THE EVOLUTION OF CONSERVATION HARVESTING IN ATLANTIC CANADA

JOANNE VOKEY

The Evolution of Conservation Harvesting in Atlantic Canada

by

Joanne Vokey

A major report submitted to the

School of Graduate Studies

in partial fulfillment of the

requirements for the degree of

Master of Marine Studies

Fisheries Resource Management

Fisheries and Marine Institute of
Memorial University of Newfoundland

September, 2001

St. John's Newfoundland

ABSTRACT

In Atlantic Canada fishing has been an essential provider of food and employment for centuries. The development of engine power and more efficient fishing techniques made it possible to fish in previously inaccessible areas and to improve harvest levels, leading to destructive effects on the marine ecosystem. Overexploitation, bycatch and subsequent discards are the side effects of fishing on the ecosystem. These combined with ghost fishing have all led to depletion of fish stocks and destruction of fish habitat. Recently there have been attempts to reverse this damage to the marine environment and to prevent further destruction. There have been many influences on these attempts to develop environmentally friendly harvesting techniques. Environmental groups, the media, the general public, markets, fish harvesters and governments have all played a role in responsible harvesting developments. Fishing gear modifications have led to improved gear selectivity and a reduction in damage to the seabed. Efforts have been made to retrieve lost fishing gear and to prevent the loss of gear in the future. Regulations have been put in place to ensure that responsible harvesting techniques are used and that mistakes from the fishery of the past are not repeated. Despite the initial costs associated with improving fishing gear, the benefits far outweigh the costs, improving the quality and landed value of catches as well as ensuring a sustainable fishery for future generations.

ACKNOWLEDGEMENTS

Throughout the writing of this manuscript there were a number of individuals who provided me with guidance, support, advice and motivation. Without their contributions I would have had great difficulty overcoming the obstacles I encountered while writing.

I must thank Dr. Pinnguo He of the Centre for Sustainable Aquatic Resources at the Marine Institute. His expertise on the subject of conservation harvesting provided me with the information and advice required to complete my work. I am grateful to him for his comments and suggestions that contributed to this final document.

Fellow students in the department were also of tremendous help to me, in particular Roy Gibbons, Tom Brown, Noel Milley and Sam Azizan, all of whom shared their knowledge of fisheries with me and engaged in various discussions on fisheries issues.

For much of my research I turned to the Department of Fisheries and Oceans for knowledge and expertise. Gerry Brothers, Bill Hickey and Steve Walsh were especially helpful in enlightening me on the subject of conservation harvesting in Atlantic Canada, and in guiding me to other sources of information.

My friends and colleagues at Fishery Products International provided me with encouragement for which I am truly thankful and, in particular, I thank David Foster for teaching me a great deal about conservation harvesting and its vital role in commercial fisheries.

I cannot express enough how grateful I am to my parents who have been behind me in everything I have taken on. Their love and support were with me throughout the duration of my Masters' program and I know it will continue as I take on other challenges. I owe them my deepest gratitude and love.

Finally, I must thank Geoff. His understanding of the difficulties faced during post-graduate study helped to see me through my writing. His strong work ethic and persistence in everything he does provided me with the motivation I needed to complete this work. I am thankful for his love and companionship and I only hope that I can provide him with the same in his future endeavors.

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

TABLES:

FIGURES:

LIST OF ABBREVIATIONS

AFAP	Atlantic Fisheries Adjustment Program
CAFID	Cooperation Agreement on Fishing Industry Development
CASEC	Cooperation Agreement for Salmonid Enhancement/Conservation
CCPFH	Canadian Council of Professional Fish Harvesters
DFA	Department of Fisheries and Aquaculture
DFO	Department of Fisheries and Oceans
FAO	Food and Agricultural Organization of the United Nations
FPI	Fishery Products International
FRCC	Fisheries Resource Conservation Council
ICES	International Council for the Exploration of the Sea
ICNAF	International Commission for the Northwest Atlantic Fisheries
MPA	Marine Protected Area
MSC	Marine Stewardship Council
NAFO	Northwest Atlantic Fisheries Organization
NGO	Non-Governmental Organization
NMFS	National Marine Fisheries Service (United States)
OMS	Ocean Management Strategy
QFFDP	Quebec Federal Fisheries Development Program
TAC	Total Allowable Catch

1. INTRODUCTION

Fisheries throughout the world have played a vital role in providing food and employment for hundreds of generations. Billions of people depend on seafood as an important source of protein and other nutrients. In fact, fish and shellfish together make up the single largest source of animal protein in the world (Weber, 1994). If humans could not access marine resources the land area required to support the animal life needed to provide an equivalent amount of protein would exceed the space available (Mathews-Amos, 1997). Consequently it is necessary that fish be harvested from the sea to sustain human life as well as to provide employment.

Originally fisheries were of a subsistence nature, providing food for families and communities on islands and in coastal regions. The operations were simple. A fisherman would sail a short distance in a small boat to catch the fish needed for the day and return before nightfall. However, as time passed and developments took place more advanced fishing techniques evolved. Trawls and complex traps were developed to make it easier to catch the fish. Eventually crews of fishermen could leave for days or weeks in larger vessels to harvest greater amounts of fish. As long as there was a method to preserve the fish (often salted, dried, or cured) they could remain at sea until the storage holds were filled. They would return with enough to feed themselves and their families as well as enough to sell, enabling them to earn a living. Fishing became an important business, providing incomes for many, as they were now able to sell large quantities of fish to provide food to others.

Prior to World War I fishermen were still very limited as to where and what they could fish. After the War, however, technology advanced quickly and soon diesel engines were widely available to everyone. Large fishing vessels no longer had to depend on wind to bring them to the fishing grounds; they could use engine power. There was more control over vessels and greater distances could be traveled in shorter periods of time. Increased horsepower was not the only advancement. Having powerful engines meant that a vessel could tow heavier fishing gear. Trawls and dredges became larger and heavier and catches increased as a result.

Along with being able to now fish at greater distances for longer periods of time, advances in fishing gear allowed harvesting to take place in environments where it was previously impossible. In the Bay of Fundy in the early 1980s fishing vessels were seeing success with rockhopper gear (DFO, 1994a). Developments of such gear as rockhopper and streetsweeper gear meant that nets could be towed on the roughest of bottom types. Any substrate from sand to gravel to boulders was now vulnerable to fishing gear and fishermen could harvest larger catches in many areas without having to worry about extensive gear damage.

This translated to lower costs for gear repair and replacement and in return resulted in increased incomes. However, along with being able to catch more of the fish they sought, fishermen were also catching more fish that were not wanted. The unwanted marine life that was captured, also known as bycatch, was more often than not simply thrown back into the sea to die, if it was not already dead. This practice of discarding was a waste of food and also impacted fish populations and the complex marine ecosystem as a whole.

Despite the obvious social and economic benefits of the fishing industry, many groups and individuals, such as environmental groups, scientists and the public in general, have become concerned about the environmental damage caused by modern fishing gear, particularly in recent years with the developments of heavier, more durable and efficient gear. Environmental groups, such as Greenpeace and Americas Oceans, have led campaigns proclaiming that fishing gear is destroying the seafloor, lost nets are needlessly catching many fish, and that extremely high levels of bycatch exist in many fisheries, large quantities of it being wasted by discarding. This has resulted in a wide range of opinions on the matter, but it has also led to increased efforts to significantly reduce environmentally damaging fishing practices and a search for solutions.

A great deal of conflict surrounds the issue of the effects of fishing on the marine environment. There are some groups with extreme opinions on both sides of the matter. Some environmental groups are of the opinion that any type of fishing that affects the environment in any way whatsoever should not take place at all and that the marine environment would be better left in its undisturbed natural state. At the other extreme, there are fish harvesters who are of the opinion that they are simply making a living by fishing and that their effects on the environment are minimal or, in some cases, are simply the cost of doing business. When the groups representing these opinions meet, the conflict proves to be disastrous and little progress can be made to appease either group, due to the opposing points of view. Fortunately, the majority of the population lies between these two extremes making it possible for opposing sides to communicate in a civilized manner to best determine solutions to their conflicts.

Such controversy often attracts media attention. Unfortunately it seems that only the most extreme or "newsworthy" stories are used to attract public attention and these are usually the most damning for the fishing industry. Rarely does one see or hear a news headline stating that fishermen are working towards improving selectivity devices to decrease bycatch or trying to modify gear to reduce contact with the seabed. Countless headlines claim destruction by fisheries, often spurred by an environmental group seeking to draw media attention to the issue. Of course, these claims of destruction may well be justified since a great many of the world's fisheries are either fully- or over-exploited. However, one cannot help but wonder why the many successes in fishing gear developments leading to more environmentally friendly fishing gear have not received the attention deserved. On a more positive note, such negative reviews by the media often result in greater effort by fishers and companies associated with fish harvesting to improve fishing gear.

The fishing industry is a necessary presence in the global community. It is necessary as a provider of food and a source of employment. There will always be a fishery; therefore groups of opposing views must work towards reconciliation. This should allow the fishing industry to maintain optimum performance, providing food in an efficient manner, yet also following conservation measures to preserve the environment and assuring that there will be sustainable fisheries.

What follows is an examination of the development of conservation harvesting, and, in particular, its progress in Atlantic Canada. The development of fisheries in the Northwest Atlantic and the associated technology will be discussed along with the controversies, pressures and perceptions surrounding the issues. Public perceptions of fisheries and policies implemented by government play major roles in fisheries development. Continued research and demands for solutions are also of importance in addition to the successful developments in conservation harvesting that have been achieved so far within the fishing industry in Atlantic Canada and around the world.

2. EVOLUTION OF FISHING IN ATLANTIC CANADA

2.1. The Evolution of Fishing Gear

Atlantic Canada's fishing history spans thousands of years. Almost ten thousand years ago the Maritime Archaic people followed the edge of retreating glaciers and found their way along the coasts of what are now Atlantic Canadian provinces (Employment and Immigration Canada, 1993). They fished in the cold North Atlantic waters, as did their descendents. Other native groups migrated to the area and learned about and further developed fishing techniques to ensure their survival from the sea. Included amongst these people were the Innu and Innuit of Labrador and the Beothucks of the island of Newfoundland (Employment and Immigration Canada, 1993).

Historically, hook and line gear has been the most commonly used fishing method in Atlantic Canada (Figure 1). From the late 1400s, when John Cabot discovered Newfoundland's rich cod-fishing grounds, to the mid-1800s hook and line gear was the predominant fishery (Ryan, 1990). This changed with the invention of the cod trap (Figure 2) in 1866 by Captain William H. Whitely at Rivière du St Paul off the coast of Labrador (Employment and Immigration Canada, 1993). The development of the cod trap was extremely important to the inshore cod fisheries of Newfoundland and Labrador and the Quebec Lower North Shore. It enabled an increase in the size of fishing crews and allowed men to spend more time ashore, relieving the women of much of the splitting, salting and curing that had to be done on shore (Ryan, 1990). The cod trap was very efficient for catching fish since it was able to catch large volumes of fish in relatively short periods of time (FRCC, 1997). Until the 1950s hook and line gear and cod traps were the centre of the Newfoundland fishery, and the fishery was focused almost exclusively on cod.

Figure 1: Hook and line fishing (www.stemnet.nf.ca/cod/hook.htm)

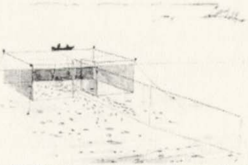


Figure 2: Cod trap (www.stemnet.nf.ca/cod/codt.htm)

In the first decade of the 1900s, small inshore fishing boats acquired gasoline engines. In 1908 otter trawlers were introduced in Atlantic coast waters (Lear, 1998). By the 1920s Nova Scotia fishing schooners had diesel engine power, which allowed for more operational freedom when fishing, better catches and higher earnings and profits (Andersen, 1998). It also meant that fishing was intensified, for longer periods of time in previously inaccessible areas. Although these important technological changes developed rapidly in most Atlantic Canadian fisheries, the changes were slower to take place in Newfoundland (Lear, 1998), leaving the island (at the time a separate country from the rest of Canada) slightly behind in technological advancements and improved fishing methods.

The introduction of diesel engine power for vessels in Atlantic Canada enabled the use of otter trawls for more efficient harvesting of fish. Trawling is a method of fishing whereby a large, cone-shaped net is towed with steel cables, or warps, at relatively low speeds. "Wings" extend the large, open end of the net, and the small end is closed by a bag, or codend. A vessel's engine power is used to tow the net and trawl doors are used to spread the connecting warps and hold the mouth of the net open, as seen in Figure 3 (DFO, 1999a). The net may be towed over the seabed or at any depth in the ocean as required to catch a particular target species (DFO, 1994a).

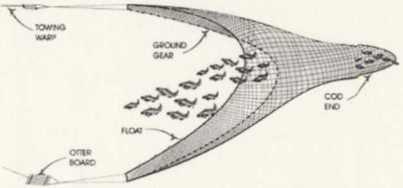


Figure 3: Otter Trawl (adapted from Smolowitz, 1998)

The method of trawling has a long history. From the time it was first carried out in the fourteenth century until the early 1900s, trawls were used mostly in shallower waters, such as in estuaries, bays and continental shelf areas at depths up to several hundred metres. However, the introduction of the diesel engine in the 1920s resulted in a sharp acceleration of the use of trawls (Lindeboom and de Groot, 1998). Many were opposed to the use of trawls, in particular inshore fish harvesters who were unable to achieve the efficiency of the large trawlers and felt it was a threat to their livelihood. To protect the inshore markets, in the late 1920s a Royal Commission banned trawling in the Atlantic region of Canada, a ban that lasted until 1948 (Gough, 2001). Although the French and Spanish had already been trawling on the Grand Banks for several years, the arrival of groundfish trawling technology in the Newfoundland fishery in 1935 allowed the industry there to move beyond its focus and dependence on Atlantic cod, and to expand by exploiting other target species such as haddock, redfish and flounder

(Lear, 1998). Trawler captains learned how to fish new species on new fishing grounds and at depths they had never fished before. As the numbers of Canadian and foreign trawlers grew so did the competition and fishing intensity for fish on the Grand Banks. During the period of 1948 (after the Canadian trawling ban had been lifted) to 1965 the groundfish populations were subject to extensive exploitation. European fleets increased in size and brought with them new fishing methods such as pair trawling and longlining. Large factory freezer trawlers were introduced, which could fish in much rougher water and in which fresh fish could be filleted and processed at sea (Lear, 1998) As a well-known Newfoundland trawler captain, Captain Arch Thornhill, once said, "Pity the fish and their sea bottom home" (Andersen, 1998;242).

Although traditional fishing methods were still widely used by independent inshore fishermen, trawling for fish intensified offshore. New developments in trawling technology were constantly evolving. More engine power allowed larger nets to be towed. Trawls were being modified to hold more fish, to be more durable, and to fish on substrates that had been avoided before because of the rough terrain that would tear and destroy nets.

Like bottom trawling, mid-water or pelagic trawling also requires a large mouth opening to gather shoals of pelagic fish, such as redfish and hake. Mid-water doors and deep side panels in the net help to maintain the horizontal spread of the trawl opening (Sainsbury, 1996), while the vertical opening is maintained by weights on the bottom of the net and floats on the top (DFO, 1994b). Unlike bottom trawls, pelagic and semi-pelagic trawls do not touch the seabed and therefore have little influence on its physical and chemical properties (FRCC, 1994). However, as in many other fisheries, there are problems associated with bycatch, including bycatch of large marine mammals such as whales and porpoises. In the present Atlantic Canadian fishery pelagic trawling is used primarily for the harvest of redfish, or ocean perch (Sainsbury, 1996).

The 1930s saw the modernization of the traditional hook and line fishery in the Gulf of St. Lawrence with the development of the "longliner". Longliners were vessels capable of fishing further offshore, and were equipped with mechanical hauling devices for more efficient use of the traditional hook and line gear (DFO, 1983). Longlining involves the use of a "long line" with a series of baited hooks spread along the ocean floor or through the water column (Industry Canada, 1996). In Atlantic Canada this method is used mainly to catch species such as cod, haddock, hake and turbot. In the 1970s longlining became even more efficient with the development of a mechanical baiting system by O. Mustad and Sons Ltd. The Mustad Autoline System uses a line hauler to retrieve the gear from the water, which is then passed through a machine that removes any bait still present. When the gear has been inspected by the fishers and is ready for shooting, the high-flyer and buoy line, which are attached to the line, are launched. The resistance of the buoy and the rope in the water pulls the hooks on the line through the baiting machine, where each hook activates the baiting machine, which in turn double-baits each hook as it passes through. Despite the efficiency and effectiveness of the Mustad system, it is not widely used in the Newfoundland fishery. This is probably because the system is expensive, and it is difficult to justify the purchase given the seasonal nature of the fishery (DFO, 1993). DFO has encouraged the use of longlines since this method of fishing produces a top quality, high-value product (Industry Canada, 1996) and it is viewed by many scientists and fish harvesters to be one of the most conservation friendly of all the gear types used in Atlantic Canada (FRCC, 1997).

