are also home to two of the three grey seal herds (DFO, 2013c). This fishery uses retrievable baited lobster pots.

Other less profitable fisheries that are still highly important to coastal communities are also susceptible to conflict with seals. Inshore multispecies groundfish fisheries still exist on the Eastern Scotian Shelf and Gulf of St. Lawrence, and use gillnets to catch species such as Pollock, halibut and several flatfishes (OECD, 2004). Gillnets are nets that float vertically in the water column and rely on fish becoming entangled in their mesh; they are often anchored to the seafloor (Fuller et al., 2008). Inshore herring fisheries are found in the Gulf of St. Lawrence and coastal Nova Scotia (OECD, 2004). Herring are fished using gillnets, traps and weirs (OECD, 2004). Herring traps are floating, bottom anchored gear which consist of a leader net and wings to guide fish into the chambers, and a fish bag to trap fish (He, 2010). Weirs are heart-shaped traps built from poles and netting; a leader net directs fish into the mouth of the weir, where they enter and become trapped inside the 'bowl'. Capelin is also fished using traps and weirs along the Northeast coast of Newfoundland and the North shore of Quebec (OECD, 2004).

Atlantic Canadian fishermen have long perceived interaction with seals as a problem for coastal fisheries. In 1984, DFO commissioned a study that used fishermen's knowledge to provide a baseline estimate of gear damage caused by grey and harbour seals in Nova Scotia inshore fisheries (Farmer & Billard, 1984). Approximately 9% of the fishing industry using fixed, inshore gear was interviewed. Gear damage due to seals was reported to occur most heavily in herring/mackerel traps, and moderately in groundfish gillnets and wooden lobster traps. Trawls, longlines and wire crab traps were not damaged by seals. Damage was concentrated along the Northern and central shores, most likely because these areas received the largest share of grey seals that dispersed from Sable Island after whelping. Total gear damage to N.S. inshore fisheries was estimated at over $1 million dollars (Farmer & Billard, 1984). This value is small when compared to the total value of all Nova Scotia commercial landings, which was over $400 million dollars in 1990 (DFO, 2013d). However, the uneven distribution of damage can result in high costs to individual fishermen. Also, the costs of depredation or hidden losses are not considered in this assessment.

Rapidly increasing grey seal populations and decreasing stocks of some commercial species have seemed to only heighten fishermen's concerns for the livelihoods. A questionnaire presented to Atlantic Canadian commercial groundfish fishermen found that they perceive increasing operational and ecological conflict with grey seals (Matte, 2007). Fishermen reported observing grey seals in large numbers and in areas where they were previously limited or absent. They have witnessed seals raiding their gear, often causing extensive gear damage and stripping the bait and fish. In some areas it was observed that seals were so prevalent as to prevent fish from approaching the gear altogether. Seal predation was also perceived as a major factor in preventing recovery of groundfish stocks, as seals are consuming groundfish and there is imbalance between the two populations. Grey seals also transmit the sealworm parasite to cod and other groundfish, reducing their marketability (DFO, 2011). Fishermen are demanding management actions to protect groundfish stocks from predation and protect their fishing gear (Matte, 2007). The fishing industry has been actively seeking attention for the issue, demanding advisory meetings on grey seals and in some cases boycotting advisory meetings for other species (DFO, 2011).

Despite the concerns regarding depredation and gear damage, it appears that no research has attempted to quantify this problem in Atlantic Canada since the 1984 study. The only management measure that directly addresses this problem is the licensing of fishermen to shoot 'nuisance' seals that represent a danger to fishing equipment despite deterrence efforts. This type of licensing is permitted through the Marine Mammal Regulations, and fishermen and aquaculture operators must apply for the license and file reports on seals dispatched. However, few reports are actually filed, indicating either a problem with compliance to the regulations or underuse of nuisance seal licenses (Hamill & Stenson, 2011). Furthermore, the effectiveness of this mitigation method is questionable, and the practice is controversial especially given the strong interest by activist groups in the welfare of seals in Canada (Lavigne, 2003).

Recent research and management efforts have strongly focused on the perceived ecological interaction between grey seals and cod. DFO has commissioned studies and workshops in recent years to examine the ecological role of grey seals and determine how endangered Atlantic cod fit into their diet (DFO 2011b; Trzcinski, Mohn, & Bowen, 2009). It has been concluded that grey seal predation is a major cause of large cod mortality in some areas of the Atlantic, as they may consume up to 20 000 tonnes per year in the Southern Gulf of St. Lawrence (DFO, 2011b). To aid cod recovery, many fishermen advocate a reduction of the grey seal population, either through a cull or increased commercial hunting (Matte, 2007).

In 2011 The Standing Senate committee on Fisheries and Oceans, which is tasked with investigating policy matters and making recommendations, was authorized to examine and report on the management of the grey seal population off Canada's East Coast. In October 2012, the committee released suggestions for the establishment of a grey seal management plan that included a cull in the Gulf of St. Lawrence as a strategy to reduce pressure on Atlantic cod (Senate of Canada, 2012). The cull would be established with the goal of removing 70 000 animals, or approximately 70% of the grey seals foraging in the Gulf of St. Lawrence. Further population reductions are also suggested for the future, including the potential for further culls after initial assessment, examination of population control feasibility for Sable Island, and establishment of

markets to promote a grey seal commercial hunt. A large seal cull poses great uncertainties, including the potential for unanticipated ecosystem interactions (Bowen & Lidgard, 2012). The proposed cull has already begun to receive negative attention from some scientists, conservation, and animal rights organizations (Marketwire, 2012, IFAW). It is still uncertain whether the proposed cull will take place.

The interaction between seals and fisheries in Atlantic Canada is a complex problem with many interested stakeholders (figure 2). Fishermen are experiencing unquantified losses due to depredation and gear damage by seals, and the lack of research and management in this area may threaten vulnerable coastal fisheries. Many outstanding questions exist regarding these operational interactions: how serious is this problem? Which areas and gear types are most heavily affected? Can this problem be managed, and if so how? Is the shooting of nuisance seals effective? Would a grey seal cull lessen interactions with fishing gear? To answer these questions, a strategy must first be devised for approaching the problem of operational interactions. The following chapters of this paper will use existing knowledge from other areas of the world to help develop that strategy.

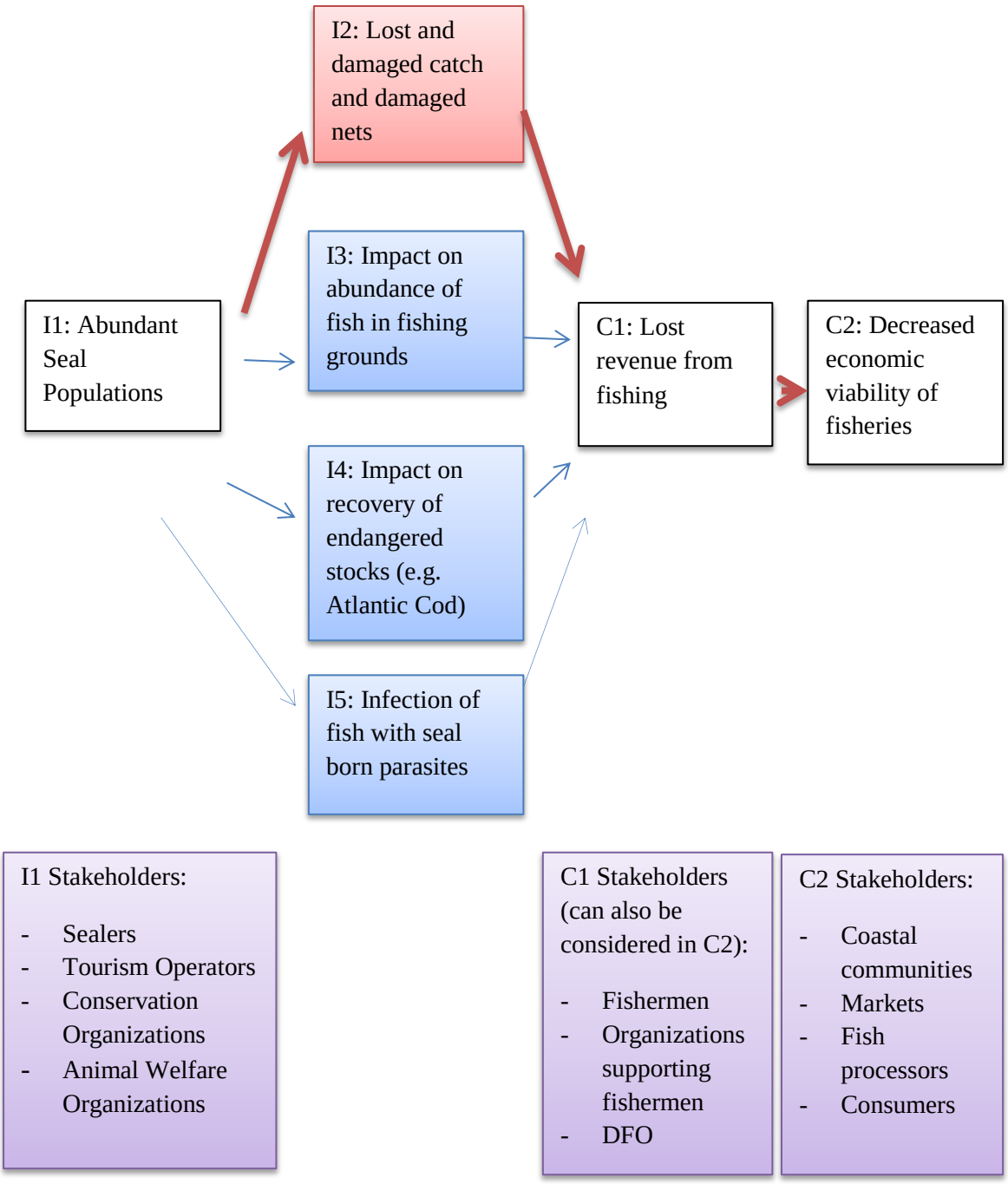

Figure 2: Scheme of the problem dynamics in Atlantic Canada (limited to seal's effects on fishing operations), where I1-I5 represent influences on the coastal fishery and C1 and C2 represent consequences. Operational conflicts are in the red box (I1), and the path of focus for this study is represented by red arrows. Ecological conflicts, which will not be focused on in this study, are in blue boxes. Interested stakeholders at each stage of the problem are displayed in purple boxes below the diagram. (Adapted from Varjopuro, 2011).

