THE IMPACT OF IMPROVING FISHING GEAR TECHNOLOGY ON THE FISHERIES RESOURCES

BRIAN JOHNSON

THE IMPACT OF IMPROVING FISHING GEAR TECHNOLOGY ON THE FISHERIES RESOURCES.

by

© Brian Johnson

A paper 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

April 2006

St. John's **Newfoundland**

Library and Archives Canada

Published Heritage Branch

395 Wellington Street
Ottawa ON K1A 0N4
Canada

Bibliothèque et Archives Canada

Direction du Patrimoine de l'édition

395, rue Wellington
Ottawa ON K1A 0N4
Canada

Your file Votre référence
ISBN: 978-0-494-31292-6
Our file Notre référence
ISBN: 978-0-494-31292-6

NOTICE:
The author has granted a non-exclusive license allowing Library and Archives Canada to reproduce, publish, archive, preserve, conserve, communicate to the public by telecommunication or on the Internet, loan, distribute and sell theses worldwide, for commercial or non-commercial purposes, in microform, paper, electronic and/or any other formats.

The author retains copyright ownership and moral rights in this thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without the author's permission.

AVIS:
L'auteur a accordé une licence non exclusive permettant à la Bibliothèque et Archives Canada de reproduire, publier, archiver, sauvegarder, conserver, transmettre au public par télécommunication ou par l'Internet, prêter, distribuer et vendre des thèses partout dans le monde, à des fins commerciales ou autres, sur support microforme, papier, électronique et/ou autres formats.

L'auteur conserve la propriété du droit d'auteur et des droits moraux qui protège cette thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation.

In compliance with the Canadian Privacy Act some supporting forms may have been removed from this thesis.

While these forms may be included in the document page count, their removal does not represent any loss of content from the thesis.

Conformément à la loi canadienne sur la protection de la vie privée, quelques formulaires secondaires ont été enlevés de cette thèse.

Bien que ces formulaires aient inclus dans la pagination, il n'y aura aucun contenu manquant.

Canada

Abstract

Since man first caught a fish he has strived to catch them more efficiently and in greater quantities with less effort. The way the fishery is prosecuted in Newfoundland and Labrador has been evolving for over 500 years, but the most sweeping changes have occurred during the past 100 years. Theses changes, or "improvements", can be divided into three (3) areas: 1) fishing gear technology, 2) vessel design, and 3) electronic aids. This paper examines the effects of improving fishing gear technology with emphasis on the negative and positive effects these changes have had on the abundance of fish stocks harvested in the Newfoundland and Labrador Region.

The primary species harvested in the Newfoundland and Labrador region at the turn of the century was Atlantic cod (*Gadus morhua*). Fishing gears used within the Region prior to the twentieth century were passive (e.g. traps and longlines) and depended primarily upon the voluntary movement of cod during their seasonal migrations from the offshore spawning grounds to inshore feeding grounds where they were harvested. Seasonal distribution in inshore waters also largely limited the fishing season to a few months during the summer and autumn, and during the winter for overwintering bay stocks. The range of operation for the fishermen was also limited to the distance they could travel using oars and sails in their small vessels. The use of passive fishing gear persisted in coastal waters, however, harvesting in offshore areas was predominantly conducted using mobile fishing gear. The fishing gear of today is mobile, as are the fishermen, in their larger, diesel powered vessels with electronic equipment for identifying and tracking the movements of fish. Improvements in technology have

provided fishermen with the means of finding and fishing in virtually all areas, both inshore and offshore, in the Newfoundland and Labrador Region year round.

The abundance of virtually all species of fish has declined in the Region during the past 100 years as the fishing gear has improved and new technologies have been introduced to the fishery. Improvements in technology make it possible to capture so many fish that it is now possible to drive many of the fish stocks in the ocean to commercial, and possibly even, biological extinction.

This paper examines the interaction between improved fishing gear technology and the decline of many groundfish fish stocks harvested in Newfoundland and Labrador Region during the past 100 years, both before and after the collapse of these stocks. The emphasis is on Atlantic cod (*Gadus* morhua). I review the history of the fishery in the Region, examine the changes in fishing gear technologies, evaluate the changes, detail the status of the Northern cod stocks, and draw my conclusions from the information presented in the paper. The evidence to support my conclusions is largely circumstantial; however, I believe that it is sufficient to reach the conclusion that the improvements in fishing gear technology contributed substantially to the decline in the groundfish fisheries in the Region.

Acknowledgments

Preparation of this paper would not have been possible without the help of two (2) people.

The first is my wife Elizabeth. She has supported my studies since I entered this program and given me much needed moral support as I progressed through the program. Elizabeth believes in the benefits of education, as can be seen in her own continuing studies.