European and Scandinavian seining technology has also become a popular method of fishing in Atlantic Canada in the past 50 years. Danish seining originated in Denmark in 1848 and was adopted by Scottish fish harvesters in the 1920s (FRCC, 1994). In the 1950s it was introduced to the fishery in the southern Gulf of St. Lawrence, where it is still used more widely than in other areas of Atlantic Canada (FRCC, 1997). In both Danish and Scottish seining, a net and a series of ropes are spread out in a pear-shaped form along the ocean floor (Industry Canada, 1996). The primary function of the ropes is to sweep over the seabed, herding fish into the path of the net (DFO, 1994b). The environmental impact of seining may be less significant than that of otter trawling, due to the absence of otter boards, the slower towing speed, and the shorter tow duration (FRCC, 1994).

In the 1960s gillnets (Figure 4) were introduced to Atlantic Canadian fishing operations in Trinity Bay, Newfoundland for turbot fishing (Brodie *et al.*, 1999), and quickly became one of the most widely used groundfish gears in the region. Gillnets are extremely efficient, are very size selective, can be fished in very deep waters (up to 1600m) and can be used to catch pelagic fish, such as salmon and herring, and almost any species of groundfish, such as cod and turbot (FRCC, 1997).

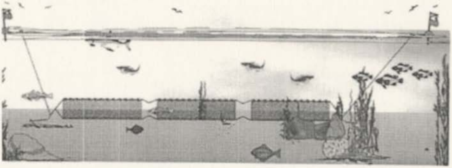


Figure 4: Gillnets (adapted from Smolowitz, 1998)

Later developments in Atlantic Canadian fisheries included the introduction of shellfish pots and scallop rakes or dredges. The use of crab pots has expanded rapidly in Eastern Canada since 1970 with many larger vessels that used only gillnets and seines in the past now having great success with crab pots (DFO, 1992/93).

The past 150 years has seen major advancements in fishing gear technology in the fisheries of the Northwest Atlantic. Harvesting fish has become more efficient with increasingly larger catches being taken in shorter periods of time. Such developments have been vital to the survival of Atlantic Canada, providing food and employment and feeding local economies that otherwise would probably not exist. Table 1 lists species, the areas where they are harvested and the types of gear used.

Table 1: Major species harvested in Atlantic Canada, areas fished and gear types used

(table continued on next page)

Species	Area Fished	Primary Gear Types	Information Source
American plaice	Gulf of St. Lawrence	Seine, Otter trawl	SSR A3-26 (2001)
	Eastern Scotian Shelf	Seine, Otter trawl	SSR A3-34 (2000)
	St. Pierre Bank	Otter trawl, seine, gillnet	SSR A2-02 (1999)
	Northeast Nfld. Shelf	Otter trawl, Gillnet	SSR A2-11 (2000)
	Labrador Shelf	Otter trawl, Gillnet	SSR A2-11 (2000)
Yellowtail Flounder	South Gulf of St. Lawrence	Otter trawl, Gillnet	SSR A3-16 (1999)
	Georges Bank	Otter trawl	SSR A3-15 (2000)
	Grand Bank	Otter trawl	SCR Doc. 99/42
Cod	Southern Scotian Shelf	Otter trawl, Gillnet, Longline	SSR A3-05 (2000)
	Bay of Fundy	Otter trawl, Gillnet, Longline	SSR A3-05 (2000)
	Georges Bank	Longline, Gillnet	SSR A3-04 (2001)
	South Gulf of St. Lawrence	Otter trawl, Seine, Longline, Gillnet	SSR A3-01 (2001)
	St. Pierre Bank, South Coast Newfoundland	Otter trawl, Seine, Gillnet	SSR A2-02 (2000)

Species	Area Fished	Primary Gear Types	Information Source
Haddock	Southern Scotian Shelf	Mid-water trawl, Longline	SSR 06/69E (1996)
	Bay of Fundy	Mid-water trawl, Longline	SSR 06/69E (1996)
Pollock	Scotian Shelf	Otter trawl, Gillnet, Longline	SSR 96/94E (1996)
Redfish	Scotian Shelf	Otter trawl, Mid-water trawl	SSR 96/88 (1996)
	Laurentian Channel	Otter trawl, Mid-water trawl	SSR A1-01 (1999)
	Southern Grand Bank	Otter trawl, Mid-water trawl	SSR A1-01 (1999)
Turbot	Gulf of St. Lawrence	Gillnet	SSR A4-03 (2001)
	Northeast Nfld. Shelf	Gillnet, Otter trawl	SCR Doc. 98/47 (1998)
	Labrador Shelf	Gillnet, Otter trawl	SCR Doc. 98/47 (1998)
Witch Flounder	St.Pierre Bank, Fortune Bay	Otter trawl, Seine, Gillnet	SSR A2-09 (1999)
	Scotian Shelf	Otter trawl, Seine	SSR A3-19 (1997)
	Grand Bank	Otter trawl	SCR Doc. 98/49 (1998)
Snow Crab	Gulf of St. Lawrence	Conical crab pots	SSR C4-01 (2001)
	Eastern Nova Scotia	Square, Conical Pots	SSR C3-02 (2001)
	Northeast Nfld. Shelf	Conical crab pots	SSR C2-01 (2001)
	Labrador Shelf	Conical crab pots	SSR C2-01 (2001)
Scallops	Georges Bank	New Bedford Scallop Rake	SSR C3-17 (2001)
	Brown's Bank	New Bedford Scallop Rake	SSR C3-18 (1998)
	Eastern Scotian Shelf	New Bedford Scallop Rake	SSR C3-19 (2001)
	German Bank	New Bedford Scallop Rake	SSR C3-20 (1997)
Northern Shrimp	Eastern Scotian Shelf	Otter trawl	SSR C3-15 (2000)
	Hopedale Channel	Otter trawl	SSR C2-05 (2001)
	Cartwright Channel	Otter trawl	SSR C2-05 (2001)
	Hawke Channel	Otter trawl	SSR C2-05 (2001)
	East Coast Labrador	Otter trawl	SSR C2-05 (2001)
	Northeast Coast Nfld.	Otter trawl	SSR C2-05 (2001)

***SSR = DFO Stock Status Report**
SCR = NAFO Scientific Council Report

Despite these fishing gear advancements and the benefits to the fishery and the economy in general, controversies surrounding many of these advancements have surfaced, blaming fishing gear for the depletion of valuable fish stocks and destruction of the marine environment. The sections that follow will discuss many of these controversies and the fishing gear developments that have focused on solving many of the negative aspects of the traditional fishing gear used in Atlantic Canada since the mid-1800s.

2.2. Fisheries Management in Atlantic Canada

Although the fishery in Atlantic Canada has been very active for hundreds of years, it was not until the late 1800s that some form of management for fisheries was established. In 1857 the first comprehensive fisheries legislation in British North America was passed, mainly for conservation of river and salmon fisheries, followed by the Dominion Fisheries Act in 1868, which gave the Governor in Council power to make regulations as deemed necessary for better management of inland and marine fisheries (Parsons, 1993).

Until the end of World War II there appeared to be little need to regulate fisheries in the Northwest Atlantic. However, the arrival of new distant-water fleets in the 1950s gave rise to concerns about fisheries off the Atlantic Coasts of Canada and the United States. In response to these concerns the International Commission for the Northwest Atlantic Fisheries (ICNAF) was established in 1951. By the early 1950s ICNAF started to regulate fisheries through the use of mesh size controls. Unfortunately, there were no limits on amount of fishing or catches until 1971 (Parsons, 1993).

In 1971 the Fisheries and Marine Service was formed in Canada, to protect Canada's interest in its own fisheries resources and as a result of growing concern for environmental protection. The Minister for the Environment was responsible for fisheries until 1979 when Parliament created the new Department of Fisheries and Oceans (DFO) (Parsons, 1993).

At the same time the Northwest Atlantic Fisheries Organization (NAFO) was formed in 1979, taking the place of ICNAF on the international fisheries management scene. The NAFO Convention Area covers the Northwest Atlantic, including waters under national fisheries jurisdiction, such as that of Canada or the United States. The main purpose of NAFO is to establish fisheries management measures, in particular total allowable catches and national allocations for stocks in the Convention Area (Parsons, 1993).

The formations of ICNAF, NAFO and DFO have been instrumental in protecting the fish stocks of Atlantic Canada. In particular, NAFO and DFO have had a major influence on conservation harvesting and continue to do so with consultations with other nations and with many representatives of the fishing industry in Atlantic Canada.

3. SOME MAJOR EFFECTS OF FISHING

Within the marine environment fishing is the most extensive human exploitative activity (Jennings and Kaiser, 1998). Without a doubt any human activities in which natural resources are exploited are bound to have negative impacts on the state of that resource and its surrounding environment.

The various types of fishing gears used and the manners in which they are employed directly affect the state of fish stocks in the area, including both target and non-target species, and the physical habitat in which these organisms live. Demersal otter trawls and dredges are designed to contact the seabed to maximize fishing efficiency. This contact with the substrate disturbs the bottom, moving organisms and marine debris, suspending sediment, scraping and ploughing the seabed, and destroying benthos. Non-selective fishing gears take both targeted and non-targeted species, often simply discarding the unwanted fish, which has led to worldwide concern for such wastage as a result of bycatch. Nets that have been lost or left unattended, also known as "ghost" nets, catch many fish and shellfish, which are left to die, contributing to unaccounted mortality of marine species.

Not a lot of research has been conducted so far in the Northwest Atlantic on the direct effects of fishing gear, although recently there have been increasing efforts by research scientists. The International Council for the Exploration of the Sea (ICES), of which Canada has been a member since 1967 (Parsons, 1993), has been conducting bottom impact studies since the 1960s. ICES research has found that bottom trawls can remove some physical features from the ocean environment, such as peat banks or boulder reefs, and that these changes are almost always permanent. ICES has also found that bottom trawling can result in a reduction of structural biota, such as sponges and oyster beds, and a reduction in population complexity (ICES, 2000). There are many opinions on the severity of direct fishing gear impacts, some conveying total disregard for the effects of fishing, some others demanding a complete elimination of fishing effects.

There are also many indirect effects of fishing, most of which are extremely difficult to study or quantify. The long-term effects of benthic disturbances have not been determined with any degree of certainty, and the degree of post-fishing mortality has only been studied carefully in the past decade or so. ICES has completed some research on post-fishing mortality and has determined that fish that escape from the mesh in fishing gear are indeed often damaged or even killed (ICES, 1995). The quantities of fish that escape cannot be readily assessed, however the proportions that are likely to survive escaping from some types of trawls are given in Table 2.

Table 2. Range of survival rates reported for fish escaping from various trawls. (ICES, 1995)

Gear	Species	Percent Survival
Otter trawl	Cod, Haddock	67-94%
Beam trawl	Sole	60-100%
	Plaice	85%
Pelagic trawl	Herring	60-97%

Another indirect consequence of fishing is the effects of sediment resuspension on benthic organisms. The effects of light reduction and the clogging of feeding tubes are unclear. There are also questions relating to the effects of sediment resuspension on the chemical composition of the water in the area of disturbance, but again, these are questions that do not yet have any clear answers.

This section examines some of the major effects of fishing on marine species and habitats. It is important to realize that much uncertainty surrounds these issues, however the effects of fishing are becoming increasingly important to scientists, fish harvesters, environmentalists, and many other stakeholders with fisheries interests. It is imperative that much more research be completed in this area so as to provide a better understanding of fishing effects on the marine environment and the socio-economic effects that will ensue.

3.1. Bycatch and Discards

In Biblical times it was common for the undesired fish to be thrown back into the water. Matthew 13: 47-48 states that "the kingdom of heaven is like a dragnet cast into the sea, and gathering fish of every kind; and when it was filled, they drew it up on the beach; and they sat down, and gathered the good fish into containers, but the bad they threw away". In recent years however, bycatch has become a central issue in the management of fisheries throughout the world. The public has become increasingly aware of the seriousness of bycatch and there has been an emerging consensus that measures must be taken to minimize incidental catch levels to insignificant amounts (Crowder and Murawski, 1998).

Before attempting to discuss this issue in detail one must first decide what indeed "bycatch" actually refers to as it often has different meanings. Alverson *et al* (1994), through a review of various sources of literature, have found that "bycatch" has been used to identify:

1) Species retained and sold.
2) Species or sizes and sexes of species discarded as a result of economic, legal, or personal considerations.

3) Non-targeted species retained and sold, plus all discards.

Other words are also often used interchangeably, including the words "bycatch" and "discards" which, although they will have quite different meanings in this document, are often used synonymously. These discrepancies in definitions only add more complexity to an issue that is already confusing to many. To prevent confusion to readers the following definitions will be used in this manuscript:

Bycatch

- Undesired fish which are caught when targeting a particular species of fish
- Includes non-target species as well as those of target species which are of undesirable sizes or sex
- May also include birds and marine mammals

Discards

- Catch that is not retained (returned to the sea, dead or alive)
- Returned to the sea due to economic, legal, or personal considerations
- Usually unwanted bycatch

3.1.a. Extent of Bycatch Problems

Recent estimates by the Food and Agriculture Organization of the United Nations (FAO) show that approximately 20 million metric tonnes (mt) of fish are discarded annually from commercial fisheries around the globe. With world landings from marine fisheries being approximately 83 million mt, discards represent about one quarter of the total world catch (Pascoe, 1997). These figures indicate the magnitude of discards and emphasize the importance of reducing incidental catches if such high discard levels are also to be reduced.

To further demonstrate just how much fish is discarded on an annual basis, Table 3 demonstrates discard weights in some of the world's major fishing regions.

Table 3: Discard weight by major world regions (Alverson *et al*, 1994)

Area	Discard Weight (mt)
Northwest Pacific	9,131,754
Northeast Atlantic	3,671,346
West Central Pacific	2,776,726
Southeast Pacific	2,601,640
Southwest Atlantic	802,884
Northwest Atlantic	**685,949**
Atlantic Antarctic	35,119
Pacific Antarctic	109

As shown in Table 3 the Northwest Pacific fisheries contribute to the majority of discards in global fisheries. The Northwest Atlantic, which includes

Newfoundland's fishery, was ranked 11th in the world in 1994 with an annual discard weight of 685,949 mt. This amount has most likely been reduced since 1994 due to advances in gear technology for reducing bycatch, some of which will be discussed later. In addition, Canada introduced a "no discard" rule, or the mandatory landing of all groundfish, in the Atlantic fishery regulations in 1993 (DFO, 1994c). This should also have resulted in a major reduction of discards in the Northwest Atlantic since then.

There is, however, the potential for problems associated with mandatory landing of all groundfish. Since this results in the landing of fish of a wide range of sizes, most fish processors have created a two-tier pricing system whereby the larger fish, such as cod, bring a higher price, and the smaller fish are of lesser value. This most likely results in high-grading, which is the illegal discarding of smaller fish so that a harvester can continue to fish in search of larger fish to fulfill his/her quota (Pascoe, 1997). Since most small vessels have little or no observer coverage, it is difficult to determine if this practice is common, but it is suspected that minimum fish size rules are ignored. This works against the "no discard" rule and can be detrimental to conservation efforts.

Although almost all fisheries have some levels of bycatch, it appears that shrimp fisheries have the highest bycatch rates, most likely due to the small mesh size, which is required to catch the tiny shrimp. In the early 1990s it was estimated that shrimp fisheries accounted for approximately 35% of global fisheries discards (Alverson *et al.* 1994). However the development and widespread use of separating grates and other sorting systems, which will be discussed later, has significantly reduced bycatch in recent years.

Almost any marine species is vulnerable to being caught as bycatch and, if discarded, survival of the bycatch is poor in most gear types. Bycatch tends to selectively remove specific cohorts and species of fish and therefore leads to changes in the composition of marine communities. As well as biological effects there are also economic effects such as the increased cost associated with extra time and labour needed to sort the catch and the long-term economic cost of damaged fish populations (Highsmith, 1997). In addition to the detrimental effects of bycatch, discarding is a wasteful practice. Not only is it a waste of marine protein, but it also represents a loss of employment for potential food processors, and it is also wasteful to the environment itself in terms of lost biomass, disruption of food chains and removal of nutrients (McAllister, 2000). These are indeed serious issues and measures must be taken to reduce bycatch and subsequent discards.