Chapter 4: Literature Review and Case Studies

Conflict between pinnipeds and fisheries is a common problem. A review completed for the FAO in 1995 (Wickens) found that operational interactions with seals occur in fisheries throughout the world. Depredation and gear damage in different countries varies in extent and impact. The methods used to collect data on these interactions vary greatly, as do the temporal and spatial scales considered. Although this complicates the process of comparing the interactions between countries, the review highlights some common findings from numerous studies. Interactions often vary seasonally and annually, as well as within regions and local areas. This makes findings in one region difficult to extrapolate to a larger scale. Many hidden losses to fisheries during direct conflict with seals are difficult to quantify, such as the frightening of fish from nets or the loss of fish due to gear damage. The most reliable way to quantify damage is considered direct observation, as fishermen sometimes exaggerate during interviews when interactions are detrimental to the fishery (Wickens, 1995).

The review also suggests that depredation and gear damage are most prevalent in passive fishing gear, and seem to be frequent in gillnet fisheries and aquaculture farms. Different mitigation measures have been tried to eliminate or decrease the impact of seal conflict, with little success. Because damage is often caused by a small number of repeatedly offending seals, culling to reduce the population is not considered a general solution. Killing of these repeat offenders or ‘nuisance seals’ is a common tactic, but it not thought to be consistently affective, possibly because it is a difficult practice or dispatched individuals may be replaced by others. At the time of Wickens’ (1995) review, the most promising mitigation measures were gear modifications, which are a fishery specific solution.

In some fisheries damage by seals is tolerated and considered the cost of doing business, while in others there is a wealth of conflict and demand by fishermen for a solution to the problem (Wickens, 1995). Since the FAO review, many seal populations have experienced substantial increases, which have led to concerns of losses by fishermen. New studies have attempted to quantify these losses and suggest mitigation measures, and management plans have developed in some countries to consider

seal/fishery interactions. The purpose of this chapter is to review the recent state of knowledge on operational conflict, and to examine how other countries have approached the problem, so that suggestions for Atlantic Canada can be developed.

Case Study 1: Baltic Sea

The Baltic Sea is a small brackish water sea in Northern Europe, and is bordered by nine countries inhabited by over 85 million people (figure 3, HELCOM, 2005). Fishing has historically been an important economic activity in the region, and has traditionally been dominated by small-scale coastal fishing with fixed gear (HELCOM, 2008a). However, commercial landings have decreased by approximately 400 000 tonnes since the 1990s, and stock fluctuations and decline have produced negative economic consequences for Baltic fisheries (HELCOM 2008b). Conflict with seals is thought to add to this economic hardship, especially since small scale coastal fisheries are most vulnerable (Königson, 2011).

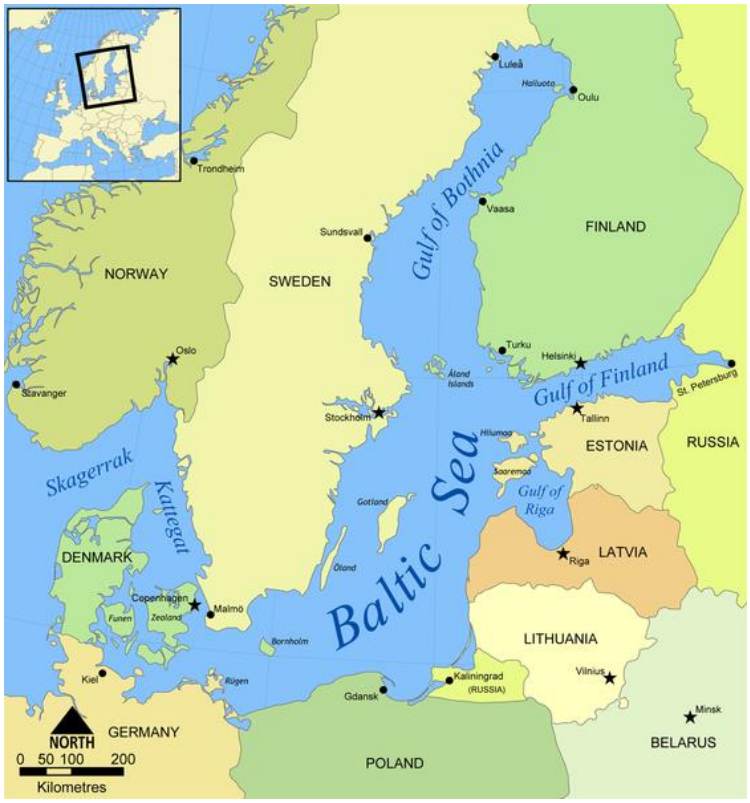

Figure 3: Map of the Baltic Sea region. ©Norman Einstein, retrieved from Wikipedia.com

The Baltic Sea is home to its own populations of grey and harbour seals (HELCOM 2008c, HELCOM 2008d). The region also hosts sub-populations of ringed seal; however they do not commonly cause damage to fisheries (Königson, 2011). Harbour seals declined from their traditional population size of over 17 000 to approximately 2 500 due to hunting in the early 1900's. Protection began in the 1980s, and the population has since undergone periods of recovery and decline due to disease outbreaks (HELCOM 2008c). The current population is over 15 000 (HELCOM 2008c). Grey seals declined from tens of thousands to only approximately 2 000 due to hunting and contaminants prior to the 1980s, when conservation efforts were established (HELCOM 2006d; Varjopuro & Kettunen, 2008). The population has since been increasing at rates of up to 10% per year, and currently numbers over 22 000 animals (HELCOM 2008d). Both harbour and grey seals are now protected under the European Union habitats directive, which requires specific areas to be designated for their protection (HELCOM 2008c; HELCOM 2008d).

Although concern over ecological interaction is growing, especially the potential of seals to inhibit recovery of salmon and cod, depredation and gear damage are considered the main problems in the Baltic (Königson, 2011). Although seals have long been considered a threat to the fishery even when population numbers were much lower, they seemed to begin to cause a significant problem for fishermen in the 1980s and 1990s after decline of many near shore fish stocks and movement of fishermen to archipelago areas (Varjopuro & Kettunen, 2008). Thus, it is only recently that many studies have begun to quantify damage, and the search for potential solutions has begun. (Varjopuro, 2011). The 'seal problem' is now considered one of the most pressing issues facing coastal fisheries in Baltic countries such as Sweden and Finland (Varjopuro & Kettunen, 2008). These countries appear to have the most extensive research and management efforts of seal/fishery operational interactions worldwide.

Research

Swedish Eel Fishery

In the Southern Baltic, specifically in the Kattegat region of the Swedish West coast, harbour seals depredate and cause damage to the eel fyke net fishery. Harbour seals are much more prevalent than gray seals in this region (Lunneryd, 2001). The eel fishery is a small scale, economically important coastal fishery (Königson, Hemmingsson, Lunneryd, & Lundström, 2007). The fyke nets consist of two fish bags with a leading net in between; harbour seals tear holes in the fish bag causing lost catch and gear damage (Königson, Lunneryd, & Lundström, 2003). A study by Königson et al (2003) confirmed the damage by harbour seals using video footage, and used fishermen's logbooks to estimate a catch loss of 18% or more to the fishery, and this amount is increasing. The frequency of damage to nets varies seasonally, being highest in fall (Königson et al., 2007).

The raiding of these fyke nets by harbour seals was an unusual phenomenon, as diet analysis showed that eels were rarely consumed (Harkonen, 1987) and prey selection experiments showed that harbour seals rejected eels in favour of other fish when they were placed in cages as bait (Lunneryd, 2001). It was thought that seals may be targeting other bycatch species caught in the nets (Königson, Lundstrom, Hemmingsson, Lunneryd, & Westerberg, 2006). However, when fyke nets were baited with eels or other species, such as cod and flounder, eel was preferentially targeted (Königson et al., 2006). This lead to the theory that certain harbour seals may have developed a specialization for raiding fyke nets, and a feeding preference for eels (Königson et al., 2006). It has previously been shown that individual seals can have different foraging habits and may specialize in foraging techniques (Tollit et al, 1998). Experimental culls that showed eels in the stomach of only seals shot near fyke nets supported this theory, as did video footage that showed the same seals repeatedly visiting fyke nets (Königson, 2011).