The second person is Dr. Scott Grant, who, as my advisor, guided me through the process of preparing this report in order for me to meet the requirements to complete my degree.

Table of Contents

Page

List of Figures

List of Appendices

Chapter 1

1.1 Purpose of Study

Several species of groundfish in the Newfoundland and Labrador Region have been under a moratorium at one time or another since 1992-93 because of overwhelming evidence of reduced abundance. The Northern cod (*Gadus morhua*) stock/fishery, which encompasses NAFO Divisions 2J3KL (Figure 1), had been a large component of the groundfish resource for several decades and suffered the same fate as other groundfish fisheries within the Region. Historically, inshore vessels using fixed gear had largely prosecuted the fishery. During the late 1930s, trawling technology was introduced in the groundfish fishery, first by foreign vessels (Vasconcellos et al. 2000), followed shortly thereafter by Newfoundland owned and operated vessels (Anderson 1998). When the moratorium on Atlantic cod was declared within the Region in 1992 (Vasconcellos et al. 2000, Mason 2002) harvesters were quick to blame each other for the decline in resources. The fixed gear fishermen blamed trawler fishermen and inshore fishermen blamed offshore fishermen. Most agree that the ultimate cause of the decline in fisheries resources was caused by over fishing. Moratoria on American plaice (*Hippoglosoides platessoides*), yellowtail flounder (*Limanda ferruginea*), and witch flounder (*Glyptocephalus cynoglossus*) were declared in subsequent years indicating overfishing of virtually all groundfish.

There was prior evidence of over fishing with mobile fishing gears in Newfoundland and Labrador waters as well as other parts of the world. These include the Atlantic herring (*Clupea harengus*) purse seine fishery on the southwest coast of insular

Newfoundland (Kelly et al. 1986), the orange roughy (*Hoplostethus atlanticus*) fishery on seamounts off Australia and New Zealand (Terra Nature Trust 2004), and the Atlantic cod (*Gadus morhua*) fishery in the North Sea (ICES 2004). The decline in these fisheries has, in part, been attributed to over fishing, but no known research has been completed that would draw the conclusion that a major factor in the decline of these stocks would be the use of mobile fishing gear technology.

I have been indirectly involved in the fishing industry within the Newfoundland and Labrador Department of Fisheries and Aquaculture since 1976, primarily in fishing gear development, demonstration, and resource development initiatives. The background knowledge attained in the field of fishing gear technology has presented me with an unique perspective and led me to question whether improvements in fishing gear technology, that is the methods by which we harvest fish, led to the decline in Newfoundland and Labrador's groundfish resources? In order to address this question I review the history of the introduction of various fishing gear technologies used within harvesting groundfish in the Region and declines in the fisheries resources during the same period of time.

The relationship between improved fishing gear technology and availability of fisheries resources has not been studied in any great depth and published papers on the topic are limited. I believe there is sufficient indirect evidence to establish a link between improved fishing technology and the decline in Newfoundland and Labrador's ground fish resources.

1.2 Area of Focus

There was a marked decline, during the period 1960-1975, in the groundfish stocks harvested in the Newfoundland and Labrador Region. Signs of trouble accrued within 10 to 20 years of the introduction of otter trawls, much earlier than when the moratorium on most groundfish fishing was introduced in 1992-93. This may be attributed to many interdependent factors. These include over fishing, improved harvesting technologies, lack of scientific information, as well as environmental (physical and biological) factors including varying oceanographic conditions. Improvements in vessel design, in fishing gear design, and the introduction of electronic fish finding and navigation equipment, increased the ability of the harvester to steadily increase the amount of groundfish harvested, with little or no increase in fishing effort. The factor discussed in this paper is improved fishing gear technology and it is recognized that all factors listed above, have in some way, contributed to declines in fish stocks. To attribute declines to a single factor would be misleading. For example, in the hands of relatively few harvesters, with moderate quotas, more efficient means of harvesting are unlikely to influence fish stocks. With improved technologies the harvester was able to find and track fish year round and catches escalated. More investment was put into enterprises (leading to overcapacity) which required the quotas to remain high, or increase, even though science suggested there were problems in various fisheries. Unfortunately, fisheries are ultimately in the hands of politicians who do not always make the correct or most informed decisions. These are the symptoms of a "boom" and "bust" fishery and the otter trawl, electronics, and larger vessels were the tools that contributed to the "bust" of the groundfish fisheries in the Region.

The main purpose of this paper is to determine whether changes in harvesting technologies were a major contributor to the decimation of many of the groundfish stocks in the Newfoundland and Labrador Region with particular emphasis on the northern cod stock. Although this paper focuses mainly on fishing gear technology other factors that impacted the cod stocks are also discussed, but in less detail. The paper focuses on the fishery from 1900 to 2000. This period witnessed many changes in the technologies used to harvest groundfish.