3.1.b. Fishing Gear Causing Bycatch Concerns

Most fisheries do have some levels of incidental catch, but the degree of bycatch varies. There are some types of fishing gear, however, which have been especially problematic and are known for their high levels of bycatch. For instance, shrimp trawls with their small mesh sizes retain almost anything that enters the codend, as do most other trawls for which mesh sizes are too small to allow all unwanted species to escape while retaining the target species. Scallop rakes retain high numbers of monkfish, flatfish, lobsters and benthic organisms (Smolowitz, 1998). Longlines are known to catch unwanted fish, as well as marine mammals and birds that are attracted by the bait. Not only is bycatch wasteful and harmful to animal populations, there are also concerns that many of the species which make up part of the bycatch are endangered, protected or are from depleted or recovering stocks.

Selectivity of otter trawls is related mainly to the size and shape of the mesh used. When the target species is a relatively large species, such as cod or redfish, then bycatch is a less severe problem, as the meshes can be large enough to allow smaller fish and other species to escape. However when the target species is quite small, such as shrimp, a small mesh size is required to retain the catch. This also results in the capture of almost anything that enters the net that is larger than the shrimp, including many groundfish. For example, in the Newfoundland shrimp trawl fishery in the early 1990s, a bycatch as high as

1.38kg per 1kg landed shrimp was recorded (Alverson, *et al.*, 1994) and, also in Newfoundland, a high cod bycatch in the winter redfish fishery led to several closures (FRCC, 1994).

Seining in the Gulf of St. Lawrence has also experienced problems relating to bycatch. In fact, in the spring of 1996 in the American plaice and witch flounder fisheries, the Danish seine fleet was temporarily prohibited from fishing after the bycatch of cod exceeded the allowable 5% limit. The fishery was closed a second time the same year because the catch of small American plaice (less then 30cm) exceeded the 15% small fish protocol (CAFID, 1997).

Although gillnets are highly size selective, they are also known to capture species other than those intended, including shellfish, marine birds and mammals. Between 1981 and 1984 in Eastern Newfoundland alone approximately 27,000 birds per year were incidentally caught in gillnets. The extent of the bycatch by gillnets is also emphasized by the fact that approximately 10,700 harp seals were incidentally caught in the area of Western Newfoundland in the spring of 1988. Although the incidents of whales caught in gillnets are less extensive, an average of 24 humpback whales per year were trapped in gillnets between 1979 and 1987 and as many as 182 collided with the gear annually (Lien *et al.*, 1989).

Shellfish pots are also known to retain bycatch. For instance, in the Atlantic Canadian snow crab fishery only males with a carapace size of 3.75" or greater are permitted to be harvested. Unfortunately, many females and small males are also captured in these pots and are discarded once the pots are retrieved. Although usually still alive when discarded, the survival rates for the crab that are returned to the water are difficult to determine and have not yet been thoroughly studied in Canada. However, a study by the U.S. National Marine Fisheries Service (NMFS) determined the injury and mortality rates for discarded undersized red king crab and Tanner crab during simulated fishing. During the study, 15% of the red king crabs and 27% of the Tanner crabs received injuries, and after 48 hours in seawater only 2% of the red king crabs and 10% of the Tanner crabs died as a result of handling (Stevens, 1995). It is possible that similar results might be seen in the Atlantic Canadian snow crab fishery.

Bycatch of species other than cod in cod traps, especially Atlantic salmon, has also been problematic in Atlantic Canada. Atlantic salmon have been showing slow rates of recovery in recent years, but with the start of the sentinel cod trap fishery on the West coast of Newfoundland, high levels of bycatch of Atlantic salmon have been reported (CASEC, 1996a). Similarly, Atlantic salmon bycatch has also been problematic in capelin traps in the Northeast coast capelin fishery in Newfoundland (CASEC, 1996b). Studies have been conducted, with funding from the Cooperation Agreement for Salmonid Enhancement/Conservation

(CASEC), to reduce bycatch of salmon in these traps, with some positive results, yet further studies have been recommended to further test the methods used.

Yet another type of fishing gear that causes bycatch concerns is shellfish rakes, such as scallop rakes. The top portion of a shellfish rake consists of a mesh cover that is intended to keep shellfish from escaping. Unfortunately it also prevents other species that enter the rake from escaping, often resulting in bycatch of many unwanted species. In Atlantic Canada, common bycatch species in scallop rakes include monkfish, flounders, and lobsters. If the bycatch that enters the rake tends to swim upwards and is able to fit through the top mesh then it is able to escape. Others are simply left in the rake, unable to escape and end up as bycatch. A unique and unfortunate aspect of the scallop fishery in Atlantic Canada is that any incidental catch in the scallop rakes may not be landed (with the exception of monkfish). This leads to the discarding and wastage of otherwise valuable seafood products.

Each of the aforementioned gear types requires attention and a search for solutions for their bycatch problems. Fortunately many of their past bycatch concerns have been and are currently being addressed. However, it is essential that fishing gear technology continue to be developed to drastically reduce bycatch in marine fisheries. Eventually complete elimination of unwanted catch is the ideal accomplishment, although an unlikely one in the near future. Atlantic

Canada has played a major role in many developments towards bycatch reduction as will be discussed in later sections.

3.2. Ecosystem Effects

3.2.a. The Extent of Ecosystem Effects Due to Fishing

A series of papers published in *Conservation Biology* in December of 1998 created a stir amongst environmentalists and fishers alike, adding to concerns which, in the past several years, have focused on the impacts of fishing on the marine environment. This particular series, entitled *Effects of Mobile Fishing Gear on Marine Benthos*, was a special section of the journal that came about as a result of a 1996 scientific workshop on the topic. The series painted a disturbing picture, describing how trawling and dredging affect benthic species composition, spatial structure, community function and the biogeochemistry of the water column, making the use of mobile fishing gear "humankind's most important physical disturbance of the biosphere" (Watling and Norse, 1998).

However there are many who insist that although fishing does affect the seabed and its inhabitants, the effects are not as severe as those portrayed in the 1998 papers (Whitney, 1998; Gordon *et al.*, 1998). Some fish harvesters even insist that fishing improves the conditions of the seabed, much the same as tilling the soil improves the condition of farmland. One of the earliest papers on the effects of fishing on the seafloor by Graham (1955) concluded that damage to species on the seafloor could not be serious because otherwise there would be a noticeable difference in these species where trawling is impossible.

Indeed there have been noticeable decreases in biomass in many fishing areas since Graham's 1955 paper. But can all of these decreases be attributed to bottom disturbances caused by trawling? There are most likely many other factors or a combination of factors involved (overfishing, for example) that have led to decreased fish stocks in trawled areas. In defense of trawling there are also areas that exist where, despite trawling for decades, possibly even centuries, fish continue to thrive and the areas remain highly productive. For example, an area located outside Casco Bay, Maine has been bottom trawled intensively for decades. The area is approximately 10 miles long and one mile wide, consists of a smooth, muddy bottom, and is trawled for different species of fish throughout the year. Several different types of trawls are used, including those with chain sweeps and rockhoppers and roller gear. However, despite the intensive fishing on the bottom the area continues to be very productive (Pendleton, 1998).

The extent of fishing effects on the marine environment and whether these effects are harmful or beneficial is a growing area of study. There have been no long-term studies that can conclusively say that fishing harms or benefits the marine environment. However the list of short-term studies has been growing in the past several years and the results of these studies vary widely.

3.2.b. Fishing Gear Responsible for Ecosystem Effects

Any gear type that disturbs the seabed is bound to affect the ecosystem to some extent. Bottom trawls, beam trawls, rakes and dredges are the gear types with the greatest degree of contact with the sea bottom and therefore are the ones most commonly accused of being detrimental to the sea floor and the marine environment.

Otter trawls are used mainly to catch groundfish and shrimp. They have a thick groundrope along the lower opening of the net which may be weighted with rubber disks, bobbins, chains or wire that help to keep the net on or near the seabed and may also help to move the net over various types of terrain. Floats along the headrope help to keep the net open. Otter trawls require trawl doors, or otter boards, to maintain the horizontal opening of the net (DFO, 1999a). Otter boards slide along the seabed, creating sediment clouds and herding groundfish into the net (Figure 5).

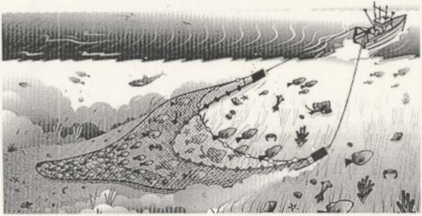


Figure 5: Mud clouds created by otter doors

(taken from www.americanoceans.org/fish/trawlbroch1.htm)

Like otter trawls, beam trawls are also towed along the sea floor, but they generally use a smaller net and use a metal or wooden beam rather than otter boards to maintain the horizontal opening of the net. Beam trawls are an alternative for smaller vessels that do not have the required power for otter trawling (DFO, 1998a). Immigrant Japanese fishermen introduced shrimp beam trawling to fish harvesters in British Columbia in the late 1800s (DFO, 2001a). Although they are used regularly in B.C., they have not been traditionally used in Atlantic Canadian fisheries and will not be discussed in detail in this paper. However, in 1997 an exploratory initiative allowed beam trawls, equipped with a mandatory Nordmøre grate, to be used by vessels <45' in Shrimp Fishing Area 6 off the coast of Labrador (DFO, 1997). To date the results of this initiative have been promising (DFA, 1998b) and may result in future growth of the shrimp beam trawl fishery in Atlantic Canada.

Trawling has been carried out since the fourteenth century when the British began using trawls in the North Sea (FRCC, 1994). Even at this time there were complaints of damage by fishing on the bottom. In 1376 the King of England received a petition from the Commons, saying that "the great and long iron of the wondyrchoun runs so heavily and hardly over the ground when fishing that it destroys the flowers of the land below water there" (Graham, 1955). As mentioned on page 9, a ban on trawling in Atlantic Canada was in place from 1928-1948, as a response to inshore harvesters who felt that their livelihoods were threatened by the efficiency of the large trawlers (Gough, 2001). Unfortunately, despite the presence of concern, not much research was conducted to confirm the extent of destruction until the latter part of the twentieth century when the environmental movement created further interest in the matter.

Studies have shown that bottom trawling destroys marine life, crushing shellfish and crustaceans and tearing up organisms embedded in the sediment (Gordon *et al*, 1998). An ongoing otter-trawling experiment taking place on the Grand Banks of Newfoundland has demonstrated that intensive trawling on the sandy bottom reduces the biomass of large epibenthic organisms, such as infaunal bivalves, and also changes physical habitat structure by smoothing the surface of the seabed (Gordon *et al*, 1998). However the rate of recovery in such areas varies depending on tides, currents and other environmental factors. In shallower areas with strong currents and wave action all traces of trawling activity may disappear within a very short period of time, often in as little as twenty-four hours. Other areas may take longer to recover, perhaps even as long as a full year (Schwinghamer *et al*, 1998). This prolonged recovery generally occurs in deeper waters with little natural disturbance where evidence of trawling may last for extended periods of time, however more studies must be carried out to determine the time-scales involved in trawling disturbances.

Rakes and dredges, most commonly used for fishing shellfish such as scallops, are pulled over the seabed. One type of rake commonly used in Atlantic Canada is the New Bedford style scallop rake (Figure 6). The scallops are collected in a ring bag that is attached to a steel frame. The front of this frame, the bale, usually rides off the seabed. Behind the bale is the cutting bar, which also rides off the bottom. Attached to the frame is a sweep chain that sweeps back into an arc and is attached to the bottom of a steel ring bag (Smolowitz, 1998). The top of the dredge is generally constructed of a twine mesh that prevents scallops from escaping but is also known to be problematic due to the fact that it retains finfish and other bycatch.

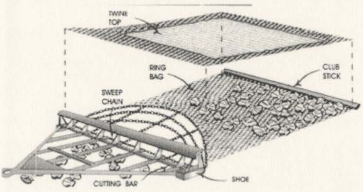


Figure 6: Scallop rake (Smolowitz, 1998)

Dredging for scallops and surf clams, which takes place on the Scotian Shelf, is also very destructive to the seabed. A hydraulic dredge is much more efficient than a scallop rake and does not damage as many shellfish. Seawater is pumped through a large hose in front of the dredge and, using pressure, is jetted into the sand to create a soft mud to make it easy for the dredge to pass through the bottom (Gorman, 1994). Carefully set spacing on the bars of the dredge allow most small scallops and other organisms to pass through while the larger scallops, as well as larger bycatch, are retained. Restrictions on hose length and pumping pressure allow dredging only to take place in shallow waters, yet within these shallows dredges can be severely destructive to life on the sea floor (New Jersey Fishing, 2000).

Another concern regarding mobile fishing gear in contact with the sea floor is sediment resuspension. Until recently the effects of trawling and dredging operations on sediment dynamics has been largely overlooked. Trawl doors often create clouds of bottom sediment that herd fish into the net. Other parts of the trawl, such as the bobbins, weights and tickler chains contacting the seabed have also been observed suspending sediment. Scallop rakes are extremely heavy and have significant contact with the sea floor, stirring up sediment and disturbing organisms. A study conducted by James Churchill off the Northeast coast of the United States demonstrated that trawling can make a significant contribution to the time-averaged suspended sediment load over heavily trawled regions, particularly in areas with fine sediment (Churchill, 1989). Although it is not yet known if this physical disturbance has a positive or negative effect on fisheries, it has been determined that mixing of the upper layers of the seabed impedes the colonization of gravel bottom by attached organisms, reduces the roughness of the terrain, and reduces overall biological diversity and abundance (Valentine and Lough, 1991). Besides preventing colonization, suspended sediment may also have some adverse direct effects on organisms such as abrasion of gill membranes and impairment of feeding for visual feeders due to increased turbidity (DFO, 199_) and clogging of feeding apparatuses for various sessile benthic organisms (Rhoads, 1974).

Although fishing may disturb the seabed, natural disturbances also take place. These natural disturbances to the sea floor must also be considered when discussing the impacts of fishing on the marine environment. In many shallow areas storms and rough wave action alter the seabed on a regular basis. Icebergs can plough deep into the seabed in Arctic and Antarctic waters, destroying organisms and the structure of the seabed. Many of these naturally disturbed areas are also frequented fishing grounds. Although the fishing activity may disturb the seabed and suspend sediment particles, there is debate on whether such effects are detrimental to life on the sea floor.

3.3. Ghost Fishing

The term "ghost fishing" is used to describe lost or discarded nets (usually gillnets and drift nets) and pots that continue to fish for extended periods of time after being left in the water. This lost gear is a source of concern, as many believe that this continuous fishing causes unnecessary losses to both commercial and non-commercial stocks (Bech, 1995).

Modern fishing gear tends to be made of durable material, such as plastic monofilament twine in gillnets, which is not biodegradable (DFO, 1993). Although such durable gear is advantageous for fishers in that it is less susceptible to damage and fewer repairs have to be made to the gear, it can be detrimental if the gear is lost. This occurs if the gear is able to remain intact for an extended period of time and continue to fish and destroy marine life. The best example of this is lost gillnets.

3.3.a. Extent of Ghost Fishing in Atlantic Canada

There are concerns not only for the fish and shellfish that are killed unnecessarily but also for marine birds, mammals and turtles that become victims of lost or untended gear. Records show that worldwide there are at least 136 species reported to have been entangled in lost fishing gear (Laist, 1995). These include seven of the eight sea turtle species, 60% percent of the baleen whale species, 16% of all seabird species and many species of commercial fish and shellfish. Most of these entanglement cases involve small pieces of lost fishing gear, in particular pieces of trawl netting, gillnets and monofilament fishing line (Laist, 1995).

In Atlantic Canada ghost fishing has been a serious problem, especially throughout the 1960s to the early 1990s. It has been estimated that for a number of years prior to 1992 an average of 8000 gillnets were lost each year in the Atlantic Region (Fisheries and Marine Institute, 1995). In addition to this, between 1980 and 1990 approximately 30,000 pots were lost in the DFO Gulf region alone (Fisheries and Marine Institute, 1995). In the past several years growing awareness and concern for the effects of ghost fishing as well as gear-loss prevention programs have resulted in attempts to reduce ghost fishing. Despite this, ghost fishing is still a problem in some areas of Atlantic Canada. For example, when the Department of Fisheries and Oceans closed the cod fishery in Placentia Bay, Newfoundland in March 2000, some fishermen left their nets in the water. Officials from DFO hauled as many nets as possible out of the water and in one week alone pulled in 43 nets containing 25,000 pounds of cod and 2,000 pounds each of crab and flounder (Welsh, 2000).