Several types of deterrents have been used by fishermen with no success (Königson et al., 2007). Fishermen would like to cull harbour seals in the area, but if damage is caused by a few specialized seals than a general population reduction would likely not be effective (Königson et al., 2007). The ineffectiveness of population reduction was demonstrated when damage to the fishery remained high even when disease greatly reduced the local harbour seal population (Königson et al., 2007).

However, experiments involving controlled killing of specific seals frequenting gear have been practiced, although the number of seals killed was too small to assess effectiveness (Königson et al., 2003). Gear modifications have shown some promise. The use of thicker, knotted mesh in the fish bag increased the resilience of the gear, although it did not deter the seals from pulling eels through the holes in the mesh (Königson et al., 2007). The fate of the eel fishery on the Swedish west coast is uncertain, both because of seal damage and increasing regulations as eels are a threatened species (Königson, 2011).

Swedish Cod Fishery

In the central region of the Baltic Sea, reports of depredation and gear damage to the Swedish coastal cod fishery are increasing (Königson, Lunneryd, Stridh, & Sundqvist, 2009). The coastal cod fishery in Sweden is small-scale and uses fleets of bottom-set gillnets (Königson et al. 2009). The fishery is also plagued by a recent decline in cod stocks, and, as in Canada, there is growing concern that increasing grey seal populations may inhibit cod recovery (Königson et al. 2009).

A study by Königson et al. (2009) examined grey seal depredation by having a researcher join fishermen to record catches, damaged fish and observations of seals. The study also attempted to quantify hidden losses due to complete removal of fish by catching, measuring, marking and resetting fish in some of the fleets. It was found that seal interaction varied by location, season and year. While only 14% of the marked fish were damaged by seals, 42% were lost from the nets (Königson et al. 2009). As no other predators were observed in the area and estimated losses due to handling were accounted for, it is likely that the lost fish were consumed by grey seals (Königson et al. 2009). Thus, the coastal cod fishery in Sweden likely suffers significant losses due to seal depredation.

Protecting gillnets from seals is a difficult process, and as of yet no gear modifications exist for this purpose (Varjopuro and Salmi, 2006). It has been suggested that switching to alternative gear types may be in the fishermen's best interest (Königson, 2011; Varjopuro & Salmi, 2006). For example, cod have been shown to be just as

effective at catching fish in some areas and may be more easily protected from seals, as well as being less environmentally destructive (Königson, 2011).

Swedish and Finnish Salmon Fisheries

In the Northern region of the Baltic Sea including the Gulf of Bothnia, the set trap salmon fishery experiences extensive depredation and gear damage due to grey seals. The trap nets are similar in design to herring traps used in Atlantic Canada which originated in the Baltic, but have larger mesh sizes (He, 2010; Kauppinen, Siira, & Suuronen, 2005). The traps are considered an ideal gear type because they are energy efficient, selective and environmentally benign (Königson, 2011). Seals can hunt fish on the way to the fish chamber as well as enter the traps through the main entrance, over net panels, or by tearing holes in the fish chamber (Königson, 2011).

A study by Kauppinen et al. (2005) used observations recorded either by the Finnish Game and Fisheries Research Institute or by fishermen to quantify seal depredation and damage. Observations recorded by fishermen were found to be reliable as they did not differ significantly from researcher's observations in the same region/time. It was once again found that frequency and severity of gear damage and depredation varied both seasonally and by region. It was also found that the location at which damage occurred in the traps (wings, chamber or fish bag) varied by region, possibly suggesting that different seals are specialized to attack gear in different ways. Frequency of gear damage also depended on the type of netting used in the trap (nylon and monofilament were more vulnerable than Dynema and polythene netting). Damage to salmon ranged from 3 to 37% of the catch depending on the region (Kauppinen et al. 2005). This is similar to the 2 to 29% catch damage found in a study that used observations from fishermen's logbooks (Jounela, Suuronen, Millar, & Koljonen, 2006).

An attempt was also made to quantify hidden losses using a database in which catch and damage data were recorded in fishermen's logbooks (Fjälling, 2005). Catches on days when gear went undisturbed were compared to catches on consecutive days when gear was disturbed by seals, so that seasonality and unrepaired gear damage would not skew the results. Using this method, it was found that hidden losses are likely 37%

greater than observed fish damage (Fjälling, 2005). Thus, total losses to the set trap salmon fisheries in the Northern Baltic are substantial.

Many different gear modifications have been attempted with support from the Swedish government. The use of stronger netting in the fish bag and grating on the entrance to the fish bag reduced gear damage but did not stop depredation (Varjopuro & Salmi, 2006). One promising gear modification - a 'push up' fish bag which was heavier due to an extra strong layer of netting but floated to the surface to ease hauling – was invented by a fisherman (Varjopuro & Salmi, 2006). The push-up trap also made fishing easier and safer, and was initially highly effective at reducing seal interactions when combined with larger meshes in the wings and chamber that prevented seals from herding fish (Lunneryd, Fjälling, & Westerberg, 2003; Varjopuro & Salmi, 2006). Unfortunately it was also very expensive (Varjopuro & Salmi, 2006). A cheaper and effective gear was developed in Finland; however it was not practical for fishing (Lehtonen & Suuronen, 2004; Varjopuro & Salmi, 2006). This shows the importance of fishermen's traditional knowledge in the development of solutions that are both practical and effective.

Despite the initial success of the push-up trap, seals in the Northern Baltic have learned to continue to depredate salmon in trap nets. Video footage has shown that they now stay by the entrance to the fish bag and catch the salmon before they enter (Varjopuro & Salmi, 2006). Although acoustic harassment devices (AHD's) were initially ineffective or excessively expensive, new developments in which the acoustic pulse length and intervals were randomized are more affordable and have been shown to deter seals (Fjälling, Wahlberg, & Westerberg, 2006; Jefferson & Curry, 1996). However, some seals have already learned to adapt to the deterrent by putting their head above water when sounds are emitted, allowing them to continue to interact with gear (Fjälling et al., 2006). Mitigation attempts in Northern Baltic salmon fisheries appear to be an arms race, in which the seals adapt their behaviour as technologies improve.

Video footage in which animals with unique markings were identified has shown that a small number of seals repeatedly visit salmon traps, indicating specialization (Lehtonen & Suuronen, 2010). Fishermen believe that selective removal of these nuisance seals is an effective mitigation strategy, although there is currently no scientific evidence

that it would reduce losses or damage. A device has been designed to trap these seals in the middle chamber of a salmon trap and subsequently signal fishermen, so that these seals can be killed. This simplifies the dispatching of nuisance seals, which is often difficult in open water and because seals often attack nets at night (Lehtonen & Suuronen, 2010).

Management

National management initiatives by Baltic Sea countries are based on international conventions, such as the EU habitats directive and Helsinki Commission on the Protection of the Marine Environment of the Baltic Sea Areas (HELCOM), which establish principles for seal protection (Varjopuro & Kettunen, 2008). Management of the seal/fisheries conflict was spearheaded in Sweden and Finland by regional fisheries organizations in the 1990s after national initiatives were lacking or insufficient to mitigate the problem (Varjopuro & Kettunen, 2008).

A cooperative cross-border initiative focusing on the role of grey seals in the Kvarken region of the Northern Baltic, called Grey Seals in Kvarken (GiK), began in 2001. The Swedish national grey seal management plan was implemented that same year (Varjopuro & Kettunen, 2008). The GiK project brought together fisheries organizations, nature conservation authorities and fisheries authorities at the regional level, with the aim to reach a common understanding among stakeholders about the role of grey seals, and reduce damage to the fishing industry (Varjopuro & Kettunen, 2008). The GiK project was successful at gaining national attention, and a Finnish national seal management plan was implemented in 2007 (Varjopuro & Kettunen, 2008, Varjopuro, 2011). The project has been criticized as not adequately including local level stakeholders such as local fishermen, and management has been dominated by regional and national level organizations (Bruckmeier & Larsen, 2008). The incorporation of fishermen's traditional knowledge into management plans is thus limited (Bruckmeier & Larsen, 2008).

Sweden

The Swedish government has taken the stance that both fisherman and seal should be able to coexist while using the same resource. Solutions to the conflict are currently

sought through integrated management of seals and fisheries in the national grey seal management plan. The plan was developed under the guidance of overarching national institutions, the Swedish Fishery Board and Environmental Protection Agency. However, the plan is implemented at a regional level to account for geographical differences in seal and fishery interactions. (Brukmeier & Larsen, 2008). National management of seal/fishery interactions in Sweden seems to have focused on the grey seal, despite interactions with harbour seals in the eel fishery to the South.

The guiding principle of the plan is that operational conflict between seals and fisheries should be mitigated while still protecting the gray seal population and allowing it to recover. To help manage the conflict, the plan allows limited protective hunting of the species (by allowing limited special licenses to shoot nuisance seals), gives compensation payments for seal damage and further financial support for gear modifications. (Brukmeier & Larsen, 2008).