There are two fundamental types of fishing gear, which are classified, as either fixed (passive) or mobile (active). The main type of fishing gear used to capture groundfish in the early 1900s was fixed gear, which included the cod trap, handlines, and longlines, whereas today the majority of vessels use mobile fishing gear such as otter trawls. The comparison used in this paper is between fixed and mobile types of fishing gear. These gear types are compared with respect to long-term sustainability of the resource being prosecuted. The decline in stocks may be found to correspond with the introduction of otter trawling in the groundfish fishery.

The hypothesis is that the change in harvesting technologies from fixed fishing gear (e.g. cod trap) to mobile fishing gear (e.g. otter trawl) was a major factor in the decline of groundfish stocks in the Newfoundland and Labrador Region.

1.3 Methodology

The research for this paper started with the collection of various papers on the northern cod stock (NAFO Divisions 2J3KL) pertaining to the biology, history of abundance and distribution, and current state of the resource. The second step was to review the changes in technologies used during the harvest including the fishing gear, vessel design, and electronic aids. The third step was to compile and review the statistical information relating to the biomass levels over the years, the changes in fishing effort from 1900 to 2000, and review papers on the potential factors that may have contributed to the decline of the Northern cod stock. Once this was completed the history of the Northern cod stock and the fishery was outlined. The development in fishing technology was detailed, the decline in the biomass of the Northern cod stock was quantified, and the last step was to determine whether there indeed was a relationship between the changes in technology and the decimation of the stock.

Chapter 2

2.1 Cod in Newfoundland and Labrador: Decimation of Groundfish Resources

The following quotes illustrate how Atlantic cod has played one of the most important roles in Newfoundland and Labrador's fishery over the past 500 years:

> "Since the discovery of the New World, the Atlantic cod has been the dominant commercial species of the Northwest Atlantic." Further "The Atlantic cod figured predominantly in the early colonization of North America." (MUN 2003)

The earliest fishermen to the New World came from various European countries such as Spain, Portugal, and England in search of fish to sell in their home countries (McGuire 1997; Mason 2002). They did not live here year round, but returned home at the end of the fishing season. Eventually they did stay and settle in Newfoundland. They chose the location of their communities based on the most productive fishing grounds. It was important to be close to the fishing grounds as the early settlers had to row or sail their vessels to and from the fishing grounds, and day trips were preferred because of the unpredictable nature of the North Atlantic (DFO 1990; Harris 1990; Ryan 1990). Cod were salted and stored by the fisherman until the end of the season when the local merchant purchased them. The merchant then exported the fish to the market. The purchase of the product was done through a system known as the "*truck*" system, whereby the merchant extended credit to the fishermen to allow him to "*gear up*" for the fishing season. At the end of the season the fishermen and the merchant would settle these accounts, any balance would be paid to the fishermen. The norm would be for the fishermen to break even. This system allowed the merchant to control the fishermen that came under the umbrella of his credit (Sinclair 1985). This fishery continued from the early days of the fishery, until the mid 1900s, and was gradually replaced with cash payments to the fishermen by the company that purchased his fish. In the mid 1950s refrigeration was introduced (Baker 2001) by the fish plant owners reducing the need to salt fish, which also freed up much of the fisherman's time to pursue more fish. However, there was still a market demand for salt fish, as there is today, and many fishermen produced both fresh and salted product. A fishermen was no longer restricted as to who he had to sell his fish to and was not under the control of the fish merchants, as he was earlier in the century.

The capacity within the fishing industry continued to grow for both harvesters and processors, which contributed proportionally to the increased landings (Figure 2). The number of harvesters grew to approximately 15,000 by 1990 and the number of processing workers stood at 25,000 (Figures 3 and 4). The capacity of both sectors of the industry grew as the quotas were increased, particularly, following the introduction of the Exclusive Economic Zone (EEZ) in 1977, when the foreign fleets were limited in their access to resources inside the 200 mile EEZ. Canadian vessels now replaced the foreign vessels and the harvesting effort and processing capacity were ratcheted up to meet the requirements of the processing industry. This ratcheting effect is where the quota increases are easy to implement, but decreasing quotas and effort is very difficult to realize due to political, economic, and social pressures. The effort in the fishery was to increase the amount of fish landed rather than focus on the value of the landed product; quantity as opposed to quality. The increasing ability to catch fish contributed to the dumping of fish when the fish plants could not cope with the volumes of landings and discarding at sea to get rid of smaller fish. These factors, combined with the lack of an auditing system (e.g. dockside monitoring) to verify the amount of fish actually harvested, lead to scientists having incorrect data to input into their calculations in preparing stock assessments.