3.3.b. Ghost Fishing Gear

In Atlantic Canada lost gillnets make up the majority of lost fishing gear (Figure 7). Most gillnet losses are due to environmental conditions such as powerful currents, movement of ice and heavy seas. Conflict with other fishing gear, particularly mobile gear, and vessel traffic are also contributing factors. Negligence on the part of the fisher, such as leaving the net for a long period of time, forgetting the location, or not marking the gear properly also results in gillnet losses. In the early 1970s a gear replacement program was in effect for Atlantic Canadian fishermen who lost gillnets. This also may have led them to be more careless with their nets and, since the gear could easily be replaced, probably led to more gillnets being lost or abandoned than there would have been otherwise (DFO, 1992b).

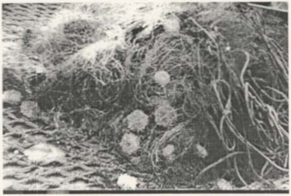


Figure 7: Retrieved ghost net containing living and dead marine organisms (Ocean Net, 2000)

There are other factors that may contribute to gillnet losses. Some may become caught on the sea floor causing part of the net to be torn away and left on the bottom. Whales and other cetaceans feeding in the same areas where gillnets have been set often become tangled in the gear and result in lost nets. Unfortunately the animal is also likely to be lost, drowning as a result of the entanglement. Illegal gillnetting also takes place, although the extent of this is not known since numbers on illegal activity are difficult to determine. In these cases fishers may abandon their gear rather than face the consequences of being caught by fisheries officials. Unfortunately competition and personal conflicts may also lead to sabotage and destruction of nets belonging to others, adding to the quantity of ghost gear already causing problems (Aquaprojects, 1992).

The long-term impact of gillnet losses may be reduced in shallower inshore waters where tide and wave action can roll up the netting, reducing its catching ability (DFO, 1999a). Algal growth on the nets in shallow waters also reduces fish capture (DFO, 1999a). However as fish harvesters move to deeper waters, net losses become more common and catching ability is not so easily reduced. In recent years losses in deeper waters have increased significantly over those lost closer to shore despite the fact only a fraction of the number of vessels partake in deepwater gillnetting compared with the many inshore vessels. As fishers move to deeper waters they tend to continue to use gillnets intended for use in shallower waters, which are not designed for the severe conditions of the deep North Atlantic. This, combined with the fact that deep-water sites are difficult to monitor, also results in gear losses (Aquaprojects, 1992).

In addition to lost gillnets, lost pots also pose problems as ghost gear. In Atlantic Canada snow crab (*Chionoecetes opilio*) is harvested using conical pots (Figure 8). These pots are sometimes lost, usually due to unfavorable weather conditions and moving ice at the beginning of the fishing season. Research results indicate that a lost pot, if baited, will capture crabs to its saturation level, and then decline in the number of crab due to cannibalism and amphipod predation. Throughout the summer months this number does not tend to increase, however from September until the following summer the pot's catch will increase again to its saturation level and restart the ghost-fishing cycle. Those pots lost with no bait may also be as damaging as baited pots in the long term (Vienneau and Moriyasu, 1994).

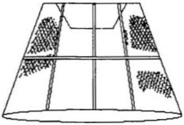


Figure 8: Sketch of a traditional Newfoundland snow crab pot (www.nfl.dfo-mpo.gc.ca/fm/ppc/Pubs)

The length of time for which lost gear continues to fish has not yet been determined. Some reports state that ghost gear may fish for up to ten years while others argue that after a few weeks the gear is no longer able to capture fish and shellfish. The studies that have been conducted on this matter have determined that a variety of factors affect the fishing abilities of lost gear, including the type of material used for the netting, the condition of floats and weights, tides and currents, and depth.

A study conducted off the coast of Norway in July of 2000 concluded that lost gillnets may be very effective at fishing for quite some time, especially in deeper (80 m) waters. Humborstad *et al* (2000) studied gillnets that had been cut loose, to simulate loss, and found that even after 45 days the nets showed no signs of wear and tear, nor any fouling by organisms such as crab, and after 45 days the average catch was 480 fish per set. This did not include the fish that had already been caught and eaten or decomposed. At such deep depths Humborstad *et al* (2000) concluded that degradation of monofilament gillnets is slow and they may continue to fish very effectively for quite some time. In fact, another study by Carr and Cooper (1987), found that groundfish gillnets that had been lost at least four years caught 15% as many fish as commercial nets would normally fish. This represents a very high rate of unaccounted mortality that, along with fishing mortality, is contributing to the depletion of fish stocks.

4. RESPONSES TO FISHING EFFECTS

With so many stakeholders and other organizations with interests in the fishing industry there are bound to be many conflicting points of view, many differing values, ideas and opinions. Scientists will claim objectivity in their opinions, conservationists will value other, more subjective opinions and economists will be likely to have other arguments regarding employment and growth (Cole-King, 1993). Such differences in opinion have brought the issue of conservation harvesting to the surface, resulting in heated debates and encouraging pro-active approaches to improve fishing gears so that the effects on the marine environment are reduced to a minimum.

4.1. Environmental Groups and Other Non-Governmental Organizations

Environmental groups and other non-governmental organizations (NGOs) exist in a variety of extremes and are diverse in their opinions and goals. It is unfortunate that a stereotype has been cast that portrays many of these groups as extremists who demand a total cessation of all activities that affect the natural environment. In fact this view only represents a very small proportion of environmental groups. There are others that are more than willing to cooperate with the fishing industry, to work towards a common goal whereby people are able to continue to make a living while the marine environment is protected in the best possible way, with damage inflicted by humans kept to a minimum.

Increasingly, however, environmental groups are questioning fishing practices around the world, challenging the methods used to harvest fish, the bycatch levels, the impacts on endangered species and on essential fish habitat, and a number of other related issues. Many of these interest groups, such as Greenpeace and SeaWeb, are quite powerful and are challenging the global seafood industry at a level never experienced before. The future viability of the entire seafood industry is at stake, including many of the jobs both directly and indirectly related to the fishery. The fishery is an extensive industry, including not only fish harvesters, processors and government workers involved in the management of the resource, but also wholesalers, distributors, retailers, and gear and equipment suppliers.

Some of these groups have gone so far as to take legal action against government fisheries agencies. In May 2000 the Conservation Law Foundation, the Centre for Marine Conservation, the National Audubon Society, and the Natural Resources Defense Council, filed a lawsuit in Washington, D.C. charging that the National Marine Fisheries Service is violating the U.S. Sustainable Fisheries Act of 1996 by allowing the continued overfishing of groundfish, such as cod, haddock and yellowtail flounder, off the coast of New England. The groups also charged that since NMFS has not taken action to prevent this overfishing, as is required by law, it is jeopardizing the ecological and economic health of the fishery (U.S. District Court for the District of Columbia, 2000). This case has not yet been resolved.

Similarly, in July 2001 the Ecology Action Centre (EAC) of Halifax, Nova Scotia, filed a lawsuit against DFO for deciding to re-open Georges Bank off Nova Scotia to trawlers. The EAC believes that trawling and dragging damages fish habitat and that DFO should encourage the use of less destructive gear as well as restrict trawlers and draggers to areas with less sensitive habitats. Canada's Fisheries Act prohibits the harmful alteration, disruption or destruction of fish habitat, and the EAC feels that DFO is violating the Act by allowing trawling on Georges Bank (Ecology Action Centre, 2001).

The fishing industry, the employment it creates and its other economic spin-offs will depend on how issues with such powerful interest groups are handled. A commitment to resource conservation from the fishing industry, as well as a follow-up to that commitment, will improve relations with these interest groups once major improvements in the way fisheries are conducted and managed are accomplished. Cooperation between the seafood industry and the environmental movement will eventually be the only way for the fishing industry to survive (Johnson, 2000).

4.2. Media

It is not surprising that media forums such as newspapers and television news programs print articles and report stories that will attract the most attention. The same situation holds true for topics surrounding fisheries issues and related conservation issues. This is especially true for areas such as Atlantic Canada where the fishing industry plays a major role in the lives of a large proportion of the population and fisheries issues are of great interest and considerable concern. News about fisheries and marine resource issues attracts large audiences. According to a survey conducted by Environics Research Group, the majority of Canadians rely mainly on television and newspaper coverage as their source of information when it comes to fisheries issues (DFO, 2000a). This indicates that Canadians' knowledge of fisheries is heavily influenced by what is reported in the media; therefore it is necessary that the media portray an accurate picture of the industry.

The media is very selective about what is reported and this somewhat biased form of education often leads to distorted opinions and misleading ideas, especially to those who are otherwise uninformed on the subject matter. This is not to say that positive stories are not reported, but it appears that more often than not it is the sensational story that casts a negative shadow over the fishing industry that is reported to the public.

Very little, if any, literature exists on the effects of media attention on fisheries and developments in conservation harvesting. However a personal review of recent newspapers articles indicated that negative stories about fisheries issues are far more common than those of a positive nature, despite the increasing efforts in conservation harvesting and the developments of new technology, which should lead to improvements in the fishery.

In January of 1999 The Evening Telegram, a prominent newspaper in Newfoundland, printed many articles surrounding fishery issues. Several of those were related to harvesting issues, each one depicting some unfavorable aspect of harvesting activities. The following illustrate some of the negative media coverage surrounding fisheries in this one-month period alone:

- On Sunday, January 17^{th} an opinion article by Cabot Martin criticized the government for allowing trawling to take place in Atlantic Canadian waters and suggested that the idea of marine protected areas is a viable concept that will allow dragging to take place only in designated areas. Martin used the term "draggers", another term for trawlers but one that connotes a negative image of the nets uprooting everything in their paths, emphasizing his remark that this is a destructive form of technology (Martin, 1999).
- Monday, January 18^{th} revealed another article on the destructive effects of trawling, summarizing the aforementioned series of articles published in *Conservation Biology* in December 1998. In comparing fishing to forest clearcutting the author wrote:

  "The area of forest loss in the world each year equals about the size of the Gulf of Maine and George's Bank. The area trawled is about 150 times larger – larger than all of Canada" (Surette, 1999).

In his article Surette failed to mention that although the combined total area trawled may be quite large, much of it is repetitive trawling in the same areas and, in effect, the actual total area trawled is much less than this. Although some fisheries may be spread out over large bottom areas, the majority of fisheries are localized, taking place in areas where the target species are concentrated. In addition to this, not all trawling takes place on the sea floor. Surette should have distinguished between bottom trawling, which does contact the seabed, and pelagic trawling, which takes place in the water column and has no contact with the seabed. Readers whose lack of knowledge and understanding of the facts involved are often misinformed by comments such as that made by Surette. This may lead to strong opinions on one side of an argument where the other sides are rarely heard or understood.

At the same time, another article printed in The Evening Telegram cast a shadow on the effects of fishing. The article, entitled "Save the Whales", discussed a Newfoundland-based whale research group and its accomplishments. The article's aim was not to criticize fisheries, but it did describe instances where whales, sharks and dolphins have been caught in fishing nets (Benson, 1999). Although these instances were factual, and do cause concern for bycatch of large marine life, statements such as these are often the start of a movement to ban fishing nets and other forms of fish harvesting. These issues do need to be addressed, however more articles of a positive focus on fisheries would provide a balance of information about fisheries issues, on which people can base their views and opinions.

However the Benson article did go on to say that a program has been put into place whereby acoustic alarms on nets are used to prevent whales and other large marine animals from colliding with the fixed gear. The alarms have been a success with a seventy percent reduction in whale entanglements in gear (Benson, 1999).

Fish harvesters themselves also feel that the media is selective in what is reported. In a 1999 workshop on minimizing seabed impacts of trawling gear, many discussions turned to the negative image of trawling and its impacts and the manner in which it is portrayed by the media. One participant commented that "The media is only interested in 'bad press' and when there are 'good news' items they never make it to publication" (DFO, 1999b). The main subject of the workshop was minimizing seabed impacts, so the discussion on the media was short-lived. However, it is an important topic that some harvesters felt strongly about, and, if given the opportunity, they may be open to further discussion on the matter. It should not be out of the question to hold another workshop on the media's portrayal of the fishing industry, allowing fish harvesters and other industry representatives to discuss their concerns and to generate possible solutions that would help the media describe more of the positive aspects of the fishing industry.

It is possible that selective reporting may be only part of the reason why there are so few articles and accounts of conservation harvesting developments. Perhaps those involved in the harvesting side of the fishing industry feel that by making it known that they are working to improve harvesting technology for conservation purposes they are also admitting that a problem exists. If the media were to report accounts of individual fishermen or large harvesting companies searching for solutions it may indicate to the public that there are problems that require solutions.

To portray the Atlantic Canadian fishery in a more positive light, it is necessary that efforts in the area of conservation harvesting be made known to reporters and newsgroups. This will ensure that the people of Atlantic Canada are aware of the issues and are exposed to a broad range of opinions and ideas so that they can make informed, unbiased decisions regarding fisheries matters. Making use of existing programs such as the *Fisheries Broadcast* on CBC Radio, *Land and Sea* on CBC Television, and *The Fishery Now* on Newfoundland Television to broadcast new developments in fisheries would also help to spread information to a wide audience. Phone-in radio talk shows, such as *Open-Line* on VOCM in Newfoundland, and Letters to the Editor in local and national Newspapers are also means to bring fisheries issues to the public's attention. If members of the fishing industry wish to let others know about new developments and improvements in the fishery, they should make use of these readily available media outlets.

4.3. Public Concerns

Fisheries resources are public resources, or common property. Therefore the public will have input in decision-making, even though it may not always be welcome by industry and government decision-makers. Public concerns surrounding the effects of fishing are influenced by a variety of factors, but the information put forth by environmental groups and media sources are probably the most influential.

It is unfortunate that negative images portrayed by the media often set members of the general public against those who harvest fish for a living. And, according to a Massachusetts fisherman, it is sometimes difficult for fish harvesters to see that what they do for a living is a public matter, despite the common property nature of the resource (Stuart, 1995).

However, the opinions of the public regarding environmental issues have increasingly more influence on those making decisions that affect fisheries policies and regulations. For example, in the area of Port Phillip Bay, Australia, all scallop licences were cancelled in 1997 because of public concern about the environmental effects of scallop dredging (Currie and Parry, 1999). In Canada the Fisheries Resource Conservation Council (FRCC) provides recommendations to the Minister of Fisheries and Oceans on such issues as total allowable catches, scientific research and conservation measures (FRCC, 1998). FRCC recommendations are public and are open to public scrutiny and opinions, ensuring that all Canadians have the opportunity to participate in decision-making. It is only a matter of time before public interest in the environmental effects of fishing influences decisions to close fisheries in the Atlantic Canadian region.

It is important to realize that members of the general public are also the consumers who will eventually make the final decision on which seafood products to choose and their impressions on fisheries will be reflected by their choices. This is discussed further in the following section on markets and eco-labels.

4.4. Markets and Eco-Labels

It is becoming increasingly common that fish consumers demand that the seafood products they purchase be caught using "environmentally friendly" methods. Suppliers of fish products are finding that international markets demand assurances that the raw materials being purchased come from responsibly managed ecosystems and that they are harvested and extracted by sustainable means (Sproul, 1997).

"Eco-labels" or "green labels" are now a common trend as more consumers use them in choosing seafood products. Seafood companies are now more widespread in their use of eco-labels as part of a plan to involve consumers in the active enhancement of sustainability in fisheries (Blichfeldt, 1998). These labels may be defined as "seals of approval" given to products that are recognized as having fewer impacts on the environment than similar products (Deere, 1999). For example dolphin-safe labels are seen on many tuna products, making them the choice of products for consumers, particularly those concerned with dolphin safety in tuna fisheries. Labeling these products as "dolphin-safe" is subject to detailed rules, which are enforced by the U.S. National Marine Fisheries Service under the Dolphin Protection Consumer Information Act. It requires that "dolphin-safe" products be accompanied by documentation showing that the tuna was not caught by means harmful to dolphins. This means that the tuna cannot be caught using large-scale driftnets on the high seas, or by large purse-seine vessels unless documentation is provided stating by an observer and the captain that the tuna was not caught by deploying the net on or around dolphins (National Fisheries Institute, 1992).

According to Carolyn Deere of the World Conservation Union, "eco-labelling has been endorsed by the international community as one of the tools that can help improve environmental management through market-based means" (Deere, 1999). One of the major arguments for green labels is that they allow consumers to exercise their right to gather information about products, including information that may be related to their values and concern for the marine environment.

Eco-labels are a fast-growing presence in the marketplace. Although strict and detailed guidelines and international standards have yet to be established for the use of these labels on seafood products, there is little doubt that in the near future they will be a strong force in the seafood market and will affect consumers' choices. This should therefore be an incentive for Atlantic Canadian fish harvesters and managers to ensure that conservation harvesting technologies are developed and put into widespread use. This will ensure that the requirements needed to meet eco-label standards are achieved and that Atlantic Canadian fish products will not be boycotted and will continue to be in demand in the global fish market.