Each of these mitigation measures has pros and cons for both the Swedish fisheries and society in general. Protective hunting is thought to help psychologically mitigate conflict for the fishermen and has low costs for society, especially since regional administrators involved in nature protection do not perceive protective hunting as posing a threat to seal populations or their behaviour. However, the shooting of nuisance seals takes a large amount of time and effort on the part of the fishermen, and the strict limitation of 180 seals shot per year is unlikely to solve the problem. Compensation payments, which amount to 50% of reported losses, have a high cost to society but support both individual fishermen and the coastal fishery in the short term. Plans to reduce the payments have been difficult, as the coastal fisheries have become dependent on the subsidy for their maintenance. (Bruckmeier & Larsen, 2008).

Financial support for “seal-safe” gear modifications, which is the preferred long-term solution, has lower costs to society than compensation payments. Gear modifications can also be designed to be more efficient for fishermen and to reduce by-catch mortality of seals. They provide an opportunity for local fishermen to participate and share their knowledge at the development stage. However, they can have high costs to fishermen during their development and adaptation. As was previously discussed, gear

modifications have had only limited or short term success at deterring seals so far. (Bruckmeier & Larsen, 2008).

Finland

Prior to 2007, mitigation measures in Finland were introduced one at a time without any coordination or coherent management plan. Hunting of grey seals in Finland began to resume after population recovery in the 1990's. The Finnish Ministry of Agriculture and Forestry has supported extensive grey seal culls in recent years at the demand of fishermen, despite protests from regional nature conservation groups. However, the culls have not been successful at reducing operational interactions with fisheries, nor have they succeeded at scaring the seals away from coastal fishing areas. (Varjopuro, 2011).

Like Sweden, Finland has provided subsidies to fishermen for seal-safe gear development, but the basis for these subsidies differ. Subsidies for new fishing technology in Finland come from the EU Financial Instrument for Fisheries Guidance, which are only available for gear that has clear environmental benefits. Thus, any subsidized modifications must also protect the salmon populations. The Finnish government also provided temporary compensation for losses in 2000 and 2001, and commercial fishermen can receive partial compensation for seal induced gear damage through a fishery insurance system present in the country. (Varjopuro, 2011).

In 2007, the National Management Plan for Marine Seals provided a more comprehensive approach to managing the conflict between seals and fisheries. Finland's plan focuses on seal protection, but also acknowledges seal management with respect to fisheries. The plan introduces new seal management areas, proposes a special right to kill nuisance seals that frequent fishing grounds, emphasises the need for development of new technology and proposes future subsidies to compensate economic losses. The plan still supports hunting in areas where seals cause substantial losses, with a goal of maintaining the population size at a level at which damage to the fishery is 'reasonable' and the seal population is still viable. (Varjopuro, 2011).

Attempts to manage the conflict can also be found within Finnish fisheries policy, particularly Finland's program for the implementation of the European Fisheries fund (the main support program for the future of commercial fisheries). Like the view of the Swedish government, one of the long term goals of the Finnish government is no longer removal of seals from the system, but the sustainable co-existence of fisheries and seals. The policy introduces a 'seal tolerance reward', which is a payment made to commercial fishermen who accept the national management plan for marine seals and present a plan on how they will reduce seal induced damage and avoid harming seals in their fishing methods. (Varjopuro, 2011). Both Finland and Sweden have recently taken an active, integrated approach to managing the interaction between seals and fisheries. They have employed a variety of mitigation measures, each with unique pros and cons, as no one mitigation measure appears to provide a complete solution to the problem.

Case Study 2: United Kingdom

The United Kingdom is located to the East of the North Atlantic, and is also bordered by the North Sea, Irish Sea, and English Channel (figure 4). The sovereign state consists of four countries: England, Scotland, Wales and Northern Ireland. The UK hosts a large fishing industry, and landings are concentrated primarily in Scotland (Elliott, Hargreaves & Pilgrim, 2012). Although the majority of fishing is done with mobile gears, there is a small coastal fishery that uses passive gear such as shellfish pots and fixed nets. As in Canada, stocks of groundfish species such as cod and haddock have experienced declines in recent decades, limiting fishing opportunities. As a result, increasing importance has been placed on pelagic species such as mackerel and herring, as well as shellfish such as crab. Restructuring to limit capacity threatens the coastal fishery as the industry shifts to fewer, larger boats. Extensive inland fisheries for Atlantic salmon are also found in the region, but are threatened by declining stocks (Elliot et al., 2012). There is a history of conflict between seals and fisheries in the UK (Bonner, 1989).

Figure 4: Map of the United Kingdom. Adapted from denverlibrary.org

A Northeast Atlantic population of grey seal and a European subspecies of harbor seal reside in UK waters year-round (Special Committee on Seals, 2012). Arctic species such as ringed, harp, bearded and hooded seals are occasionally found in the area as well. The majority of both grey and harbour seals are found along the coast of Scotland. Little is known about the historical status of either population. Grey seals have been increasing since the 1960s despite large scale culls in some areas of the UK; culling was abandoned in the late 1970s due to public protest. The current population is estimated at over 111 000. The current population of harbour seals is over 36 000, which is a 22% decline from 2005 counts. Harbour seals have been declining drastically in some areas of the UK since the 1990s. Some of this decline is due to a disease outbreak in 2002; however, not all the areas experiencing decline were affected by this outbreak and it is unclear what is causing the most recent declines (Special Committee on Seals, 2012).

Seals in the UK are also protected under the European Union habitats directive, as well as regional legislation. The Conservation of Seals Act was established in 1970 and

prohibits the killing of seals during a closed breeding season except under specific license, and this close season can be extended if needed. However, seals can be killed for the protection of fisheries outside of closed season with no required license, and during closed seasons if they are found in the vicinity of nets (s. 9, 1c). More recent national legislation in both Northern Ireland (Wildlife Order, 1985) and Scotland (Marine Act, 2010) require licenses to shoot seals and prohibit the disturbance of seals in those countries. (Special Committee on Seals, 2012).

Research

Surveying Fishermen in England and Scotland

Efforts to understand operational interactions between seals and fisheries in the UK have relied heavily on Fishermen's local knowledge. In 1999, a study using in depth interviews and questionnaires was conducted in the county of Cornwall to the Southwest of England (Glain, Kotomatas, & Adamantopoulou, 2001). This study revealed that gillnets and salmon nets were most likely to experience interaction with seals, and that conflict was more likely with small to medium sized boats fishing near the coast (6-20 miles offshore). Fishermen believed that depredation was a more prominent problem than gear damage, possibly due to adaption of stronger netting material. The level of concern about the problem varied greatly, with only 34% of fishermen being very concerned. The most concerned fishermen often reported changing fishing areas or geartypes (particularly those using gillnets) in an effort to reduce depredation, and thought they lost up to 10% of their potential profit due to seals. When asked to propose solutions, two thirds of respondents were in favour of killing nuisance seals or practicing limited culls (Glain et al., 2001).

A similar study was conducted in the Clyde Sea to the Southwest of Scotland in 2003 (Moore, 2003). Fishing in the Clyde Sea is mostly done with baited near-shore creels or deeper water trawls. Creels are fixed traps similar to Atlantic Canadian lobster traps but with doors at each end held closed by rubber bands. The main target species for both trawls and creels is Norway lobster. Surveys were developed in collaboration with the Clyde Sea Fishermen's Association and distributed to the entire fishing fleet. All

fishermen in the Clyde Sea reported operational interaction with seals. For trawlers this was mostly depredation, but for the more vulnerable fixed creels both depredation and gear damage were reported, including the stealing of bait from traps. The fishermen seemed to have difficulty distinguishing seal damage to their gear and fish from other types of damage (for example damage done by other predators), as they often gave contradictory verbatim accounts. Both types of fishermen had mixed opinion on the threat seals posed to their livelihoods, ranging from 'none' to 'considerable'. Few fishermen were able to estimate the associated financial cost. The majority of fishermen thought that operational interactions occurred with both grey and harbour seals, and did not believe that conflict was with only a small number of nuisance seals (Moore, 2003).

Salmon Fisheries in Scotland

Both ecological and operational conflict between harbour and grey seals and salmon fisheries are believed to occur on the East coasts of England and Scotland. Seals are known to raid salmon fishing stations in rivers and estuaries where they damage both nets and fish, but no research has been done to quantify the extent of this damage (Anderson & Hawkins, 1978). Salmon are commonly fished with a sweep net, which is a curtain of netting set in a semi-circle in the water and then hauled ashore (Moray Firth Partnership, 2011). Several mitigation measures have been attempted by fishermen in the past, including trapping, poisoning, and unregulated shooting of seals, with little success. Field studies have shown that scaring of seals using assorted noises is ineffective (Anderson & Hawkins, 1978). A recent study by Graham, Harris, Matejusova, & Middlemas (2011) found that only a small number of harbour and grey seals frequent rivers, and these seals have a much greater percentage of salmon in their diet than the general population. This suggests that the raiding of salmon nets may be by a few seals that specialize at hunting in rivers; therefore targeted removal of these seals may help mitigate the problem (Graham et al. 2011).

Management

Moray Firth, Scotland

Coordinated national management plans that focus on conflict between seals and marine fisheries have not yet been developed in the UK, and the only mitigation method that appears to be used is the indiscriminate and unmonitored shooting of seals for fisheries protection. However, a regional management plan that focuses on conflict between seals and freshwater or estuarine salmon fisheries has been developed for the Moray Firth in Northeast Scotland (Butler et al., 2008). The management of seal and fishery interactions is particularly important to fishermen given recent drastic declines in salmon stocks in the Moray Firth. However, management is complicated by conservation of seals, as disease outbreak in harbour seals sparked a national conservation order in 2002 and a second order specific to the Moray Firth in 2004. The 2004 order also included grey seals, to ensure that harbour seals were not mistakenly shot. These orders meant that seals could no longer be shot without a special license unless they were attacking nets. Management is also complicated by the growing marine wildlife tourism industry, which promotes the conservation of seals. A series of stakeholder meetings led to establishment of the Moray Firth Seal Management Plan in 2005 to balance these conflicting interests in an adaptive co-management framework (Butler et al., 2008).