Several groundfish fisheries were placed under a moratorium in 1992-93 when science stock assessments showed the biomass fell well below their predictions and could no longer support a commercial fishery (Steele et al. 1992) without risking commercial, if not biological extinction. The loss of employment and the subsequent economic downturn in the Newfoundland economy (DFO 2003) was to be felt for many years to come. During the period of the moratorium the Fisheries and Oceans Canada (DFO) provided income support, early retirement, and educational training to the people that were affected by the loss of employment through two programs: the Northern Cod Compensation Adjustment and Recovery Program (NCARP) (DFO 2004), and the Atlantic Groundfish Strategy, or TAGS (HRDC 2000). These programs assisted those affected, but did not provide a long-term solution to the displacement of many fisheries workers. The numbers of processing workers had dropped to under 15,000 in 1992, and have remained at this level since. However the number of harvesters has remained stable between 13,000 and 15,000, as before the moratorium (Figures 3 and 4).

The fishery in the Newfoundland and Labrador Region grew during the moratorium on groundfish, due to the increasing quotas and landings of shellfish. Initially, the moratorium was expected to last no more than 2 years according to the Minister of Fisheries and Oceans Canada (DFO 2004). However, the biomass of the

Northern cod stock did not improve to the point that a large-scale commercial fishery could be opened even up to 2005. It was during this period the fishery shifted from a finfish (groundfish) based fishery to a shellfish fishery (Figures 5 and 6). Despite the lack of groundfish landings, the shellfish fishery has enabled the value of the fishery to rise to approximately 1 billion dollars. However, the increasing value of the fishery has not been equally distributed within the harvesting and processing sectors of the industry. The employment levels in the harvesting sector have remained relatively stable (Figure 3), while the employment levels in the processing sector did not recover to previous levels (Figure 4). The main reason is that the labour requirements for processing shellfish are less than that of groundfish, as shellfish processing is highly machinery oriented (pers. comm. M. Rumboldt, DFA). The codfish have not returned, but the value of other fisheries in the Newfoundland and Labrador Region continued to grow past 2000 while leaving many people in rural Newfoundland and Labrador displaced from the industry. The conversion from a groundfish fishery to the shellfish fishery is an example of fishing down the food chain. That is when a fishery shifts to species within a lower tropic level than those previously fished. In this case it not only decreased employment in the fishing industry, but also raises the question: what effect does fishing down the food chain have on other species in the ecosystem within the northwest Atlantic?

2.2 The Northern Cod Fishery 1900 to 2000

The population of cod in the northwest Atlantic is made up of 12 to 14 distinct stocks (Scott and Scott 1988) and includes a stock known as Northern cod. This stock is located in the Northwest Atlantic Fisheries Organization (NAFO) Divisions 2J3KL, exhibits distinct biological differences from other stocks, and does not appear to mix with adjacent stocks (Underwater World 2004*)* (Figure 1).

The northern cod fishery is based on the stock of cod located southeast of Labrador and northeastern Newfoundland and was formerly considered the most important of the stocks in the northwest Atlantic (Scott and Scott 1988). Estimates of the historical biomass of Northern cod were 2 to 4 million metric tonnes (mt) (Rose 2003).

The catches of cod from the Northern cod stock have been estimated for the period 1900 to 2000 by various methods. Harris (1990) depicted landings of cod from NAFO Divisions 2J3KL as growing, or stabilizing, between approximately 200,000 and 300,000 mt from 1850 to the early 1960s. The catches then rose quickly to over 800,000 mt by the mid 1960s, followed by declines to less than 200,000 mt in 1978 (Figure 7) (Harris 1990). Steele et al. (1992) depict a similar increase in landings of Northern cod from 1800 to the early 1960s, and a comparable decline from the mid 1960s onward (Figure 7). To quote Harris (1990):

> "Between 1804 and 1947 Newfoundland catches of northern cod increased linearly from about 75,000 to 200,000 metric tons." He goes on to say "Yearly fluctuations in landings in this period amounted to 35,000 metric tons above and below the regression line and seem to have been related mainly to economic conditions…." While, "From 1948 onwards, Newfoundland catches of northern cod declined.".

Harris (1990) broke the landings down by inshore and offshore, and by Newfoundland and foreign vessels. A second source of data was prepared by the Department of Fisheries and Aquaculture (DFA) and details the period from 1875 to

1995 (Figure 8). The data is similar in both reports, however, the latter breaks the landings down into Canadian and foreign contributions. This data was then further broken down to show Canadian and non-Canadian, and inshore and offshore landings (Figure 9).