The Marine Stewardship Council (MSC), established in 1997, was formed based on the realization that market incentives have the ability to improve fisheries management in such a way that sustainability and economic stability are possible and that such incentives can "provide the fishers, processors and retailers with greater security of supply and employment than has been possible to date" (MSC, 1998). The Council has outlined Principles and Criteria that will enable conforming fisheries to become eligible for certification through MSC-accredited certifiers. Such certification will allow consumers to select fish products with the confidence that their purchases came from sustainable, well-managed resources. The use of eco-labels will enable these certified fish products to be recognized by consumers as having been caught in an environmentally-friendly manner and will be an incentive for fish harvesters to demonstrate that they are fishing with conservation in mind if they wish to be certified and compete in the global seafood market.

During the International Boston Seafood Show in March 2000, the MSC introduced consumers and industry to its first eco-labelled seafood (Fiorillo, 2000). The Western Australian rock lobster fishery was recently certified by the MSC and the product is now able to carry the new "Fish Forever" label, which is expected to increase demand for Western Australian rock lobster. Since those fisheries with MSC certification receive regular reviews, audits and annual re-certification, it is ensured that the fishery will remain sustainable and that fish harvesters and suppliers will also benefit by receiving higher profits from their certified products.

If fisheries in Atlantic Canada are able to receive MSC certification, similar benefits could be accrued in the fishing industry, increasing demand for seafood products from the area and boosting economic returns to the industry.

Such mediums as magazine and newspaper articles, news programs, and other media influences, as discussed earlier, also affect consumer choices. In 1998 the National Audubon Society published The *Audubon* Guide to Seafood to help consumers make informed choices when choosing seafood (Safina, 1998). The guide lists seafood groups and a number of marine species for which it briefly describes the population status, ranks management regulation, and outlines any bycatch and habitat concerns for each particular group. By informing consumers through such a list, it is hoped that they will be better able to choose seafood, confident in their decisions that their seafood products come from abundant populations and properly managed fisheries.

Since it is consumers' choices that affect which fish products are purchased, it is up to suppliers to provide them with the products they desire. It appears that future trends in consumer seafood choices will dictate how fisheries are managed. Increasing demands for products from healthy, well-managed fisheries, with minimal environmental impacts will require fisheries managers to ensure that fisheries are not over-exploited and that fish are harvested in manners that have the least effects on the marine environment. The conservation if marine resources will play a major role in all aspects of future fisheries, especially in harvesting and fisheries management.

4.5. Fish Harvesters

The fishery crisis that struck Atlantic Canada with the Northern cod moratorium in July 1992 and subsequent moratoria of several other cod fish stocks has become a worldwide example of fisheries management gone wrong. Although many factors have been cited as the reason for the collapse of cod and other fisheries, it is undeniable that lack of concern for the state of the fish stocks and insufficient focus on conservation of the fish resources was a major part of the reason. No one knows the impacts of a fishery collapse better than the fishers and processing workers in Atlantic Canada, whose livelihoods were devastated by fishery closures. Along with this came the realization that it is vital to work towards rebuilding and protecting fisheries resources and that conservation must be foremost in a fishery if it is to be sustainable. Many Atlantic Canadian fish harvesters now show great concern for their fisheries resources and play major roles in the development and implementation of conservation harvesting techniques.

Many fishers are concerned about the state of the fish stocks on which they depend to earn a living. So great is the concern of some that in the winter of 2000 fishermen in Placentia Bay recognized that the cod population in the bay was not as large and healthy as was earlier thought and, to protect the fishery, asked DFO to close the fishery in the area. Placing such concern above their livelihoods demonstrated that fishers are willing to make sacrifices at the present time to ensure a sustainable fishery will exist for future generations.

Fish harvesters are also concerned with bycatch and have been taking measures to reduce bycatch by using sorting grates, increasing mesh sizes and using other such techniques. Not only is bycatch a concern from the point of view that it damages fish stocks, it is also a concern to fishers because it requires the use of more time and energy that could be better used elsewhere. Bycatch can reduce fishing time as the unwanted fish cause the net to fill up more quickly and, once it is brought aboard, the bycatch must be sorted from the targeted species. This can take away from time that might otherwise be used for other fishing activity. In the long run this reduces efficiency and can become costly.

Also worthy of consideration is the fact that if bycatch levels become problematic there is the possibility that area closures may result. This gives further incentive to reduce bycatch levels to a minimum. Of course most fish harvesters are not only concerned with saving time, energy and money and making sure that fishing areas remain open for their own benefit, they are also concerned with ensuring that depleted stocks are given the opportunity to recover and protecting the marine environment. Despite the common misconception that fishermen do not care, many are, in fact, very much involved in reducing bycatch and trying to minimize fishing gear effects. Some have even taken the initiative to develop programs aimed at helping fish harvesters work towards improving conservation harvesting in Atlantic Canada, a positive indication that those closest to the resource are indeed working towards sustaining the fish resource base for generations to come. An example of this is the Canadian Code of Conduct for Responsible Fishing Operations developed in 1998 by Canadian fishers. The

Code contains principles and guidelines for all commercial fishing operations that take place in Canadian waters and will contribute to conservation of stocks and protection of the marine environment far into the future (Anonymous, 1998).

Not all harvesters, however, show this concern for their fishing effects on the environment, nor are they all concerned with conservation. Despite the poor state of the cod stock in area 3Ps on the south coast of Newfoundland, the fishery remains open, mainly because of pressure from fish harvesters. Juvenile turbot bycatch in inshore shrimp fisheries and the destruction of crab by turbot gillnets still pose serious threats to turbot and crab populations, yet most fishers have not had the desire to stop these destructive practices. When it comes to conservation and working towards sustainable fisheries some harvesters may be concerned and are trying to come up with solutions, but the fishing industry as a whole has not changed dramatically (Blackwood, 2001).

Programs for fish harvesters providing education about the biology of fish, including life cycles, habitat and behaviour of fish as well as overall education about the marine environment as a whole will help fishers to better understand the complexity of the resource. For example, the Fishing Technology Unit at the Fisheries and Marine Institute in St. John's, Newfoundland, conducts practical workshops on a variety of harvesting-related topics, including such workshops on mobile gear selectivity, theory of trawl design, and salmon and cod traps (Marine

Institute, 2000). The Canadian Council of Professional Fish Harvesters (CCPFH) also promotes the education and training of Canadian fish harvesters. In particular, the Council addresses the professionalization of harvesters to ensure that they have the skills required to meet the requirements of the fishing industry in a professional manner (CCPFH, 2001). In 1994 the New Brunswick Department of Fisheries and Aquaculture and the Federal Department of Fisheries and Oceans successfully developed an Industrial Training Course in Responsible Fishing. The objective of this program was stated as:

> "The creation of an understanding of the issues facing the industry and through knowledge of and practice in responsible fishing to ensure that participants obtain optimum competency in those subject areas required for the long-term viability of the fishery." (Fisheries Council of Canada, 1997)

This additional education for fish harvesters, combined with their already vast knowledge and experience on the ocean, will contribute towards efforts for achieving sustainable fisheries.

4.6. Government

In Canada both the Department of Fisheries and Oceans (DFO) and the Northwest Atlantic Fisheries Organization (NAFO) oversee the management of fisheries, each implementing regulations and policies to control fisheries, observing fishing practices, and conducting research in many forms, including resource surveys and collecting catch data from commercial fisheries, to gather information to be used in assessing the state of fish stocks.

NAFO is responsible for the Regulatory area that lies outside Canada's 200-mile limit, which essentially is the Nose and Tail of the Grand Banks and the Flemish Cap, while Canada is mainly responsible for fisheries inside the 200-mile limit. However, NAFO and DFO work closely to share resource data, develop conservation measures, and NAFO provides advice to Canada about the status of various stocks within the Canadian zones (Parsons, 1993).

In recent years DFO has turned its focus to preserving the ocean and the marine life contained within it. A great deal of emphasis has been placed on conservation and the manner in which fisheries take place. As part of this new approach to management, Canada's Ocean's Act came into force in December 1996. Part II of the Act, entitled "Oceans Management Strategy" (OMS) is built on an ecosystem approach to oceans management and is based on the principles of integrated resource management, sustainable development and the precautionary principle. The OMS directs the Minister of Fisheries and Oceans to involve stakeholders in integrated management plans so that representatives from various sectors of the fishing industry and the general public are able share their ideas and have some influence on management decisions with both regional and national goals in mind. In addition to this the OMS also allows the

Minister to establish Marine Protected Areas, establish and enforce criteria and standards to conserve and protect ecosystem health, and develop Management Plans, provided these are all used within the context of the integrated management plans.

The Government of Canada has developed several programs designed to encourage environmentally friendly and sustainable fishing practices and to continue fisheries research. The following are samples of some of these programs.

The Fishing Gear Selectivity Program was introduced after the groundfish moratoria of 1992 and 1993 with funding provided by the Atlantic Fisheries Adjustment Program (AFAP) and the Quebec Federal Fisheries Development Program (QFFDP). During 1992/93 alone, 32 projects were approved at a value of over $3 million. Projects included a ghost net study, separator trawl research, a study of mesh size and shape, and a marine mammal bycatch study (DFO, 1992/93). Not only did the program provide valuable research results to be used in designing and implementing selective fishing gear in the future, it also provided Atlantic Canadian fish harvesters displaced by the moratoria with opportunities to use their fishing skills to help improve the fishery of the future and to adjust to changing circumstances. The projects were beneficial to all sectors of the fishing industry.

The Canadian Fish Harvesting Program for Responsible Fishing, set forth in 1992, was designed to provide solutions to serious fish resource problems and a growing environmental consciousness. Consultations among representatives of the Canadian fishing industry and international consultations were a vital starting point for the program. Research followed in fishing vessel design, technology transfer and training and gear selectivity, and assessment studies were conducted on lost and abandoned gear and on fish discarding. In Atlantic Canada gear selectivity workshops were held involving fishing gear experts from across Canada and around the globe. These workshops were invaluable to participants who focussed on the needs for future work in gear selectivity experimentation (DFO, 1992a).

DFO also works closely with fishermen and fishing companies as well as other industry representatives to conduct research and collect data to better estimate the health and size of various fish stocks and to test new harvesting gear and methods needed to improve the conservation aspects of harvesting. A case in point in Newfoundland involved a jointly administered development between the Federal Department of Fisheries and Oceans and the Provincial Department of Fisheries and Aquaculture entitled the Cooperation Agreement on Fishing Industry Development (CAFID), a multi-year development agreement started in the late 1990s (CAFID, 1997). With funding provided through CAFID and Fishery

Products International (FPI), a major international fish harvesting and processing company, several experiments were conducted on board an FPI vessel to test shrimp size selectivity in an in-trawl sorting system. The results showed a minimal increase in the size of the shrimp entering the codend, but this small increase did slightly improve the value of the shrimp (CAFID, 1998). Such joint projects between various representatives of the fishing industry are quite common in Atlantic Canada and are an essential part of developing and improving conservation harvesting techniques. They also help to improve communication among the various sectors and encourage the generation of new ideas and suggestions that might further benefit the fishing industry.

DFO and NAFO are also responsible for setting forth regulations and policies to control fishing gear and the quantities of fish caught in keeping with the Department's management plans. Some of these regulations that have been implemented are related to new fishing technologies that have been recently developed, such as the mandatory use of separating grates in shrimp fisheries.

General regulations outlined in the Atlantic Fishery Regulations (DFO, 1985) have also been imposed as part of DFO's commitment to ensuring that conservation is an important element in harvesting fish. As an extension of this, more specific details with regards to these regulations are contained in documents specific to various fleets sectors. For example, the Atlantic Canadian

Conservation Harvesting Plan for vessels greater than 100' lists minimum mesh sizes, maximum bycatch levels, small fish protocols and area closures, among other conservation measures for each groundfish fishery in Atlantic Canada (DFO, 1999c). These regulations ensure that small fish are left in the water to grow and reproduce and to be recruited to the fishery at a later time. They also minimize the numbers of non-targeted and undersized fish that are caught. Careful monitoring of bycatch levels in various fisheries allows closure of a fishery in an area if levels exceed regulatory limits over a specified period of time.

Despite the imposition of government regulations and policies, they only help to control some of the problems rather than solving all of them, and there are still numerous problems associated with bycatch, over-exploitation, habitat disturbance and other related issues. As is discussed in the following section, input from various sectors of the fishing industry and groups representing public opinions are also vital to the achievement of sustainable fisheries.

4.7. Interactions Among Stakeholders and Others Influencing Fisheries

Each of the influences encouraging conservation harvesting as discussed above cannot be considered a separate entity existing without any relationship with the others. The media influences the public's ideas and opinions based on what is reported and how it is portrayed. The public in turn makes decisions that will affect market demands and prices. This affects fish harvesters in determining what species they will target and the manner in which they will harvest the product. Environmental and other groups maintain a constant check on the harvesting of many high profile species (e.g. swordfish) using the media as an outlet when something does not comply with the regulations set forth by governing bodies or when harvesting practices do not coincide with the groups' beliefs and opinions. Figure 9 summarizes the complex relationships discussed in this paper that can develop where conservation harvesting is concerned. Certainly this paper can only deal with a small portion of a broader picture with additional factors and a more complex web of relationships and influences.

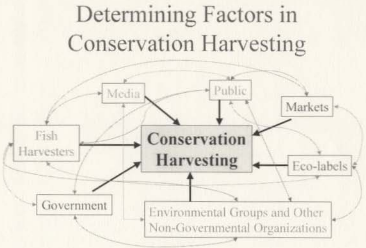


Figure 9: Determining factors in conservation harvesting

5. DEVELOPMENT OF CONSERVATION HARVESTING

5.1. Gear Selectivity

Fishing gear selectivity appears to be the area in which the most accomplishments have been achieved in conservation harvesting. Often the modifications made to gear to improve selectivity are relatively simple, inexpensive and still allow for fishers to continue to fish with the advantage of reduced bycatch which, in turn, often results in reduced costs and less wastage of the ocean's resources.

The Department of Fisheries and Oceans (1992/93) defines selectivity as:

> "the ability to target and capture fish by size and species during harvesting operations, allowing bycatch i.e. small (or juvenile) fish and non-target species to escape unharmed"

and goes on to say that selectivity requires that harvesters shift from the traditional emphasis on the quantity of fish landed to harvesting only those that are wanted and allowing those that are not wanted to be released, reducing pressure on the populations of target and non-target species.

Before fish can be selectively captured or released during fishing operations it is first important to understand how they are retained in the gear. Retention is determined by the physical parameters of the gear (e.g. mesh size and shape, twine thickness and stretching characteristics), tow duration and speed, the fishing technique being used, the biological characteristics (behavioural and morphological features) of the fish (Bublitz, 1995) and the catch size. The following gear selectivity devices and features use one or a combination of several of these retention characteristics to allow unwanted fish to escape while optimizing the retention of commercial fish.

The Nordmøre grate (Figure 10) was originally developed in Norway and was tested extensively in Newfoundland waters. The Nordmøre grate is a selectivity device consisting of a rigid grid with closely spaced bars (minimum regulatory bar spacing of 22mm) that is attached to the inside of a trawl ahead of the codend. It directs large non-target species to an opening at the top of the net where they can escape, while allowing smaller targeted species to pass through the grid towards the codend. It has been particularly useful in shrimp fisheries and, since its introduction in Atlantic Canada in 1993, it has been quite successful in reducing groundfish bycatch in the northern shrimp fishery. The grate has since become mandatory in all inshore shrimp fisheries and in offshore shrimp fishing areas where groundfish bycatch exceeds 300kg per day, although many captains prefer to use the grid at all times (DFO, 1996).

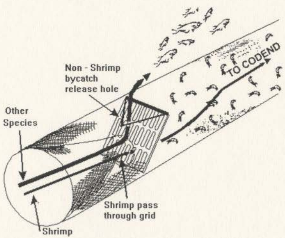


Figure 10: Nordmøre grate (adapted from DFO, 1996)

Although the Nordmøre grate has been successful in reducing finfish bycatch, it is not effective in reducing the capture of smaller, less valuable shrimp. In response to this a multi-grate system has been developed. This system is a combination of the Nordmøre grate and a shrimp size selectivity grate. The Nordmøre grate first allows large finfish bycatch to escape from the net. Once the shrimp have passed through this first grate they are guided by a mesh panel to the bottom of the size-sorting grid, which has a grate with much more closely spaced bars than the Nordmøre grid. The small shrimp are able to pass through the second grid and exit through an opening in the bottom of the net while larger shrimp pass over the top of the grid and enter the codend (Figure 11).