A partnership was formed between wildlife tourism operators and other local stakeholders, the Moray Firth District Fisheries Management Boards (DFMB) and salmon netting stations, to work cooperatively with higher order Scottish authorities. Under the Seal Management Plan, DFMBs now have to apply for a limited number of licenses to shoot ‘problem’ seals in rivers (Butler, 2004). Seals can still be shot without license when interfering at netting stations. A marksman training program that teaches species identification, management plan information, animal welfare and public relations is provided for anyone shooting seals. Species, date and location are now recorded (although only voluntarily at netting stations), and reported so that impact on seal populations can be assessed. No seals will be shot near breeding areas or tourism sites. A Seal and Salmon Research Program is also tasked with investigating the patterns of seal distribution near fishing areas, alternative non-lethal strategies to manage operational interactions (with a focus on acoustic deterrent devices), and the impact of seals on salmon stocks. Results of this research, population monitoring and the number of seals shot are assessed by a Seals Working Group, which includes members of relevant

stakeholder groups and executive bodies. The assessment is then used to inform future management decisions, giving the plan the ability to adapt as the situation changes or new information becomes available (Butler, 2004).

Early assessment of the plan's implementation reveals some problems that may provide useful lessons for Atlantic Canadian management. The plan is not effectively managing the number of seals shot. Although seals shot by marksmen in rivers have been well within the license limits, seals shot by fishermen at netting stations where licenses are not required have been increasing and thus exceeded the expected number of seals killed. Fishermen have also shown a lesser ability to identify the species of seal shot despite the training program, which may be due to impaired visibility near fishing gear (Butler et al., 2008). The plan has also been criticized for not adequately including fishermen in the management process (Butler, Middlemas, Graham, & Harris, 2011). Stakeholder meetings during development of the Moray Firth Seal Management Plan included only chairmen and managers of DFMB's, and information sharing to local fishermen does not appear to have occurred (Butler et al., 2011). Consequently, surveyed fishermen did not agree with the principles of the plan, believing instead that the entire population of seals was to blame for gear damage and that a large scale cull was the best solution. This disconnect from fishermen may affect the plan's long term success (Butler et al., 2011).

Case Study 3: United States

Canada's neighbours to the south have also been experiencing conflict between seals and fisheries. The New England region of the Northeast United States (Figure 5) is an important case study to examine, as both seal and fish stocks are often shared with Atlantic Canada. The United States is the fifth largest harvester of fish worldwide with landings worth over five billion dollars in 2011, one fifth of which came from fisheries in the New England region (Lowther, 2012). Many stocks in the region have experienced decline due to overexploitation. New England groundfish stocks began declining in the 1980s, and much fishing effort refocused on non-traditional species such as skates and dogfish (Baraff & Loughlin, 2000). However, Atlantic cod are still an important species

for New England fisheries. Pelagics such as Atlantic Herring and Menhaden also hold a large portion of landings (Lowther, 2012).

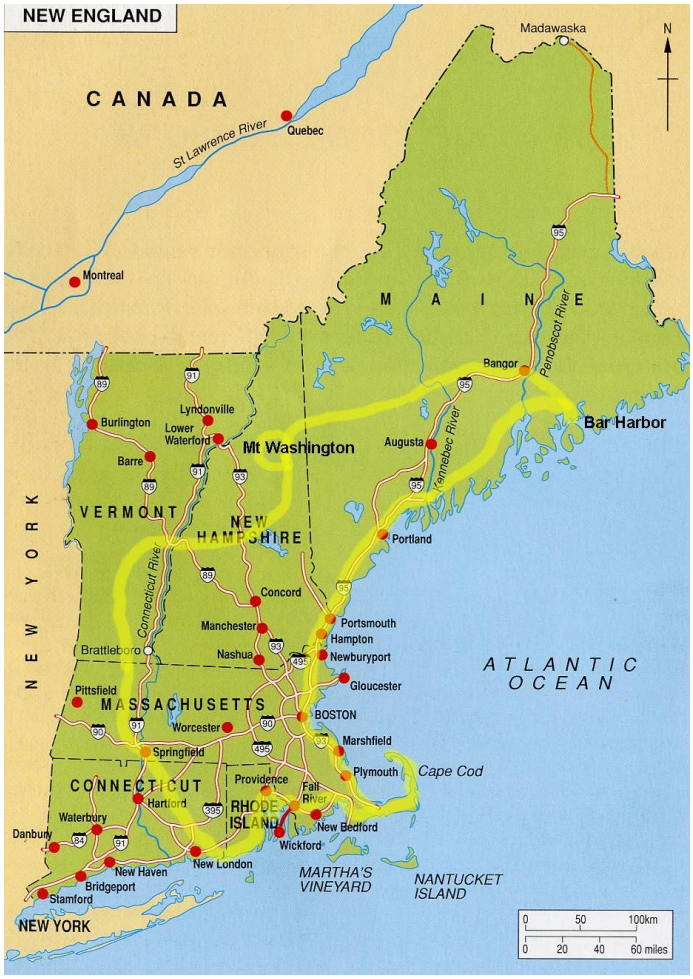

Figure 5: Map of the New England region of the United States. Retrieved from www.bakerlite.co.uk.

Harbour and Grey seals are resident species in New England. They are members of the same populations found in Atlantic Canada, and move back and forth between the two regions (NOAA, 2012a; NOAA, 2012b). Occasionally, harp and hooded seals from Canada are also sighted in New England (Baraff & Loughlin, 2000). Culls to reduce competition with fisheries in Maine and Massachusetts depleted harbour seals in the early 1900s, and breeding activities in Massachusetts were eliminated but remained in Maine. Their abundance in New England is thought to have quintupled since passage of the Marine Mammal Protection Act in 1972, and is most recently estimated at nearly 100 000 animals (Baraff & Loughlin, 2000; NOAA, 2012b). Grey seals were considered extinct

in the U.S. until 1958, when animals from Canada slowly started recolonizing the area (Baraff & Loughlin, 2000). Three small grey seal pupping colonies are now established in Maine and Massachusetts, and at least 2500 pups were counted in 2011. The total number of grey seals in New England is unknown, but is expected to be increasing (NOAA, 2012a). Growing seal abundance in New England has led to increasing concern over interaction with fisheries. The Marine Mammal Protection Act (1972) bans the harming, harassment and killing of seals, limiting potential management action.

Research

Salmon Aquaculture farms in Maine

Aquaculture farms in Maine lose high concentrations of penned fish due to harbour seals, with estimated costs of up to $27 000 a year for a single salmon farm (Nelson, Gilbert, & Boyle, 2006). Seals attack and consume fish through the mesh netting, and damage nets. Although this paper is focusing on coastal fisheries in Atlantic Canada and not aquaculture operations, the results obtained from studying seal interaction with aquaculture in Maine are interesting and may provide insight into the behaviour of seals when they interact with netted fish.

Questionnaires sent to the managers of salmon farms in Maine revealed that only some farms were frequented by seals, and estimates of damage varied greatly (Nelson, Gilbert, & Boyle, 2006). Despite higher concentrations of seals occurring in summer, the majority of damage to farms occurred in winter. Upon analysis, it was discovered that the probability and scale of losses due to seals increased at farms closer to winter haul-out sites; any farms located greater than 4km from haul out sites experienced minimal or no damage. The scale or frequency of damage was not dependent on the amount of seals at haul out sites; however, damage was more likely to occur at farms that were located nearer one another (Nelson, Gilbert, & Boyle, 2006). The implications for the fishing industry are that seals may take advantage of nets that are concentrated and within range of haul out sites, and depredation is likely caused by few animals and thus not dependent on the number of seals in the area. AHD's were also found to be ineffective at deterring

seals, while the effectiveness of 'excluder nets' set around the perimeter of aquaculture pens could not be determined.

Cod Gillnets on Georges Bank

Operational interactions have also been examined in fixed gear fisheries on Georges Bank, an extension of the continental shelf located 100km offshore between Cape Cod (MA) and Sable Island. These fisheries primarily target Atlantic Cod using gillnets (NOAA, 2009). Fishermen have observed grey and harbour seals near nets and partially consumed fish in their hauls. Unlike findings from Maine aquaculture farms, some fishermen believe the seals will swim tens of kilometres offshore to target fishing gear (Knowles, 2012). Depredation data for the gillnet fishery was collected by researchers in June 2007 (Rafferty, Brazer & Reina, 2012). The only observed predators prior to the study observations were harbour seals and spiny dogfish. These two species made distinguishable bite marks, spiny dogfish leaving a smooth edged bite and harbour seals leaving ragged bite-marks. It is likely that some depredation was also due to grey seals, although not mentioned in the study (Owen Nichols, personal communication). Only a very small amount of the catch (0.4%) was found to be damaged by seals, and damage was lowest in nets set in deeper water or with shorter net soak duration (Rafferty, Brazer & Reina, 2012).