While the catches were increasing, estimates of the biomass during the period were not fully known due to incomplete surveys and data sets. It was thought during the early 1900s that the ground fish resources were inexhaustible. This proved to be untrue, as in the early 1900s, when haddock was overexploited in the waters off eastern North America and people became concerned that this could happen to other species (Hickey et al. 1995). As a result the International Convention for the Northwest Atlantic Fisheries (ICNAF) was formed in 1949 (Mount Allison University 2003) to oversee the management of the fish stocks off the North American northeast coast. In the 1950s an international Law of the Sea Conference was held. It was from this conference, and subsequent conferences that the basis for management of the fisheries in the North Atlantic was drafted (Figure 10). It would be 25 years before the members of ICNAF agreed that quotas, for most of the various species in the Northwest Atlantic, could be set using the concept of maximum sustainable yield (MSY), and that economic considerations for the countries involved in harvesting fish in the area must also be considered in setting the quotas (Mount Allison University 2003). Although ICNAF set quotas, it did not have the power to ensure that the various countries that formed ICNAF abided by the quotas that were set for the various species in the NAFO areas (McCay and Finlayson 1995; Mount Allison University 2003).

The inshore fishery in Newfoundland concentrated on Atlantic cod as they migrated to inshore fishing grounds (Harris 1990) during the summer months. While inshore, cod were captured in various types of fixed, or passive gear deployed from small vessels; historically between 6.1 and 10.7 metres (20 and 35 feet) in length. The fishermen had to wait for the cod to come to their fishing gear. There were years when the fish did not arrive in quantities that had been experienced in most years, causing what was termed a failure in the fishery (McCay and Finlayson 1995). However, catches rebounded within a year or two and life would get back to normal. This cycle repeated itself many times over the course of the fishery up until the late 1960s. Harvesting of cod in the offshore, where the great majority of the stock over wintered and spawned, started in the 1950s when trawlers and longliners were introduced to the fishery in the western North Atlantic. These technologies allowed fishermen to access areas where they had not been able to fish before. A boom and bust fishery ensued offshore and the catches rose to over 800,000 mt in 1968 and fell to 140,000 mt in 1978 (Blackwood 1996), the year following the implementation of the 200 mile Exclusive Economic Zone (EEZ). Foreign vessels were now limited in the access to the rich fishing grounds, and they were quickly replaced with Canadian trawlers (Vasconcellos et al. 2000). The catches improved to over 200,000 mt in the late 1970s and early 1980s, then declined sharply thereafter. The trawler fleet was hard pressed to find Atlantic cod by the early 1990s (Blackwood 1996), and given the poor state of the stocks, both inshore and offshore, a moratorium was put in place in 1992 to allow the stocks to recover (Day 1995). Hutchings (2003) alludes to how the decline in the groundfish stocks could have been avoided if an offshore trawler fishery had not been allowed to develop:

> "In other words, the catches we were able to sustain from the 1850s to the 1950s were not unsustainable in the 1980s. Having this unintended MPA (marine protected area) prior to the 1950s clearly did not hurt catches and almost certainly provided a bulwark against population declines and some insurance in conserving a broad age structure. It also reduced overall fishing mortality."

The sustainability of a stock is determined by its ability to replace losses that occur through natural and fishing related mortality. Recruitment to the stock is determined by the fish's ability to reproduce and the survivability of the young. Fishery scientists study the stocks, looking at the various factors that influence mortality and recruitment, to determine the amount of fish that can be removed from the stock by fishing and allow the stock to either remain stable or grow. From 1977 to 1986 NAFO scientists used a fishery related mortality of approximately 10% ($F_{0.1}$) to set the annual allowable harvest of northern cod (Parsons 1993; Shelton 2003). At the time, available information indicated the stock could sustain a harvest similar to the maximum sustainable yield (MSY). The use of the $F_{0.1}$ level was discontinued in the 1980s as it could give a mistaken picture of the level of the stock (as it did in the case of Northern cod) along with other factors, allowing stocks to be over fished. It was replaced by using 20% of the maximum biomass as the maximum level at which the stock could be harvested and not be depleted (Shelton 2003). Both methods start with estimating the spawning biomass, fecundity (number of eggs spawned), and mortality (natural and fishing) to provide an estimate of recruitment for each year class of fish (Parsons 1993). The year class is the hatch year, whereas recruitment is the size at which the year class enters the fishery. The level of mortality must be less than recruitment if the stock is to grow. As was previously stated, maturity of fish within a stock is an indicator of the ability of the fish to produce viable eggs and sperm. As the size of the fish increases, the number of eggs produced also increases (Powles 1958). Therefore, when the size at maturity of fish within a stock decreases (as in the case of northern cod from 6 to 8 years to 4 or 5 years) (DFO 2004a) as the larger fish are selectively removed from the population, recruitment will also be reduced as the remaining fish are producing fewer eggs. The decrease in the size at maturity is an indication that a stock may be in trouble.