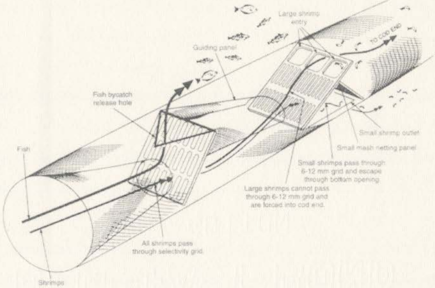


Figure 11: Multi-grid shrimp size-sorting system (DFO, 1996)

Other modifications to trawls continue to be investigated as possible ways to reduce bycatch in various fisheries. Other separator grid systems, plasticized exit windows, horizontal separator panels, and groundrope and headline height adjustments are just a few of many possible solutions to bycatch problems.

Historically, increasing mesh size has probably been the most common and simplest method of allowing small fish to escape, thus reducing bycatch. The Conservation Harvesting Plan for Atlantic Canada (DFO, 1999c) sets out minimum mesh sizes that should allow commercial sized fish to be taken while keeping undersized bycatch to a minimum. Unfortunately this is not always successful and in some fisheries, especially where larger species are targeted, the minimum mesh size is not always large enough to prevent the capture of most juveniles. Often harvesters choose to use mesh sizes larger than the regulatory sizes, especially when juvenile bycatch is a problem. However, there is a point at which increasing the mesh size becomes uneconomical for commercial fishing operations, as more and more commercial sized fish are able to escape from the net as mesh size is increased.

In 1996 a mesh size selectivity study was conducted in the Danish seine fleet in the Gulf of St. Lawrence, where a high bycatch of cod had been resulting in closures of the American plaice and witch flounder fisheries. Using a large square mesh (159mm vs. 145mm) resulted in a reduction of cod bycatch, supporting previous study results that indicate that increasing mesh size does indeed reduce bycatch.

Mesh shape is also an important factor in selectivity. In order for small fish to escape from a codend the meshes must be open. However, when a diamond mesh is used the meshes tend to close as the codend becomes full and the codend begins to stretch. The closing of the mesh under pressure prevents bycatch from escaping. Maintaining open mesh is an important feature for selective fishing gear. Using a mesh shape such as a square mesh that will remain open under load should allow better escapement of small fish and some non-target species.

In 1992-93, as part of the Fishing Gear Selectivity Program, several projects were undertaken to study optimum mesh configurations for several types of fishing gear. One particular project that took place in Newfoundland tested the effectiveness of a large square mesh codend to reduce cod bycatch while targeting American Plaice (not a targeted species in the Newfoundland region at the present time, but has been a major target species since the 1940s until 1993). A trawl with twin codends was used in the experiment, one codend with a 183mm square mesh, and the control codend with a 44mm diamond mesh. The average length of cod in the combined catches was 84cm, while the average length of cod in the control codend was 32cm. The catch from each tow in the large square mesh codend usually contained about 10 to 20 large cod, while the catch in the small mesh codend usually consisted of 10 to 20 large cod and several hundred small cod. Compared with the smaller diamond mesh codend, the square mesh codend allowed all small cod to escape (DFO, 1992/93). Since that time other studies have also indicated that square mesh codends tend to retain more juvenile flatfish while allowing more juvenile roundfish, such as cod, to escape. These differences in body shape are key when trying to separate species.

Another way to maintain open mesh in a codend is through the use of lastridge ropes. Lastridge ropes are positioned lengthwise along the codend, generally along the join seam of the top and bottom panels, to reinforce the trawl. Making these ropes shorter should allow them to absorb the towing load and prevent the meshes from being distorted and pulled closed by the load, thereby allowing small fish and other organisms to escape through the open mesh (DFO, 1999a). Experiments conducted in the Gulf of St. Lawrence as part of a Lastridge Rope Selectivity Program concluded that shorter lastridge ropes do indeed improve selectivity. Lastridge ropes hung at 72% proved to be the most selective, while those hung at 85% improved selectivity without reducing operating efficiency, making it the preferred ratio for commercial use (Figure 12). The study also concluded that the survival rate of small roundfish that escape from a codend is higher when lastridge rope codends are used rather than when regular diamond mesh codends are used. The shortened lastridge ropes allowed the small fish to escape more easily and reduced injuries, thereby improving their chances of survival (DFO, 1994d).

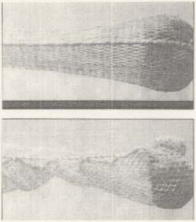
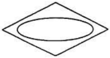


Figure 12: Lastridge ropes in a codend. Top picture shows a hanging ratio of 100%; bottom picture shows a lower hanging ratio, improving selectivity of the codend. (DFO, 1994d)

When the targeted species and non-targeted species are quite different in body shape, using a square or diamond mesh may be a relatively easy solution to reducing bycatch of the non-targeted species. As in the previous example, cod and flatfish are very different in body shape. Based on the size and shape of the targeted species and the bycatch that often occurs when directing for this species, a codend can be chosen based on its mesh size and shape (Figures 13a and 13b). Using a composite mesh codend, such as one with a diamond mesh bottom and a square mesh top or any other configuration with a variety of such features may also help to reduce bycatch while optimizing the catch of the target species. These composite codends are often based on body shape, behaviour or a number of other factors that affect fish capture and retention.

a) Juvenile flatfish conform more easily to a diamond mesh shape:



b) Juvenile roundfish are more likely to escape through a square mesh:

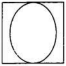


Figure 13: Mesh shape affects escapement of different body shapes

Similarly, cod traps may also be modified to have various mesh size and shape configurations. A study conducted in the summer of 1990 concluded that increasing the minimum mesh size in a cod trap from 89mm to 102mm resulted in significantly fewer small fish being retained in the traps. The results also indicated that using a square mesh might have also allowed more small cod to escape (Brothers and Hollett, 1992).

Another development improving the selectivity of cod traps came out of a 1996 project to try to reduce the bycatch of salmon in cod traps on the West coast of

Newfoundland. The study based the experiment on the fact that salmon tend to swim close to the water's surface while cod generally swim lower or closer to the bottom. Three different types of leaders were used in the experimental traps; one with a sunken leader, which would guide the cod into the trap while the salmon would swim over the top of the leader; another with deflectors attached to the top of the leader, which would lead the salmon to the side of the trap, avoiding capture; and another with the top portion of the leader constructed of large mesh (16") to allow the shallow-swimming salmon to pass through the leader and avoid the trap. All three methods showed positive results towards the reduction of salmon bycatch in cod traps with 88%, 96% and 60% reductions, respectively, in salmon bycatch for the cod traps with each type of leader (CASEC, 1996a).

In some circumstances, simply removing a portion of the net can improve selectivity. A project in New Brunswick concluded that when fishing for American plaice using a Danish Seine, cod bycatch can be significantly reduced by simply removing the square and top belly from the seine and extending the headline back over the footgear (CAFID, 1997). Such a modification was successful due to a cod's behavioural tendency to swim upwards as the net approaches, allowing it to escape over the headline rather than be trapped by the square and top belly as would have occurred if they had not been removed.

There are some bycatch problems that are extremely difficult to solve, such as when a targeted and a non-targeted species are of a similar size, exhibit similar behaviour and are found in the same area. Such is the case in the yellowtail flounder fishery on the Grand Banks where American plaice poses a significant problem as bycatch. The plaice stock is extremely low on the Grand Banks and a directed fishery moratorium has been in place since 1994. The current biomass is estimated to be less than 10% of levels in the mid-1970s (Morgan *et al.*, 2001). However the yellowtail flounder biomass appears to be growing and TACs have been increasing annually since its moratorium ended in 1998, with the 2001 TAC set at 13,000 mt (DFO, 2000b). The yellowtail flounder fishery is now a successful fishery that is well managed, but because of the low stock status of American plaice, it is necessary that its bycatch be kept to a minimum (maximum allowable bycatch is 5% (DFO, 1999c)). However, given their similarities in shape and behaviour, it is extremely difficult to separate the two species in a trawl. Studies are ongoing in the subject area but so far no solution has been found to separate out American plaice from yellowtail flounder in the codend.

Longlining has also been subject to selectivity improvements, in particular by changing the size and type of hook permitted in the longline fishery, as well as the size of the bait used. It was previously thought that the size of the hook used would determine the size of the fish caught, which, to a certain extent is true, because a small fish cannot take a large hook, only small hooks. But the effect of hook size on selectivity only becomes evident when the hooks are considerably different in size. However, recently it has been determined that the size of the bait has the greatest effect on the size selection of longlines. A large fish will take both large and small bait sizes, whereas a small fish will only take small bait sizes. Therefore, decreasing bait size will increase the size of the catch, but a higher proportion will be of smaller fish (FRCC, 1994).

Bycatch in scallop fisheries is also a serious problem and attention to the matter is escalating. At this time selectivity in scallop rakes is limited mostly to the ring size in the ring bag. This ensures that capture of juvenile scallops is kept to a minimum. However incidental catches of groundfish in scallop rakes are known to be very high and there is mounting pressure to reduce bycatch levels in this fishery. Ways to solve this problem are currently under investigation. One possible solution is to have a large mesh size in the top portion of the rake, allowing captured fish to swim free from the gear. Unfortunately the solution may not be as simple as this since altering the top part of the rake may change the fishing ability of the gear and may also allow for the escapement of valuable scallops.

Shellfish pots and traps have also been developed with selectivity characteristics in mind. In the Newfoundland snow crab fishery in Newfoundland, a 7½" high barrier placed on top of the crab pot prevents females and small males from entering the pot, allowing only males with a carapace greater than 4" to enter the pot. This also helps crab fishermen to comply with regulations that state that female crabs and immature male crabs may not be landed. Rather than capturing these unwanted crabs and discarding them at sea, such a barrier prevents them from being captured in the first place, reducing stress and injury associated with the catching and discarding process (DFA, 1997).

Simply changing selectivity characteristics of gear set out for groundfish cannot prevent the capture of large marine mammals, such as seals, porpoises and whales. However, fishermen can avoid setting their gear in areas where these animals are known to frequent, but this is not always possible, especially when fishing efficiency is compromised. Acoustic warning devices to deter marine mammals have been developed and tested on gillnets and cod traps in Newfoundland waters, and are mandatory in some areas of Europe. These devices alert marine mammals of barriers in the area, enhancing the animals' ability to detect nets. Testing of the device on cod traps indicated a 70% reduction of humpback whale collisions with the gear, a significant achievement in the protection of whales in Atlantic Canadian waters. Before the fishing moratorium was initiated in Newfoundland in 1992, the majority of fish harvesters in high risk areas had begun to use these acoustic devices on their fishing gear as standard practice (Fisheries Council of Canada, 1997).

Development in the area of gear selectivity has advanced rapidly in recent years, with Atlantic Canada playing a major role in the development, testing and use of new selective fishing gears and techniques. Research and development is ongoing and if the past is an indication of success in the future there will be many more improvements in gear selectivity in the years to come.

5.2. Reducing Impacts on the Seabed and Related Ecosystem Effects

It is clear that progress must be made in the near future to reduce contact of fishing gear with the seabed, primarily that of otter trawls and scallop rakes. This must be accomplished not only for the good of the marine environment but also to meet the demands of those who are concerned about the negative impacts of seabed contact and insist that it is destructive to fish habitat and the ocean ecosystem as a whole. Unfortunately many of the valuable species harvested throughout the world live on or near the bottom of the ocean. Shrimp, scallops, clams, crab and groundfish live on or near the seabed and are vital to the economy of Atlantic Canada. To avoid seabed contact is not an option for many species. However the need to reduce the ecosystem effects of fishing activities has been recognized by the fishing industry in Atlantic Canada and in many other parts of the world and the initiative has been taken to attempt to modify existing fishing technology or develop new gear that allows for efficient, profitable and sustainable harvesting while minimizing the damage to the marine environment.

In October 1999, DFO sponsored a workshop in Newfoundland focusing on minimizing sea bottom impacts of trawling gear. Representatives of many sectors of the fishing industry, including fish harvesters, gear manufacturers, provincial and federal government experts and researchers, attended the workshop. A major portion of the workshop was devoted to flume tank demonstrations of bottom trawls with modifications to reduce contact with the seabed.

Flume tank demonstrations at the workshop featured gear designs from different areas of Canada and the United States that have been developed and continue to be modified to reduce seabed contact. Nordsea Ltd., a company from Nova Scotia, has been experimenting with various configurations that help to minimize seabed contact. According to the Nordsea representative present at the workshop, changes to wire attachments, warps and bridles can change trawl configuration and performance in relation to the seabed. Separating footgear from the main trawl may reduce incidents of hookups with obstacles on the sea floor and paravanes that do not contact the bottom may be a feasible alternative to heavy trawl doors as spreading devices for trawls (DFO, 1999b).

Also presented at the workshop was a modified shrimp trawl with significantly reduced seabed contact. This was a joint project between Fishery Products International (FPI) and the Marine Institute's Fishing Technology Unit. FPI's Skervoy 3600 shrimp trawl was modified from its original 31-bobbin footgear arrangement to a 9-bobbin arrangement. This new configuration maintains stability in the flume tank. Sea trials have indicated that on a soft bottom fishing efficiency is as it had been prior to bobbin reductions (DFO, 1999b). This points to a significant reduction in seabed contact and should lead to future developments in reducing bottom contact of fishing gears. In fact, FPI continues to be heavily involved in reduced seabed contact projects with the Marine Institute.

Other possible gear modifications that may result in reduced damage to the ocean floor were also discussed at the 1999 workshop. Eliminating footgear altogether and using only drop chains may be feasible, as long as fishing efficiency is not compromised. Using midwater trawls near the bottom is a possibility in some areas where few obstacles pose risks of gear damage. Unfortunately it is difficult to control the distance of a mid-water net from the seabed, but further research may solve this problem (DFO, 1999b). Workshops such as this one can be very productive and encourage the exchange of ideas. Cooperation among industry representatives will hopefully result in many successful developments that prevent or minimize bottom trawl contact with the seabed while maintaining efficient harvesting operations.

Modifying a trawl that is meant to fish near the bottom so that it does not contact the seabed is a difficult task. The previously mentioned projects show that some progress has been made; yet much more research is required to achieve the elimination of seabed contact while maintaining high productivity. Other gear modifications might include reducing toggle chains, using additional floats and constructing mesh with lightweight synthetic material to lighten the weight of the trawl. Using midwater doors rather than traditional bottom doors on a bottom trawl would eliminate the problem of doors scouring the sea floor. Fine-tuning of such modifications might someday result in the perfect bottom trawl – one with high productivity, low bycatch and no bottom contact.

Using stationary or fixed gear such as cod traps and gillnets to fish for some groundfish species is an alternative to bottom trawling since using these fishing methods does not involve significant contact with the seabed. They are attached to the seabed, which may cause a minimal amount of damage in these small areas of contact, but they do not move over the seabed or disturb benthos. Although cod traps have been criticized for lack of selectivity features and gillnets can become problematic as ghost gear if they are lost, it may be feasible to work around these problems if it ensures that the sea floor is not damaged. When fishing efficiency is considered it is unlikely that such fixed gear will be as effective as bottom trawls. Yet in light of the growing trend for eco-labeled seafood products and the demand for fish that has been caught in a sustainable manner, if the demand for bottom trawled products decreases, then the efficiency changes, making fixed gear the more efficient choice of fishing method.

The method of longlining is viewed as one of the most conservation friendly of all gear types used in Atlantic Canada. Admittedly, there are some problems associated with bycatch, including seabirds, but bottom disturbance is limited only to breaking off structures above the seabed, such as worm tubes (FRCC, 1997). Although the catching efficiency of using longlines is much less than that of using bottom trawls, it is an alternative that should be considered. If used on a large scale the efficiency of using longlines may be increased while reducing damage to the seabed that may otherwise be caused by bottom trawls.

Seining technology is yet another alternative to bottom trawls. Although seines do contact the bottom, they are towed slower then bottom trawls and they are not towed for extended periods of time over the seabed, minimizing the effects fishing may have on the benthos. This may not be a suitable alternative for harvesting all groundfish species but can be highly effective when fishing for species such as flatfish in areas with a flat seabed and cod in shallow waters. In fact, in the American plaice and witch flounder fisheries in NAFO division 4R, Danish seines have been the preferred gear with which to harvest these species (CAFID, 1997).

Apart from gear modifications and the use of fixed gear and seining technology, future protection of the marine environment and essential fish habitat may be accomplished by imposing area closures, time closures and by restricting the use of bottom trawls in particularly sensitive areas (ICES 2000). In managing the fisheries in Atlantic Canada, both DFO and NAFO impose guidelines intended to protect fish stocks (such as minimum mesh sizes and total allowable catches), but there have not yet been any policies implemented by DFO or NAFO that protect the seabed and the overall health of the marine ecosystem from fishing activities.