Similar patterns of minimal seal-damaged catch were found in preliminary studies using Northeast Fisheries Observer Program trip logs (Knowles, 2012). The observer program proved a useful source of data to study depredation in Georges Bank fixed gear fisheries as the rate of observer coverage is relatively high (~22%). Specific fields such as fish discarded due to seal depredation and seal entanglement in gear are recorded, along with general fields such as gear type, haul time, location, etc. However, observers are not trained to differentiate seal damage from other types of damage, so it is possible that some damage caused by seals was recorded as being caused by another predator or as unspecified (Knowles, 2012). It appears that initial attempts to quantify depredation in Georges Bank gillnet fisheries contradict with the opinion of fishermen by indicating only minimal catch damage from seals. However, these studies do not examine the effect of

gear damage or hidden losses, so it is possible that seals are causing losses to the fishery in other less obvious ways.

Multispecies weirs in Cape Cod

Weir fishermen in Cape Cod, Massachusetts believe that operational interactions with seals are increasing and that seals are causing substantial losses of potential catch (Ernie Eldredge, weir fisherman, personal communication). The weir fishery is a small-scale coastal fishery that catches multiple species, most often squid and pelagic fish such as menhaden and scup. The weir design is similar to Atlantic herring weirs. Grey seals often enter the weir to consume catch, damage the netting, and possibly drive fish away from the weir (Nichols, Eldredge, & Cadrin, 2011). Research focusing on depredation in the weirs has been progressing in collaboration with local fishermen. High frequency sonars set to observe the entrance to the bowl showed grey seals frequenting the weir, most often at night (Nichols, Eldredge & Cadrin, 2011).

A combination of direct observations by researchers and fishermen's logbooks recorded over six years (2007-2012) was used to quantify depredation in the weirs (Nichols, Creamer & Eldredge, in prep.). Fishermen kept daily logbooks to record their haul and any seal damaged catch, and researchers joined them opportunistically on fishing trips. This collaboration allowed fishermen to contribute and help to guide the research process, and kept them informed on results. Researchers frequently observed grey seals in and around the weirs, often in small groups of 2-3 animals. Depredation showed a seasonal trend, and also varied drastically between individual weirs, which may be due to weir location. Although damaged fish were found on the majority of hauls in some years, the proportion of damaged catch was small. Once again hidden losses or gear damage were not quantified, and it is possible that seals are consuming entire fish inside the weirs. (Nichols, Creamer & Eldredge, in prep.) Fishermen added an 'excluder' net surrounding the bowl of some of the weirs in an attempt to keep seals out; however grey seals were still observed inside the weir, as well as climbing out over top of the high row of netting.

Preliminary attempts were made to quantify hidden losses using consecutive day comparisons as Fjalling (2005) used for the Swedish salmon fishery. However these attempts proved unsuccessful, as the highly seasonal trend in depredation resulted in a very limited number of available comparisons despite the extensive data set. The method used by Königson et al. (2009), of marking and replacing fish in Swedish cod gillnets to determine the quantity removed by seals, would not likely be applicable to this gear type. Because fish are free to swim in weirs and the entrance is open, it would be difficult to determine if 'missing' fish were consumed by seals or simply escaped the weir. Thus a method for quantifying the problem of hidden losses in the Nantucket Sound weir fishery is unclear, and quantitative estimates of losses remain uncertain.

Management

No national or regional management plans currently exist for the mitigation of operational interactions between seals and fisheries in the New England region. However, some local stakeholder initiatives have begun to form. Following a series of stakeholder workshops beginning in 2009, a collaborative initiative between researchers, fishermen and other stakeholders, deemed the Northwest Atlantic Seal Research Consortium (NASRC), was formed (WHOI, 2013). The goal of the NASRC is to examine the role of seals in New England waters, with a focus on research and mitigation of interactions between seals and fisheries. The most recent workshop in 2011 provided a forum for stakeholders, scientists and managers to discuss further research requirements before mitigation is possible; it was noted that potential solutions and associated costs need to be explored further (Nichols et al., 2011).

Summary

All three of the examined case studies share common characteristics, mainly that fishermen in these regions perceive significant losses due to operational interactions with both harbour and grey seals. Further knowledge on the extent and characteristics of depredation and gear damage was acquired using a variety of data sources, and results are summarized in table 2. Catch losses felt by fishermen were very high in some fisheries, particularly in the Baltic. Losses were quantified as very low in other fisheries, such as

the cod gillnet fishery in the US, however these are likely underestimates as only visible fish damage was considered. Even when hidden losses are estimated, a cause and effect relationship between seal presence and the financial loss is unsubstantiated, so that total loss estimates are still highly uncertain (David & Wickens, 2003).

Many common findings from the case studies were similar to those in the 1995 review by Wickens. Coastal, passive gear fisheries seem to be most affected by seals. The majority of interactions vary based on the season, region or local area. Most studies indicated that damage was likely caused by a small number of seals specialized in raiding gear, although fishermen in Scotland thought the entire seal population was to blame. Along with these general findings come few specific characteristics found in some fisheries, such as the tendency of harbour seals specialized in raiding eel fyke nets to target species outside of their known diet.

Case Study	Seal / Fishery conflict	Method of Research	Characteristics of Interaction	Visible Losses	Hidden Losses
Baltic Sea	Harbour seals and the eel fyke net fishery in Sweden	-Direct Observations -Fishermen's logbooks	-Seals consuming prey not found in their regular diet -Likely few specialized seals -Not dependent on population abundance	High and increasing	NQ
	Grey seals and the Cod gillnet fishery in Sweden	-Direct Observations -Hidden losses using Mark/recapture method		Medium	Very High
	Grey seals and the salmon trap fisheries in Sweden and Finland	-Direct Observations -Fishermen's logbooks -Hidden losses using consecutive day comparisons	-Losses vary seasonally and by location -Different sections of trap attacked, likely by specialized seals -Seals most often target traps at night	Low to Very High	Very High
UK	Grey and harbour seals and various fisheries in Cornwall, England	-Surveys of fishermen	-Depredation the most prominent problem -Losses varied by fishery, coastal gillnets and salmon nets most affected	None to Medium	
	Grey and harbour seals and lobster trawl and creel fisheries in the Clyde Sea, Scotland	-Surveys of Fishermen	-Depredation in both fisheries, gear damage only reported for creels -Thought to be entire local populations of grey and harbour seals	None to Very High	
US	Harbour seals and salmon aquaculture farms in Maine	-Surveys of managers	-Losses decreased with increasing distance of farms from haul-outs.	Low to Very High	
	Harbour seals and cod gillnets in Georges Bank, Massachusetts	-Direct Observations -Fishery observer program	-Seals thought to swim great distances to target gear -Distinguishable bite marks made by seals -Losses decreased in nets set in deeper water, for shorter periods of time	Low	NQ
	Grey seals and weirs in Cape Cod, Massachusetts	-Direct Observations -Fishermen's logbooks	-Seals most often target weirs at night -Losses vary seasonally and by location	Low	NQ

Table 2: Summary of the general research methods used and findings obtained when studying the different fisheries presented in the three case studies. For both hidden and visible losses, NQ = not quantified. When depredation was quantified as a percentage of the total catch, <5%=Low, 5-15%=Medium, 15-25%=High, and >25%=Very high.

The three examined case studies are in three different stages of the management process. The most advanced is the Baltic region, which has developed national level management plans to mitigate conflict between seals and fisheries. After culling proved unsuccessful at deterring seals from coastal fisheries, both Sweden and Finland have now taken a sustainable co-existence approach to managing operational interaction. Both countries employ a variety of mitigation measures in national management plans, but none has been sufficiently effective. The Moray Firth in Scotland is also struggling to conserve seal populations while mitigating operational interactions, and has developed a regional co-management plan that focuses on the elimination of nuisance seals. Lack of information sharing or inclusion of local fishermen during the plan's development threatens its effectiveness. While no coherent management plans currently exist for seal and fishery interactions in New England, developing stakeholder forums and research initiatives are taking the first steps.

Chapter 5: Discussion

A management plan for operational interactions between seals and coastal fixed gear fisheries in Atlantic Canada would coordinate efforts to research and mitigate the problem. Currently, very limited management efforts are discussed in an ad-hoc manner within the Integrated Fisheries Management Plan (IFMP) for Atlantic seals. Including operational interactions as a separate section within the IFMP for Atlantic seals would allow integration of all aspects of seal management, while providing the ability to examine fisheries interactions in more depth. The management approach for operational interactions should consider three broad aspects: stakeholder participation, research, and mitigation.

Stakeholder Participation

One similarity among all three case studies is that stakeholder initiative provided the foundation with which the problem of operational interactions was first approached. This problem involves several major policy areas, mainly fisheries and conservation, and thus has a large number of potential stakeholders as identified in figure 2. Participation and collaboration among these stakeholders is important to increase the knowledge base informing management decisions, and enhance communication and legitimacy going into the management process so that compliance with resulting policies is more likely (Varjopuro et al., 2008). As was demonstrated by the NASRC in the United States, these forums can provide a medium for the discussion of ideas and sharing of new research as it becomes available. They can also set the stage for forming research partnerships among stakeholder groups, and exploring potential sources of funding.