The scientists qualify their advice on the available biomass of fish stocks by using a level of confidence, or error margins (DFO 2004a). This is because the information collected is only an estimate, and not derived from the actual counting of all the fish in a stock or population. The forest manager can accurately estimate the number of trees in a sample area, mortality to disease, and subsequently set a harvesting level for a given area. If the estimates have been wrong, the results can be seen immediately, and adjustments made in a timely manner. The forest manager does not have to be concerned with the stock (trees) moving, or their vulnerability to the census technology as the fishery scientist does. Fish are not stationary and migrate across the various fishing grounds. The sampling procedure for fish covers a very small area relative to the total area of the fishing grounds and point in time estimates (spring) may miss migrating fish when migrations are related to local environmental conditions. The fisheries managers then take this information and use it (along with social, economic, and political factors/pressures) to prepare a harvesting plan for the fish stock and set the amount of fish that can be harvested limited by a quota. If too little information is collected, or the models used are insufficient, the advice given to the managers will be wrong. This results in a harvesting plan that could lead to over fishing of the stock. This is one of the factors that led to the closure of the Northern cod fishery. Scientists made mistakes in calculating recruitment in the Northern cod stock, fishermen misreported their catches, and the managers were unable to reduce the harvesting levels in time to keep the stocks at a healthy level due to political forces. These factors, along with others, including changing oceanographic conditions combined to create a situation that caused the collapse of the commercial cod fishery and closure in 1992.

Current biomass estimates of the Northern cod stock are at an all time low at about 2% of the biomass of the 1980s, or less than 200,000 mt, and are showing no signs of recovery (DFO 2002). The moratorium, introduced in 1992 has placed severe limitations on the fishermen allowing only very small-scale fisheries in the NAFO areas 2J3KL during the past 12 years. The information collected by fishermen in sentinal programs and by DFO during this period has allowed scientists to assess the state of the stocks to determine if a recovery is occurring. This information adds to the continuous time line of data on the stocks and will ensure that DFO can prepare the necessary management plans if, and when, the stocks recover, and should avoid a premature opening of the commercial fishery.

The fishery for many groundfish species, including Northern cod, should not be allowed until the stocks reach levels that ensure their continued rebuilding. Once the rebuilding is shown to have reached certain levels, a preemptive quota may be set allowing limited harvests. These quotas should start low, and be incrementally increased as the stocks continue to grow (erring on the side of caution). This will mean that fishermen must look at ways to ensure they get the best price for their landings (quality, not quantity), as the volume of landings may never reach the levels experienced before the closure of the various groundfish fisheries. In some regions, an adaptive strategy to low cod quotas resulted in several fishermen opting to take their fish in cod traps, hold them in pens (modified cod traps) and feeding them during the summer months (aka, grow-out). In the fall, when the weight of the fish has at least doubled, and the price per pound has traditionally been higher, the fish are harvested and sold. This strategy only works with fishing gear such as a cod trap as the fish will not be injured to the extent they would be if they were harvested using an otter trawl. This strategy could be continued once the fishery for Northern cod is re-opened, as the value of the fish harvested (price per kg or pound) would remain higher than if the fish were sold immediately after harvesting.

Chapter 3

3.1 Changes in Fishing Gear Technology 1900 to 2000

Fishermen in Newfoundland were limited in the types of gear available to them in the early 1900s. The longline, handline, and cod seine were the main types of fishing gear utilized from the 1500s to the late 1800s and are still used today (Figure 11).

3.1.1 Longlines, Handline, and Cod Seine

The longline typically consists of a 91 m (50 fathom) length of rope, called the groundline, to which hooks are attached at 1.8 m (1 fathom) intervals with a short piece of twine referred to as a sud (Appendix A). These longlines are typically joined together in various numbers to form a fleet of gear. Inshore fishermen commonly fished 10 longlines per fleet, and up to 5 fleets (2,500 hooks) per day while some fished as many as 10 fleets (5,000 hooks) per day. The longlines were stored in tubs and each hook had to be baited by hand before setting out for the fishing grounds. The longlines were set, anchored to the bottom, and retrieved within the same fishing day. The majority of the catch is alive when the longline is hauled resulting in a very good quality product. The vessel returned to the homeport where the fish was split and salted. An average catch rate of 0.5 to 1 kg (1 to 2 lbs) per hook was considered good. The process was repeated each day as weather permitted. This type of fishing gear was mostly used in the fall of the year by fishermen in small inshore vessels and for a longer season by fishermen in the larger schooners that operated farther from shore including the southern Grand Banks (Anderson 1998).