The establishment of Marine Protected Area (MPAs) to protect large areas of the ocean ecosystem has become a more widespread in recent years in other jurisdictions. However closures of traditional fishing areas and closures during various times of the year restrict harvesting operations and can become quite costly for fish harvesters. MPAs have created a great deal of controversy and there are many arguments surrounding these issues which are beyond the scope of this paper and will not be discussed here.

5.3. Lost Gear Retrieval and Ghost Fishing Prevention

In 1975, the Department of Fisheries and Oceans (at the time known as the Fisheries and Marine Service of the Department of Environment) conducted a lost gillnet retrieval experiment, the first of its kind in the Newfoundland area. Because of the thousands of nets reported lost each year it was decided that such an experiment should be carried out to retrieve as many nets as possible, to determine the extent of fishing by the ghost nets, the effects on groundfish stocks and to test the effectiveness of creep gear that had been developed to retrieve the nets (Way, 1976).

From the 1975 experiment it was concluded that ghost nets continue to fish at a declining rate until one or more of the following situations occur:

- The headrope and footrope twist together
- Leaky floats render the net to the point of inefficiency
- The weight of the catch forces the headrope to the bottom, where in areas of high crab concentration the net becomes covered with crab, and bottom debris eventually covers and buries the net
- Crabs attracted to the fish in the net cover the net to the point that groundfish are scared away, reducing catchability (Way, 1976).

It was also concluded that prior to becoming ineffective lost nets catch considerable amounts of crab and groundfish. To retrieve lost gillnets three types of retrieval gear were developed. The most effective gear was an iron pipe with three lengths of chain attached, each length of chain having three "creepers" attached. The gear was towed over the seabed and the creepers, with protruding spikes, hooked ghost nets and retrieved them from the water. Although this gear was effective, the author recommended that for future retrieval operations modifications would have to be made to the creeper gear to improve its effectiveness (Way, 1976).

During the 1975 experiment, a total of 148 lost gillnets and parts of nets were retrieved in the areas of Trinity Bay and Cape Bonavista, Newfoundland, most containing various quantities of groundfish and crab that were alive as well as those that were dead and decaying (Way, 1976). These areas represent only a small proportion of Newfoundland's inshore waters. If one were to assume that similar numbers of lost gillnets existed in other areas around the island and other areas where gillnetting takes place, then it should be obvious that ghost fishing is a problem and affects, to some degree, fish populations and biomass estimates. Unfortunately, despite the recommendation that more retrieval projects be carried out, not much more work was done in the Newfoundland area until the early 1980s.

In 1984 another retrieval project was conducted in Newfoundland in response to requests from the St. Bride's and St. Joseph's Fishermen's Committees in the St. Mary's Bay area. The retrieval gear used was simply an iron pipe with three attached creepers that was towed over the seabed, similar to that used by Way (1976). In the area west of Cape Pine a total of 16½ nets were recovered, and these did not contain many fish. However this was expected because there are very few fish in this area during the months of February and March, when the project took place. Another area around Cape St. Mary's was also surveyed in November 1984, however no gillnets were retrieved. This was likely due to some broken spikes on the creepers that reduced the gear's effectiveness, large amounts of ice in the previous year that may have destroyed some nets, and also because trawlers in the area would have destroyed some of the nets in their path (Barney, 1984).

Retrieving lost gillnets is one of the environmental initiatives of Ocean Net, a new action-oriented non-profit organization founded in Newfoundland and Labrador in 1998. To date the group has retrieved only a few gillnets, but is lobbying for support from the federal and provincial governments to put the action plan into full operation (Ocean Net, 2000). Should Ocean Net be successful in implementing its program it will be the only gillnet retrieval program currently in place in Newfoundland.

There have been renewed efforts in recent years to prevent ghost fishing. Preventing gear loss in the first place is the most successful way to put an end to this destructive form of bycatch. Limiting the number of nets allowed to be set makes it easier to manage and keep track of nets in the water For example, in the Davis Strait turbot fishery, the Conservation Harvesting Plan (DFO, 1999) limits the number of set gillnets to 500 nets set at 50 fathoms each. So far this has been successful since no nets were lost after the implementation of this new conservation rule (DFO, 1999). Imposing limits on maximum soak time ensure that the gear is not left in the water for long periods of time, reducing the risk of gear loss. Leaving gillnets unattended is not permitted in many areas, such as in the Scotia-Fundy region (DFO, 2000c), which greatly reduces the likelihood that gear will be lost. Acoustic locator devices attached to the headline of gillnets can improve the probability of finding lost gear. Notus Electronics, a Newfoundland company, has recently developed an electronic locator system. When the system is activated by an acoustic signal in the water the device attached to the net begins to transmit signals that enable the fishing vessel to determine the location of the net (Fisheries Council of Canada, 1997).

Beyond prevention, if nets are lost or discarded the amount of time spent ghost fishing can be minimized if they are constructed with a biodegradable material. This will ensure that nets will break down if they are left in the water for an extended period of time and break the ghost fishing cycle of the net. Shellfish pots and traps with time-release devices or with a portion of the trap made of a degradable material will allow the sealife trapped inside to escape. The problem of lost pots in the Gulf of St. Lawrence snow crab fishery prompted the development and introduction of a galvanic time-release mechanism. It contains a cylinder with two metal eyelets attached to the twine of the pot (Figure 14) The cylinder corrodes in seawater over time, releasing the eyelets and creating an escape hatch through which trapped crabs can exit the pot, preventing ghost fishing if crab pots are lost. This device is now a regulatory requirement in the snow crab fishery in this area (Fisheries Council of Canada, 1997). Unfortunately the Newfoundland Snow Crab Management Plan (DFO, 2001b) does not yet require the use of a galvanic time-release mechanism. Future consultations with DFO in the Gulf of St. Lawrence region should prompt Newfoundland snow crab harvesters to use the device as a conservation measure for the crab populations off the coast of Newfoundland.

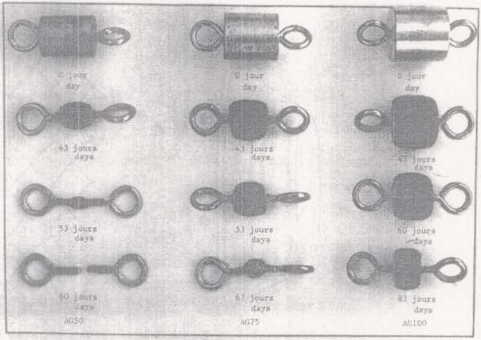


Figure 14: Change in size of galvanic time release devices with increasing corrosion. Attachments prior to immersion are shown at the top. (Gagnon and Boudreau, 1991)

5.4. Policy Implementation

Development of conservation harvesting in Atlantic Canada has come a long way in the past several years. Many of the developments, such as the shrimp size selectivity grid, improve the efficiency of harvesting operations and also improve the landed value of the catch. But some conservation measures, such as increased mesh size, do not always improve the catch and may sometimes lead to the loss of commercially valuable fish.

Despite the benefit to the fish stocks and the marine environment it is not always economically advantageous for fish harvesters to use conservation harvesting techniques. Therefore, to ensure that conservation technology is put to use policies and regulations have been implemented by DFO and NAFO.

Regulatory minimum mesh sizes ensure that bycatch of juvenile fish is kept at a low level. Small fish protocols allow only a low proportion of small (juvenile) fish in a catch. In the Grand Banks yellowtail flounder fishery, bycatch of species such as cod and American plaice are required to be kept below a maximum limit, otherwise fishery closures may result. The Atlantic Canadian Conservation Harvesting Plan contains a "small fish protocol", which states undersize fish lengths for various species. If the number of undersized fish in a catch exceeds 15%, designated fishing areas may be closed (DFO, 1999c). This is protocol is intended to let most fish spawn at least once, thereby ensuring survival of the species and the continuation of the fishery.

In all Atlantic Canadian fisheries it is required that all bycatch be landed to avoid wasting valuable seafood, thereby eliminating discards. (The scallop fishery is an exception, where only monkfish are required to be landed.) In fact, in 1993 Canada implemented a "no discard" rule in the Atlantic fishery regulations, which stated that all groundfish, including bycatch, must be landed (DFO, 1994c).

In addition, the use of selectivity grids such as the Nordmøre grate is required in areas where roundfish bycatch, such as cod, tends to be high. Numerous other similar policies and regulations, many of which are developed in cooperation with the fishing industry, are imposed by DFO in the Atlantic Region to ensure the protection of fish stocks in the area.

At this time, no regulations exist to prevent damage to the seabed. However, in the future this is likely to change as technology advances and fishing gear is developed that minimizes contact with the seabed. This will probably lead to implementation of policies requiring that such gear be used wherever possible, ensuring the protection of benthic marine habitats.

Regulations to prevent ghost fishing are also in place, including the mandatory marking of fishing gear. This will identify the owner of lost fishing gear and should prevent the intentional disposal of gear at sea. Those who do leave gear in the water for more than the allowable time or who dispose of gear in the ocean are subject to heavy fines and possible incarceration.

6. COSTS AND BENEFITS ASSOCIATED WITH CONSERVATION HARVESTING

From an economic perspective the type of fishing gear used depends on the target species, the efficiency of the gear, its economic viability and its potential impacts. The fishing gear or technique that is estimated to provide the greatest economic return is the usual choice (Sainsbury, 1996), which may explain why bottom trawls are so prevalent. However, as more and more emphasis is placed on choosing seafood products that have been harvested in a sustainable manner, fishing techniques that meet the standards for sustainable fisheries will become more widespread as they will eventually provide the greatest economic return from a discriminating marketplace. Longlining might well become a popular choice in the future as it results in a high quality catch with minimal bycatch and virtually no bottom contact.

Although there may be some initial costs associated with changing gear configurations and learning to use the new gear, improved gear selectivity should lead to greater fishing efficiency, improved product yields and quality and reduced costs for fish harvesters and processors. Greater selectivity will also mean that fewer fish will have to be sorted, requiring less time and manpower, thus saving money. The short-term loss will be well worth the long-term gain.

Using grate sorting systems in the Northern shrimp fishery has greatly improved the quality of the catch with fewer small shrimp being caught and virtually no finfish being caught. (An exception is the inshore shrimp fishery where bycatch of small turbot is still a problem (Blackwood, 2001).) Such high quality catches of shrimp are of a higher market value than were the catches prior to the use of the sorting system. Figure 15 demonstrates the dramatic increase in the value of Atlantic Canadian shrimp since 1989. Although this increase can be attributed to a number of factors, in particular the growing worldwide demand for shrimp products and the increase in the actual amount of shrimp harvested, the dramatic rise in value seen in the years from 1995 to 2000 may be partially attributed to the growing use of grate sorting systems after their introduction in 1993.

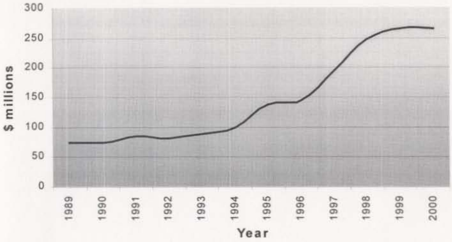


Figure 15: Atlantic Canadian Shrimp Values

(data from www.dfo-mpo.gc.ca/communic/statistics/landings/land_e.htm)

Initial gear modifications may be costly, particularly for independent fishermen or for those operating small fish harvesting companies. Investing in new nets with different mesh sizes or shapes, and made with biodegradable material, or purchasing a sorting grid system may not always be feasible for those in an industry where the economy can be volatile with variable landings and unpredictable fish prices. However it appears that in the near future demands by seafood consumers, environmental groups and members of the general public to harvest with conservation in mind will have to be met. Despite the initial costs, however, harvesters should benefit in the end by providing top quality seafood harvested in sustainable fisheries with protection of the marine environment as a priority. The resource will also benefit as population structures are restored and stocks are rebuilt to historical levels. This will result in landings of higher quality fish of greater value, reduce bycatch, and boost economic returns to the fishing industry. The image of the fishery, as perceived by those such as conservationists, seafood consumers, and the public in general, will also be greatly enhanced.

7. CONCLUSION

Conservation harvesting has been an area of rapid development in Atlantic Canada over the past several years. The proactive approaches of industry fueled by the media and environmental groups, as well as the desire to preserve and improve the state of the resource on which harvesters depend, have led to improvements in fish harvesting operations. With the cooperation of government agencies, educational institutions and others in the fishing industry, fish harvesters have been able to combine their knowledge of fishing and share their ideas to create new fishing gear designs and fishing techniques. As a result, the Atlantic Canadian fishery can be regarded as being a leader in the development of a responsible fishery, working toward sustainable fisheries for the future, and providing future generations with a source of food and employment.

Since World War II lack of fisheries knowledge and overcapitalization in the fishing industry has led to the demise of many fisheries through overexploitation and the destruction of marine habitats. The improved science of today has allowed us to better understand the status of fish stocks and the delicate balance existing in the ocean environment. The development of conservation measures, such as those discussed in this paper, along with improved management of the resource should avoid future problems associated with overcapitalization and overexploitation. It is fundamental to ensure that all members of the industry realize that increasing the catch should not be the sole objective of the fishery, but rather that our concern and understanding of the state of what remains in the ocean are of equal significance. Once this is realized conservation harvesting will become the purpose of the fishing industry, allowing harvesting to take place in an efficient and sustainable manner.

8. RECOMMENDATIONS

Based on this examination of the development of conservation harvesting in Atlantic Canada, the following recommendations are intended to improve the existing efforts and latest developments. Although some may appear to be unrealistic at this juncture, they do provide goals to work towards which may someday be realized with a viable and sustainable fishery.

- Measures must be taken to reduce bycatch to minimum levels or eliminate it altogether, especially in cases where vulnerable or recovering stocks are of concern. To this end research and development in the area of gear selectivity must continue and expand to all areas of the fishery.

- Discards must be reduced to a minimum. If bycatch makes up part of the catch it should be landed and utilized, regardless of its value.

- Further studies must be conducted on the short- and long-term effects of seabed contact by fishing gear.

- Research should be augmented to investigate new ways to fish near the seabed without actually contacting the bottom. Lighter trawl doors, semi-pelagic doors, paravanes and groundrope arrangements are just a few of many technologies that are being investigated, and this work must continue.

- Workshops such as the 1999 Fishing Industry Workshop on Minimizing Sea Bottom Impacts of Trawling Gear should be held on a regular basis at frequent intervals. Such workshops provide valuable opportunities for the exchange of ideas among various representatives of the fishing industry and can accelerate progress in conservation technology developments.

- The Department of Fisheries and Oceans, as well as industry and research institutes, should consider establishing an extensive lost gear retrieval program to rid Atlantic Canadian waters of much of the ghost fishing gear that continues to fish depleted and recovering fish stocks. Such a program would, at the same time, provide employment for fishers still seeking work after displacement due to the cod moratorium and other fishery closures.

- Acoustic locator devices should be mandatory on all fishing gear to improve the success of recovery if the gear is lost. There should also be a policy in place requiring that all fixed gear (e.g. gillnets, crab pots) be constructed of biodegradable material, to prevent the continuing fishing cycle if the gear is lost and unable to be located. The implementation of these policies will eliminate the need for expensive recovery programs.

- Galvanic time-release devices should be mandatory on shellfish pots in Atlantic Canada, particularly in crab fisheries. This will allow the escape of crabs should they be caught in lost pots.

- Fish harvesters and gear technologists need to interact with those concerned with the environment to reach agreements on what the current priorities are and what needs to be developed so that harvesting can take place in a sustainable and environmentally friendly manner while allowing commercial productivity levels to be maintained or improved.

- Recognition and rewards for conservation harvesting initiatives should be in place as incentives for the development of new fishing gear and technologies, and the prevention of fishing activities that are damaging to the marine environment. This would encourage solutions to many of the problems associated with the effects of fishing. Such rewards should also be well publicized in the media to convey to the public that improvements are being made in the fishery. Representatives of the media should be invited to discuss and examine successful developments that have taken place in conservation harvesting, as well as to see where there are problems for which there are yet no solutions.

- Harsh penalties should be in place and enforced for those who disregard regulations pertaining to conservation harvesting. These penalties should range from fines, to jail time, to loss of fishing rights, depending on the severity if the offense.

- New developments that improve harvesting operations and are regarded as being environmentally friendly should be made known to the media and publicized so that it be known that Atlantic Canadians are working to protect the marine environment and fish stocks. This will help to portray a more positive image of the Atlantic Canadian fishing industry than has been characterized in the past.

- Public concerns surrounding fishing effects on the marine environment should be addressed through public meetings or some other similar forum and discussed with members of the fishing industry. Transparency in the decision-making process will allow public concerns to be taken into account in the development of new fishing technology aimed at conservation.