One of the biggest problems that usually occur during participatory processes is the exclusion of important stakeholder groups (Glicken, 2000). This was shown in both the GiP project for the Baltic Sea and the Moray Firth Seal Management plan, where failure to include local level stakeholders (mainly local fishermen) in these forums resulted in the exclusion of local knowledge and disagreement with resulting policies. Fishermen are the most important stakeholders in this problem, as their livelihoods are directly affected, they have local knowledge about the problem, and they seek and will

likely share responsibility for implementing any management solutions. Thus they should form the largest representation at stakeholder forums, likely through participation of fishermen's organizations. Government representatives and scientists that can provide information on the problem dynamics should also be thoroughly represented, as well as any related research organizations. Although I1 stakeholders are not directly affected by the problem, they have a vested interest in any management measures that may affect seal populations, thus inclusion of representatives from these interest groups is important. C2 stakeholders are only indirectly affected by the problem, and their inclusion is likely not necessary (figure 2).

Stakeholder forums designed to gather opinion and discussion on Atlantic Canada's Integrated Seal management plan are held intermittently. These forums include some limited discussion of seal/fishery ecological interactions, as well as some similar stakeholders, such as fishermen's organizations from across the region, and conservation and animal rights representatives (DFO, 2005). But the focus, like the current management plan, is strongly directed toward sealers and the sealing industry. Expanding the stakeholder base at these forums and including separate discussions on management of seal and fisheries interactions is recommended to maintain stakeholder participation once a management plan is established. However, more frequent meetings focused on operational interactions will be integral to develop stakeholder relationships, manage initial conflict, and establish research and management strategies as exploration of this problem begins. The establishment of a consortium to bring together these relevant stakeholders is an integral first step.

Research

Knowledge of the extent and characteristics of operational interactions between seals and fisheries in Atlantic Canada is limited, and based primarily on unstructured accounts by local fishermen. While the case studies prove that losses to fisheries can be substantial, they do not provide an indication of their severity in Atlantic Canada, as losses differ regionally and do not seem to be correlated with seal abundance. The case studies can be used, however, to determine methods and best practices for Atlantic Canadian researchers when gathering data on operational interactions.

The case studies have shown that quantifying damage caused by seals results in uncertain estimates, especially because hidden losses cannot always be determined. Quantification of operational interactions can still provide important information to managers, so long as these uncertainties are acknowledged. For example, research may provide comparisons of damage between fisheries that can inform where management efforts should be targeted. Even uncertain estimates of damage can provide a baseline to assess the effectiveness of mitigation measures at reducing the problem. Little information is available on conflict involving harp or hooded seals, and their interaction with fisheries should also be explored.

Since gray and harbour seal populations range between Canada and the New England region of the US, collaboration between the two countries will be important. The sharing of research and resources can facilitate the documentation of interactions along the entire range of these seals. The creation of standardized methods to collect and analyze data will allow cross border comparison of results, and efforts to develop a transferable protocol for studying depredation in the Northwest Atlantic are already underway (Owen Nichols, personal communication). The purpose of this section will be to discuss the advantages and disadvantages of different research methods (table 3) and their applicability to Atlantic Canada.

Research Method	Advantages	Disadvantages	Considerations
Social surveys of fishermen	-Low financial cost -Little time/effort for fishermen -Uses fishermen's local knowledge -Involves fishermen in the research process -Can be done on a large scale -Can gather in depth qualitative information	-Fishermen may not respond to all questions -Fishermen's responses may be unreliable	-Willingness of fishermen to participate depends on communication and trust with researchers
Fishermen's logbooks	-Low financial cost -Shown to be reliable -Involves fishermen in the research process -Can be done on a large scale	-Extensive time/effort for fishermen to be trained, but little time/effort after -Potential for fishermen's observations to be misreported	-Requires collaboration between researchers and fishermen to establish the process -Training and monitoring increase reliability
Direct observations by researchers	-Reliable -Can also be used to examine characteristics of interaction	-High financial cost -Limited scale	-Can involve fishermen -Financial cost depends on research design
Using existing observer programs	-Low financial cost -No time/effort for fishermen	-Potential for observations to be misreported -Only available for certain fisheries	-Requires high observer coverage -All required fields must be recorded -Observer training can increase reliability

Table 3: Data collection methods used in the three case studies with associated advantages, disadvantages, and considerations. Costs were estimated as either high or low based on the required time and resources; compensation of fishermen was not considered.

Surveys of fishermen are a way of exploring fishermen's local knowledge. Surveys provide a cost effective method to collect both summary data, such as the number, location and gear type of fishermen that experience conflict with seals. Early surveys in Atlantic Canada proved useful to estimate the amount of gear damage caused

by seals, and this information should be updated (Farmer and Billard, 1984). Questions can also be designed to collect qualitative information useful for management, such as how fishermen perceive seal behaviour when interacting with fishing gear (e.g. in which season is seal damage most severe? Do seals steal bait from lobster traps?) or how they have responded to the problem (e.g. have you ever changed your fishing practices due to problems with seals?). They also have the potential to provide evaluation of existing managing measures in Atlantic Canada (e.g. Do you hold a license to shoot nuisance seals? If so, do you find it affective at reducing damage caused by seals? Why or why not?)

For social surveys, there are a number of disadvantages that must be considered when deciding how they should be used. Fishermen's knowledge of the interaction can be limited in some areas; for example, in Scotland, fishermen did not agree on the distinguishing characteristics of seal damage to gear or fish, and were unable to estimate total financial losses. Also, the potential for unreliability in fishermen's accounts cannot be ignored. Palmer & Wadley (2007) showed that information given by fishermen can be falsified or exaggerated based on factors such as uncertainty, competing viewpoints, fear of loss of income, and to elicit a desired response from those collecting the data. Given the highly controversial nature of seal and fishery interactions in Atlantic Canada and the consideration of a seal cull, it is possible that fishermen may exaggerate the severity of damage.

Given these disadvantages and the limited quantitative information that can be collected using surveys, they should not be used as the only source of data to inform managers. However, the ability to distribute surveys on a large scale make them useful as exploratory studies that provide a broad overview of which fisheries experience most conflict with seals in which locations. This can allow more quantitative and directed research efforts to focus on those fisheries. It is also recommended that smaller, more focused follow-up surveys be used to determine how fishermen have responded to the problem, and to evaluate the usefulness of the current nuisance seal policy to fishermen. Surveys should be designed with clear, direct questions. The stakeholder consortium can

provide a forum for communication and trust between researchers and respondents, and appropriate questions can be developed with the help of fishermen representatives.

Efforts to survey fishermen in Atlantic Canada have already begun: a researcher with the Canadian Fisheries Research Network and the University of British Columbia has developed a questionnaire, during a collaborative project with fishermen, management and academia, that is designed to documents fishermen's interactions with grey seals in several Atlantic Canadian maritime communities (Canadian Fisheries Research Network, 2013). Both ecological and operational interactions are addressed in the questionnaire, and although the operational questions focus only on gear damage and bait stealing by grey seals, the resulting information may help focus future studies.

Once survey results have been analyzed and the most likely affected fisheries and areas identified, smaller scale studies focusing on individual local fisheries can begin. Along with descriptive fields such as date, time, gear type, target species and effort, quantitative information that needs to be collected in these studies include total catch, observations of seal species in and near gear, species damaged by seals, and quantity of fish damaged. Gear damage should also be recorded when it occurs, along with time and cost required for repair. Fishermen's logbooks allow the recording of this data consistently and over long timeframes with minimal effort on the part of the researcher, thus decreasing costs compared to direct observations. Fishermen's logbooks proved reliable methods for quantifying interactions in the Baltic Sea and the US. Initial training programs will be required to enable fishermen to identify seal species and distinguish seal damage from other types of damage.

Direct observations by researchers can be used on a limited scale in conjunction with fishermen's logbooks to facilitate monitoring and quality checking of data recorded by fishermen. Researchers can also record qualitative observations on how seals appear to interact with gear. Information on the behaviour of seals near gear can also be explored using direct scientific research, for example setting video cameras to confirm temporal patterns of seal damage, or using photo identification studies to confirm that few seals raid gear repeatedly. Multiple research efforts in the case studies suggest these characteristics, but because they have a profound effect on mitigation approaches it is

desirable to explore them in Atlantic Canada. In select fisheries where accounts from fishermen's surveys and observational studies are not in harmony, quantification of hidden losses should be attempted if possible.

All of these research methods require some involvement by fishermen, whether as a source of information or allowing researchers on their vessel and near their gear. Compensation for fishermen was not considered, as some recent policy changes within the Department of Fisheries and Oceans have asserted that the fishing industry begin to take greater responsibility for stewardship of the resource, and thus assume a greater share of the management costs (DFO, 2012). Members of the fishing industry may be willing to devote their time and effort to researching interactions with seals, as the information will ultimately be used to help develop and monitor mitigation methods to benefit fishermen. This contribution, as well as potential additional sources of funding from stakeholder organizations and DFO, will need to be discussed in the stakeholder forum.

The usefulness of observer programs to provide information on damage to catches and gear seems minimal in Atlantic Canada. Observer coverage is very limited, and the majority of fixed-gear fisheries have no onboard observers (OECD, 2004). The only fixed gear fishery with limited observer coverage are groundfish gillnets in Newfoundland (5-10% target) and the Gulf of St. Lawrence (5% target) (OECD, 2004). The data collected vary among fisheries and appear to be limited. Thus significant changes would be required to enable the observer program as a data collection method.