The handline consists of a baited hook, or jigger, on the end of a piece of twine that is lowered over the gunwale of a boat to the ocean floor. The hook is moved with a hand motion to attract the fish. Fish were hauled into the vessel and the process was repeated until fishing was finished for the day. Once the vessel returned to port the catch was split and salted.

The cod seine was used to enclose fish into a small cove. The two ends of the net were drawn together until the fish were sufficiently concentrated to allow them to be dipped from the net into the fishing vessel. When the catch was landed it was split and salted.

The longline and hand line limited the amount of fish that could be caught. The longline by the number of hooks that were used as only one fish can be caught on a hook. The handline generally limited the users to one fish per haul. The cod seine could catch various quantities of fish, but fishermen were limited by the amount of fish they could carry in the boat and the amount of fish that could be split and salted in a day. In effect, the ability to process the days catch limited the total catch, as if more fish were taken than could be processed they would be wasted. Traditional longline, handline, and seine fisheries had been used for many years without decimating the stocks. Catches were limited by the amount of gear a crew could set and retrieve, and the amount of fish they could process during a day.

3.1.2 Trapnet (Cod Trap)

The Newfoundland cod trap was invented in the late 1800s and quickly became the gear of choice and proved to be the most efficient method for capturing cod during the first half of the 20th century. A cod trap is a box of netting, anchored to the sea floor to a depth of up to about 36 m (20 fathoms). The corners of the cod trap are held in place with grapnels to maintain the open box shape in the water. The cod trap is attached to the shore with a long sheet of netting, referred to as the leader, which guides the fish into the net as they follow the shoreline (Appendix A). The fish are retrieved when the cod trap is hauled. Hauling a trap net consists of pulling up the doorway so the fish do not escape. The excess, or slack netting, is hauled up to the fishing boat until the fish are packed dense enough to allow them to be dipped out of the cod trap into a boat with a dip net. The fish were then taken to shore where they were split and salted, or in later years sold fresh to a fish plant. The advent of fresh fish processing plants allowed fishermen to take larger quantities of fish in a shorter period, hauling a cod trap two or three times a day, depending on the catches. Selling the fresh fish to the plant eliminated the time consuming job of splitting and salting the fish so more time could be spent fishing. They were still limited by the amount of fish the boat could carry, but multiple hauls each day could give greater overall landings. The cod trap is a large piece of fishing gear, and once set, in a "trap berth", was very difficult to move. Therefore the selection of a good berth was essential and was usually done with a draw process where each fisherman in a community entered his name into a draw. Names were selected from the draw for the various berths around each fishing community. The success of the fishing season relied on the fish coming inshore each year to feed (Ryan 1990) and many times the cod trap fishery failed because the fish did not come inshore for one or more consecutive years. However the cod trap did help fishermen to increase their catches during the season, which usually encompassed the summer months. The original design of the cod trap was unchanged for many years until the mid 1960s (Appendix A). The cod trap was modified from the original box shape to include doors on the front to keep the fish in the trap and was called the Modified Newfoundland cod trap. Additional modifications included a design called the cod wing trap and another called the Japanese cod trap. Both were more efficient than the original Newfoundland cod trap in that they were capable of retaining fish better than with the original cod trap. If the trap could not be hauled, due to weather or strong tides, the fish would not be lost due to the delay in hauling. The size of the netting used in the cod traps was regulated at 89 mm (3.5") resulting in catches of small fish that in many cases were released alive by "rolling" them over the head rope. Many times however the fish were meshed in the netting and could not be released but were dumped after removal from the cod trap.

To the late 1800s the cod trap, a passive fishing gear technology, was the only major improvement in fishing gear in the commercial cod fishery in Newfoundland and Labrador since it began in the 16th century. The fishing gear used by the fishermen did not change very much until the otter trawl and gillnets were introduced to the province in the late 1940s and early 1960s respectively.