- The education of the public on fisheries matters must be improved to ensure that they receive all information pertaining to the issues rather than the biased information often found in various media sources.

- Representatives of the fishing industry in Atlantic Canada should consider working towards receiving MSC certification to increase demand and value of seafood products from Atlantic Canada. This would improve profits for all sectors of the fishing industry. It is essential that the process be started immediately so that the Atlantic Canadian fishery will be prepared to meet the demands required for eco-labeling in the near future. TAVEL Certification Inc. based in Halifax, Nova Scotia is a certification company approved by the MSC and is readily available to work towards MSC certification of fisheries in Atlantic Canadian. This should be observed as an opportunity by the fishing industry to show its progress in the fishery and improve demand for Atlantic Canadian seafood products.

9. REFERENCES

Alverson, D.L. Freeberg, M.H., Murawski, S.A. and Pope, J.G. (1994). A Global Assessment of Fisheries Bycatch and Discards. FAO Technical Paper 339. Rome, Italy.

Andersen, R. 1998. Voyage to the Grand Banks. Creative Publishers. St. John's, Newfoundland.

Anonymous. 1998. Canadian Code of Conduct for Responsible Fishing Operations Consensus Code. Ottawa, Canada.

Aquaprojects. 1992. Retrieval of Lost Gillnets and Prevention of Ghost Fishing Within the Atlantic Fishery. Submitted to Fishing Industry Services, Department of Fisheries and Oceans in association with Le Groupe Poupart, deBlois Inc., Laval, Quebec.

Barney, W. 1984. Lost Gillnet Retrieval Project: 1983-1984. Fisheries Development Branch, Department of Fisheries and Oceans. St. John's, Newfoundland.

Benson, B. 1999. Save the Whales. (Sunday, January 17). The Evening Telegram. p.13.

Bech, G. 1995. Retrieval of lost gillnets at Ilulissat Kangia. NAFO SCR Doc. 95/6.

Blackwood, G. 2001. Personal Correspondence. September, 2001.

Blichfeldt, G. 1998. Eco-labels: Implications for fisheries management. Presented at the Ninth International Conference of the National Institute of Fisheries and Economic Trade. Tromso, Norway, July 8-11, 1998.

Brodie, W.B., Bowering, W.R., Power, D., Morgan, M.J. and Boland, G. 1999. An assessment of Greenland halibut in NAFO subarea 2 and divisions 3KLMNO. NAFO SCR Doc. 99/38.

Brothers, G. and Hollett, J. 1991. Effects of Mesh Size and Shape on the Selectivity of Cod Traps. Can. Tech. Rep. Fish. Aquat. Sci. No. 1782.

Bublitz, C.G. 1995.Mesh size and shape: Reducing the capture of undersized fish. In Solving Bycatch: Considerations for Today and Tomorrow. Alaska Sea Grant College Program Report No. 96-03. University of Alaska Fairbanks.

CAFID. 1998. Shrimp Size Selectivity Using an In-trawl Sorting System. No.57.

CAFID. 1997. Danish Seine Mesh Size Selectivity Study – St. George's Bay, Newfoundland 1996. No.31.

Carr, H.A. and Cooper, R.A. 1987. Manned submersible and ROV assessment of ghost gillnets in the Gulf of Maine. In Proceedings Oceans '87: an International Workplace. Halifax, Nova Scotia. 2:622-624.

CASEC. 1996a. Project Summary: Salmon Bycatch in Cod Traps. Fisheries Management Branch, Department of Fisheries and Oceans.

CASEC. 1996b. Project Summary: Salmon Bycatch in Capelin Traps. Fisheries Management Branch, Department of Fisheries and Oceans.

CCPFH. 2001. Strategic Plan. (online) <www.ccpfh-ccpp.org/stratpln/shtml> September 11, 2001.

Cole-King, A. 1993. Marine conservation: A new policy area. Marine Policy. May, 1993.

Churchill, J.H. 1989. The effect of commercial trawling on sediment resuspension and transport over the Middle Atlantic Bight continental shelf. Continental Shelf Research 9(9):841-864.

Crowder, L.B. and Murawski, S.A. (1998). Fisheries Bycatch: Implications for Management. Fisheries 23(6):8-17.

Currie, D.R. and Parry, G.D. 1999. Impacts and efficiency of scallop dredging on different soft substrates. Can. J. Fish. Aquat. Sci. 56:539-550.

Deere, C.L. 1999. Eco-Labeling and Sustainable Fisheries. IUCN: Washington, D.C. and FAO: Rome.

DFA. 1998a. Harvesting. (online) <www.gov.nf.ca/fishaq/Harvesting> September 10, 2001.

DFA. 1998b. The New Fishery. (online) <www.gov.nf.ca/fishaq/Publications/NewFishery> September 10, 2001.

DFA. 1997. Snow Crab Selectivity Experiment. Department of Fisheries and Aquaculture - Fisheries Development Division. October-November, 1997.

DFO. 2001a. Shrimp Beam Trawling. (online) <www.nfl.dfo-po.ca/fm/ppc/Pubs> September 15, 2001.

DFO. 2001b. Newfoundland Snow Crab Management. Backgrounder NR-N-05-01. April 19, 2001.

DFO. 2000a. Canadian Attitudes Toward the Seal Hunt. Prepared by Environics Research Group.

DFO. 2000b. News Release NR-HQ-00-93E. September 22, 2000.

DFO. 2000c. Integrated Fisheries Management Plan – Scotia-Fundy Fisheries, Maritime Region. April 1, 2000 - March 31, 2002.

DFO. 199_. Effects of Silt on Fish and Fish Habitat. Factsheet.

DFO. 1999a. An Assessment of Trawling Technology in Canada. Program Planning and Coordination, Fisheries Management. Ottawa, Canada.

DFO. 1999b. Report of the Fishing Industry Workshop on Minimizing Sea Bottom Impacts of Trawling Gear. October 21-22, 1999. St. John's, Newfoundland.

DFO. 1999c. Conservation Harvesting Plan (CHP) – Atlantic-Wide for Vessels >100'

DFO. 1999d. Conservation Harvesting Plan. (online) <www.ncr.dfo.ca/communic/Reports/Nunavutresp_e.htm> March 5, 2001.

DFO. 1996. Conservation Harvesting Technologies – Northern Shrimp Fishery. Canadian Fisheries Responsible Fisheries Summary. October 1996.

DFO. 1994a. Fishing Gear and Harvesting Technology Assessment. Fishing Industry Services Branch. Ottawa, Canada.

DFO. 1994b. Fishing Gear and Harvesting Technology Assessment. Canadian Fishery Consultants Limited. Halifax, Nova Scotia. March 1994. Project No. B519.

DFO. 1994c. Backgrounder. B-HQ-94-97E. December, 1994.

DFO. 1994d. Lastridge Rope Selectivity Program: Gulf of St. Lawrence – 1993-94. Atlantic Fisheries Project Summary. Fisheries Operations. February 1994.

DFO. 1993. Detection of lost gill nets with side scan sonar technology. Scotia-Fundy Region, Halifax, Nova Scotia. No.43.

DFO. 1992/93. Fishing Gear Selectivity Program – Atlantic Canada 1992-1993. Fishing Industry Services. Ottawa, Canada.

DFO. 1992a. Canadian Fish Harvesting Program for Responsible Fishing. Fishing Industry Services – Fisheries Operations. Canada.

DFO. 1992b. Retrieval of lost fishing gear in the Northern Gaspé. Atlantic Fisheries Adjustment Program Report No.27.

DFO. 1985. Atlantic Fishery Regulations.

DFO. 1983. The Newfoundland Longline Fishery. Fishing Gear and Equipment No.1. December 1983.

Ecology Action Centre. 2001. Media Release. July 4, 2001.

Employment and Immigration Canada. 1993. The Fishery of Newfoundland and Labrador – Overview of the Fishery: History. Marine Institute. St. John's, Newfoundland.

Fiorillo, J. 2000. Eco-labeling could benefit fishermen. (online) <www.fishmonger.com> March 10, 2000.

Fisheries Council of Canada. 1997. Responsible Fishing in Canada. Submitted by TAVEL Limited.

Fisheries and Marine Institute. 1995. Phase 1 – Prevention of Ghost Fishing in Atlantic Canada. Fisheries and Marine Institute of Memorial University of Newfoundland and Department of Fisheries and Oceans, Fisheries Management Division. March 1995.

FRCC. 1998. What is the FRCC? (online) <www.ncr.dfo.ca/frcc/intro.htm> December, 1999.

FRCC. 1997. A Report on Gear Technology in Eastern Canada. Report of the Gear Technology Subcommittee. FRCC.97.R.1.

FRCC. 1994. Conservation Aspects of Groundfish Gear Technologies in Eastern Canada. Gear Technology Subcommittee. FRCC94.TD.4 Ottawa, Canada.

Gagnon, M. and Boudreau, M. 1991. Sea trials of a galvanic corrosion delayed release mechanism fro snow crab traps. Can. Tech. Rep. Fish. Aquat. Sci. No. 1803.

Gordon Jr., D.C., Schwinghamer, P., Rowell, T.W., Prena, J., Gilkinson, K., Vass, W.P. and McKeown, D.L. 1998. Studies in Eastern Canada on the Impact of Mobile Fishing Gear on Benthic Habitat and Communities. In Effects of Fishing on the Sea Floor of New England (pp. 63-67). Eds. E.M. Dorsey and J. Pederson. Conservation Law Foundation. Boston, Massachusetts.

Gorman, T. 1994. Dredging. Fishing Boat World. May, 1994.

Gough, J. 2001. Key issues in Atlantic fishery management. Canadian Museum of Civilization. (online) <www.ciclization.ca/hist/lifelines/gough1e.html>. February, 2001.

Graham, M. 1955. Effect of trawling on animals of the sea bed. Deep-Sea Res. 3(suppl):1-6.

Highsmith, R.T. (1997). The Sea's Unwanted Bounty. Conservation Sciences Fall, 1997.

Humborstad, O.B., Furevik, D.M., Løkkeborg, S. and Hareide, N.R. 2000. Catches of Greenland halibut (*Reinhardtius hippoglossoides*) in ghost fishing gillnets on the Norwegian continental slope. ICES Theme Session on Efficiency, Selectivity and Impacts of Passive Fishing Gears. CM 2000 /J:08.

ICES. 1995. Report of the Study Group on Ecosystem Effects of Fishing Activities. ICES Cooperative Research Report No.200.

ICES. 2000. Effects of different types of fisheries on North Sea and Irish Sea Benthic Ecosystems – Report of the IMPACT II Report. Extract from the 2000 Report of the Advisory Committee on the Marine Environment. January, 2000.

Industry Canada. 1996. Atlantic Fishing Methods. (online) <www.stemnet.nf.ca/ cod/history6.htm>. March 12, 2001.

Jennings, S. and Kaiser, M.J. 1998. The effects of fishing on marine ecosystems. Advances in Marine Biology 34:201-352.

Johnson, H.M. 2000. The Conservation/Environmental Movement and its Potential Impact on U.S. Seafood Supply and Demand. H.M. Johnson and Associates. (online) <www.fishmonger.com> April 15, 2000.

Laist, D.W. 1995. Marine debris entanglement and ghost fishing: A cryptic and significant type of bycatch? In Solving Bycatch: Considerations for Today and Tomorrow. Alaska Sea Grant College Program Report No. 96-03. University of Alaska Fairbanks.

Lear, W.H. 1998. History of Fisheries in the Northwest Atlantic: The 500-Year Perspective. J, Northw. Atl. Fish. Sci. 23:41-73.

Lien, J., Stenson, G.B. and Hsun Ni, I. 1989. A review of incidental entrapment of seabirds, seals and whales in inshore fishing gears in Newfoundland and Labrador: a problem for fishermen and fishing gear designers. In Proceedings of the World Symposium on Fishing Gear and Fishing Vessel Design. Fisheries and Marine Institute of Memorial University of Newfoundland.

Lindeboom, H.J. and de Groot, S.J. (eds.) 1998. Impact II: The Effects of Different Types of Fisheries on North Sea and Irish Sea Benthic Ecosystems. Netherlands Institute for Sea Research. Texel, The Netherlands.

Marine Institute. 1998. Fishing Technology Unit. (online) <www.mi.mun. ca/~ftu/ftu.htm>. October 2, 2000.

Martin, C. 1999. Federal fisheries policies remain the same. (Sunday, January 17). The Evening Telegram. p.11.

Mathews-Amos, A. 1997. Turning the tide. Global Diversity 7(3):2-6.

McAllister, D. 2000. Personal communication via Fisheries Social Science Network (e-mail). February 4, 2000.

MSC. 1998. Principles and Criteria for Sustainable Fishing. Airlie House Draft. Washington, D.C.

National Fisheries Institute. 1992. Greenbook. Vol.2. Arlington, Virginia.

New Jersey Fishing. 2000. (online) <www.fishingnj.org/techhd.htm>. November 28, 2000.

Ocean Net. 2000. Ocean Net – To Instill an Ocean Conservation Ethic. (online) <www.oceannet1.com>. March 27, 2000.

Parsons, L.S. 1993. Management of Marine Fisheries in Canada. National Research Council of Canada.

Pascoe, S. 1997. Bycatch management and the Economics of Discarding. FAO Technical Paper 370. Rome, Italy.

Pendleton, C. 1998. "The Edge of the Bottom" – Heavily Trawled and Consistently Productive. In Effects of Fishing on the Sea Floor of New England (p. 138). Eds. E.M. Dorsey and J. Pederson. Conservation Law Foundation. Boston, Massachusetts.

Rhoads, D.C. 1974. Organism-sediment relations on the muddy sea floor. Oceanography and Marine Biology: an Annual Review. 12:263-300.

Ryan, S. 1990. The Newfoundland Cod Fishery in the 19th Century: Is There Anything to be Learned? (on-line) <www.stemnet.nf.ca/cod/history6.htm> Nov.23, 1999.

Safina, C. 1998. The *Audubon* Guide to Seafood. Audubon. May-June 1998.

Sainsbury, J.C. 1996. Commercial Fishing Methods: An Introduction to Vessels and Gears. 3rd ed. Fishing News Books. Australia.

Schwinghamer, P., Gordon, D.C., Rowell, T.W., Prena, J., McKeown, D.L., Sonnichsen, G., and Guigné, J.Y. 1998. Effects of experimental otter trawling on surficial sediment properties of a sandy-bottom ecosystem on the Grand Banks of Newfoundland. Cons. Biol. 12(6):1215-1222.

Smolowitz, R. 1998. Bottom Tending Gear Used in New England. In Effects of Fishing on the Sea Floor of New England (pp. 46-52). Eds. E.M. Dorsey and J. Pederson. Conservation Law Foundation. Boston, Massachusetts.

Sproul, J.T. 1997. Gear-up for fishing standards – ISO 14000 EMS. INFOFISH International 4/97:18-19.

Stevens, B.G. 1995. Crab bycatch in pot fisheries: Causes and solutions. In Solving Bycatch: Considerations for Today and Tomorrow. Alaska Sea Grant College Program Report No. 96-03. University of Alaska Fairbanks.

Stuart, D.D. 1995. Public awareness of bycatch issues and political pressure for change. In Solving Bycatch: Considerations for Today and Tomorrow. Alaska Sea Grant College Program Report No. 96-03. University of Alaska Fairbanks.

Surrette, R. 1999. Fishery needs "no trawling zones". (Monday, January 18). The Evening Telegram. p.6.

U.S. District Court for the District of Columbia. 2000. Complaint for Declaratory, Mandatory, and Injunctive Relief. May 23, 2000.

Valentine, P.C. and Lough, R.G. 1991. The sea floor environment and the fishery of Eastern Georges Bank. U.S. Geological Survey Open-File Report 91-439.

Vienneau, R. and Moriyasu, M. 1994. Study of the impact of ghost fishing on snow crab, *Chionoecetes opilio*, by conventional conical traps. Can. Tech. Rep. Fish. Aquat. Sci. No.1984.

Watling, L. and Norse, E.A. 1998. Effects of mobile fishing gear on marine benthos. Cons. Biol. 12(6):1178-1179.

Way, E. 1976. Lost Gillnet Retrieval Experiment. Industrial Development Branch, Department of Fisheries and Oceans. St. John's, Newfoundland.

Weber, P. 1994. Net Loss: Fish, Jobs and the Marine Environment. Worldwatch Paper 120. Worldwatch Institute. July 1994.

Welsh, C. 2000. Gillnets on the way out? The Clarenville Packet. March 2000.

Whitney, D. 1998. Fishing woes hit bottom. Anchorage Daily News. December 15, 1998.