Mitigation

For management of conflict to be successful, the benefits obtained from a mitigation 'tool' must outweigh the associated costs. An understanding of the losses caused by seals is required to properly assess potential benefits to the fishery, thus a cost benefit analysis cannot be completed until research efforts are underway. However, the case studies allow for a preliminary examination of the advantages and disadvantages of mitigation methods currently in use (table 4). As was demonstrated with the Moray Firth Seal Management Plan, mitigation of the problem can begin based on fishermen's

concerns before data is collected, providing that plans are adaptable once new information becomes available.

Mitigation Tool	Pros	Cons	Considerations
Designed to reduce damage to fisheries			
General population reduction (cull)		-Not shown to be affective at reducing operational conflict -Perceived negatively by many stakeholders	-May be used to mitigate ecological conflict (although effectiveness is uncertain)
Reduction of 'nuisance seals' disturbing fishing gear	-Nature of interactions suggests this could be an effective method -Low financial cost	-Safety, conservation and animal welfare concerns -Extensive time and effort required by fishermen -Shooting seals near fishing gear is difficult	-Regulation should balance conservation interests and ability to reduce damage to fisheries -Training of marksmen may increase accuracy and animal welfare -Effectiveness has not yet been assessed
Gear modifications	-No conservation or animal welfare concerns -Can be designed to increase fishing efficiency and/or species selectivity -Has shown to be effective at reducing gear damage	-Often high cost -Only plausible for some gear types -Not shown to be effective at reducing depredation in the long term	-Must maintain fishing efficiency; Should be developed and tested in collaboration with fishermen
AHDs	-No conservation or animal welfare concerns	-Not shown to be effective in the long term	
Designed to reduce economic losses to fisheries			
Financial compensation	-No conservation or animal welfare concerns -Provides short term support to fishermen	-High cost -Difficult to eliminate once adopted	

Table 4: Mitigation tools used in the three case studies with associated advantages, disadvantages, and considerations.

Compensation for fishermen's losses can provide relief from the financial burden caused by interaction with seals, without attempting to alleviate the problem. In Sweden, compensation schemes were introduced as short term relief measures as damage by seals seemed to escalate quickly to intolerably high levels. However, fishermen became dependent on the extra income, making the subsidy difficult to eliminate. There is also an extensive body of literature suggesting that subsidies designed to increase the income of fishermen with no goal of improving the fishery are 'negative' subsidies that can be harmful in the long term (Beddington, Agnew & Clark, 2007; Clark, Munro & Sumaila, 2005; Munro and Sumaila, 2002). Atlantic Canadian fisheries policy has adopted an objective of self-reliance, which would not be supported by income subsidies (DFO, 2004). Thus, financial compensation is not suggested as a mitigation tool, regardless of the extent of losses.

On the surface, gear modification would appear to be an ideal mitigation tool: they evoke limited concerns from stakeholders, can actually promote the conservation of seal populations by reducing the risks fishing gear poses to seals, and have the potential to increase fishing efficiency and decrease bycatch. Unfortunately, extensive efforts to develop seal-safe gear in both Sweden and Finland have not stopped seals from damaging and consuming catch. Even when the 'push-up' trap modification showed promise in the short term, seals have demonstrated an outstanding ability to adapt and continue to interact with gear. Thus, offering financial support for fishermen to change to 'seal safe' gear is risky, as any reduction in losses is likely to be only short term. Also, modifications may not be plausible for some gear types, as none have yet been conceived for gillnets. AHD's are another mitigation tool that do not provoke concern from stakeholders, but have not yet shown long term success as seals adapt to the sounds even when they are randomized.

The use of stronger netting has been shown to effectively limit instances of gear damage by seals, and funding for this gear change should be considered if gear damage proves a major problem in some fisheries. The potential for development of gear modifications to reduce depredation in Atlantic Canada should not be completely discounted. Although they have proven unsuccessful so far, the stakeholder forum can

facilitate discussion of new and innovative ideas specific to this region. Plans and collaborations for developing and testing any promising ideas can be determined if/when they arise; funding possibilities should be discussed with conservation and animal welfare organizations, as costs for development and long term testing will likely be considerable. The adaptive nature of the management plan will allow for reconsideration of gear modifications if any are found to be successful in the long term and after cost benefit analysis is possible.

General population reductions of seals have proven ineffective at mitigating operational interactions, and can raise concerns among multiple stakeholders. A cull is therefore not suggested. It remains unclear whether a cull will be initiated in Atlantic Canada in an attempt to reduce ecological interaction, and that consideration is outside the scope of this study. However, the targeted killing of nuisance seals interacting with fishing gear may be a promising way to reduce losses. Many studies suggest that few specialized seals target fishing gear as part of their foraging strategy, thus removal of these seals may reduce associated damage. Effectiveness of this solution has not yet been assessed, and thus should be a goal of the program in Atlantic Canada.

Reynolds & Tapper (1996) suggest that the decision to control predators should be based on ethical considerations, such as

- Are the aims of predator control acceptable?
- Are the methods of predator control acceptable?
- Are the consequences of predator control for the target predator population and associated non-target wildlife acceptable?

These considerations will be especially important given the highly controversial nature of killing marine mammals. DFO already provides licenses for fishermen to kill nuisance seals, and large numbers of these licenses have been issued in Nova Scotia (DFO, 2011). However, the policy and regulations surrounding this process are fuzzy, and may not be adequately enforced as evidenced by the lack of reporting by fishermen.

Concerns by animal welfare organizations over the inhumane killing of seals in Atlantic Canada have been expressed since the 1960s, and resulted in many changes to

sealing policy, including addition of a three step process to the Marine Mammal Regulations to ensure that animals are killed quickly (s.28). However, this process will be difficult or impossible to administer when shooting nuisance seals in the water. It is possible, especially given the difficulty of shooting seals near fishing gear as shown in monitoring of the Moray Firth Seal Management plan, that some seals will be shot but not killed immediately. This could be aggravated by the potential inexperience of some fishermen.

Completion of a joint federal firearms safety course and provincial hunter's safety course are required to shoot wildlife in Atlantic Canada; these courses teach general safety precautions when using a firearm, and ethics and conservation policies for wildlife (Government of Newfoundland, 2013). However, training specifically designed for the shooting of nuisance seals should help increase the humanity of seal kills, enable species identification, and give fishermen a background to the policy and marine mammal regulations as well as public relations. It is possible that licensed dispatch of nuisance seals has not been reported because the process is too difficult, and training may improve efficiency. The Canadian Council of Professional Fish Harvesters has been developing a training program for professional sealers that will be mandatory for the issuance of sealing licenses; collaboration with this organization and extension of the program to include a training course for fishermen may be an option (DFO, 2011).

Integration of the management plan for operational interactions into the current IFMP for Atlantic Seals will allow seals shot under the nuisance seal policy to be considered in conjunction with sealing when setting population reduction limits. The current policy sets a precautionary reference limit for the population at 70% of the largest recorded number to maintain healthy abundances (DFO, 2011). While the current licenses are highly unlikely to exceed these limits based on the large grey seal population and very limited amount of harvesting, conservation considerations may become important if different seal species are targeted. A grey seal cull would also increase conservation concerns, and likely require the restriction of nuisance seal licenses.

Monitoring of the nuisance seal license program will be important for ensuring population conservation and determining the effectiveness of the method. As previously

mentioned, surveys may provide some insight on the effectiveness of the current nuisance seal policy and how it might be changed. It is recommended that the licensing scheme not be extended to other provinces until sufficient baseline data is collected to estimate current losses. Once this data is collected, the extension of licenses is recommended and a regular assessment of the tool by determining changes in damage will be possible. The granting of nuisance licenses applicable to more or all species of seal may also be required, depending on research results. A strictly enforced duty to report the number and species (if possible) of dispatched seals as a condition of the nuisance seal license will also be an important monitoring tool. The fishermen's training can both be used as means to teach reporting methods and communicate the importance of reporting for improving the nuisance seal policy.

One important consideration that was not included in any of the reviewed management plans is the possibility that none of the above tools will mitigate operational conflict, and that damage to some coastal fixed gear may be extensive enough to prevent coexistence with seals in certain areas. The shooting of nuisance seals may prove ineffective due to a number of factors, such as the replacement of those seals by new seals, or a possible tendency of seals to target gear at night when they cannot be shot. If losses caused by seals are shown likely to be substantial and cannot be reduced, then the viability of coastal fisheries could be threatened. Fishermen and managers may need to re-think fishing practices, potentially restructuring fishing methods and/or areas in an effort to avoid seals.

Chapter 6: Conclusions

In conclusion, it is recommended that DFO take the following steps to begin management of operational conflict between seals and fisheries in Atlantic Canada:

- Extend the IFMP for Atlantic seals to include a strategy for researching and mitigating operational interactions.

- Create a stakeholder forum to begin discussions on operational conflict, and to share research findings. Future IFMP stakeholder meetings should also be expanded to include this topic.

- Develop and implement a research strategy in collaboration with the United States that uses social surveys and logbooks to engage fishermen in the research process, and direct scientific observations to examine the nature of operational interactions.

- Focus mitigation efforts on modification of the current nuisance seal policy to provide training for fishermen, enforce regulations and improve monitoring and assessment. Ability to adapt the policy will be crucial.

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