3.1.3 Gillnet

A gillnet is a sheet of monofilament netting mounted on a headrope and footrope. The headrope has floats to lift the top of the net up into the water and the footrope has weights to keep the bottom of the net in contact with the ocean floor. The typical cod gillnet is 91 m (50 fathoms) in length and 25 meshes in height (Appendix A). The theory is that the fish, not seeing the netting, swim into the netting, where their gills entangle them in it. Gillnets are set in fleets of 10 adjoining nets and fishermen use a varying number of fleets, depending on the size of the vessel they are fishing from. A catch rate of over 50 kg (approximately 100 lbs) per net is considered good. Gillnets are size selective, depending on the size of mesh used and fish are usually dead when the nets are hauled (12 – 24 hour sets). The standard mesh size for a cod gillnet is 140 mm (5.5") which allows the smaller cod to pass through the meshes without getting caught. The use of gillnets is controversial because of several factors. The first is that when they are not hauled every day, or are left for several days, the quality of the fish caught deteriorates rapidly and it may be necessary to dump some, or all of the catch, due to quality problems. These discarded catches are not recorded against the TAC. The second problem is that gillnets are lost to ice or storm damage and remain on the ocean floor for many years. They are made of synthetic material (nylon) that does not deteriorate and critics of this fishing method say they continue to fish for many years, destroying whatever they catch. The third problem is the by-catch of other or unwanted species. This includes by-catch of non-directed groundfish species and entanglement of marine mammals. The fourth problem is that the size selectivity of gillnets allows the fishermen to catch only the large cod, depending on the mesh size used. As the mesh size is increased, the size of the fish caught increases. The harvesting of various sizes of fish from a population, or stock, may have less effect on the reproductive capacity of the stock than the harvesting of only larger fish.

3.1.4 Otter Trawl

The otter trawl is a large, conical shaped net that is open on the front end and tied off, or closed on the trailing end (codend). It can be towed in contact with the bottom (otter trawling) or in the water column above the sea floor and on the surface (mid-water or surface trawling). The front of the net is held open by doors that spread the net as it is towed through the water, and they are attached to the fishing vessel by rope or wire called warps (Appendix A). A vessel tows the net with a large engine to overcome the resistance of the net and doors as they are towed through the water. The trawl can be used on bottom types of various conditions and is classified as mobile as the vessels can take the otter trawl to wherever the fishermen can find fish and pursue them. That is they do not have to wait for the fish to come to the fishing gear as with fixed gear. The trawl will continue to fish until it is full, unless it is hauled back (retrieved) on a schedule basis (based on the catch rates from previous tows) before it can fill up. Catches of fish can range from zero (a water haul) to many thousands of kilograms in a short period of time. For example, landings of cod and redfish in excess of 25,000 to 50,000 kg (approximately 50,000 to 100,000 lbs) per day were not uncommon, and in some cases, the net actually burst apart while being retrieved due to the weight of the fish (pers. obs.) The fishermen now had access to more fishing grounds than ever before. The first otter trawls were relatively small in comparison to the ones in use today, as was the size and horsepower of the vessels used.

The otter trawl was first used in the fishery off Newfoundland in 1935 (Lear 1998). Its use in the fishery was limited by regulations as the fishermen in the other fleet sectors thought it would damage the fishery they had participated in for hundreds of years (Lear 1998). With the otter trawl, fishermen were much more mobile, in that they could travel to where the fish were rather that wait for the fish to come to where the fishing gear was set. This also brought with it the larger, offshore, fishing vessels. These vessels were able to fish year round, in varying sea conditions, including ice-covered waters, where they could not before (McCay and Finlayson 1995). During the period from when the trawler was first introduced to today, the vessels have been redesigned and made more efficient with modern electronics and larger nets enabling them to find and catch fish in virtually any location, at any depth, at any time of the year. The fish do not have to be schooling as they did in the early days of otter trawling, as the electronics are now capable of identifying a single fish at great depths. Electronic equipment placed on the trawl allows fishermen to monitor the configuration of the trawl and can even detect individual fish as they enter the trawl. With the most recent technologies fishermen can also accurately estimate the size of the catch while the trawl is fishing and adjust tow times to maintain quality and quantity of fish taken.

The trawler technology was, for a while, limited to the offshore fishery. Eventually, the large offshore trawlers moved close to land, and were often observed from shore as they towed their nets at night. In some cases they caused much damage to fixed gear of the fishermen in nearby communities. In order to compete with the larger vessels these small to medium sized vessel fishermen from inshore had to find a way to adapt to the situation of repeatedly losing fishing gear. The fishermen on insular

Newfoundland's Northern Peninsula saw otter trawl technology as an opportunity to harvest fish in their area (Sinclair 1985). In the early 1970s, fishermen in the area were primarily using gillnets to harvest cod but changed over to otter trawls in the early 1970s (Sinclair 1985). Sinclair suggested that the need to compete with offshore draggers (both Canadian and foreign) in the Gulf of St. Lawrence may have been important in the fishermen's decision to change their harvesting methods as they were losing gillnets to the draggers. During the period from the early 1970s to 1985 the dragger fleet on the northwest coast grew and the size and power of the vessels increased. The larger vessels (20 m in length; 64' 11"), were being made wider (up to 7.3 m; 24'), and over 447 kw (600 hp) engines were becoming common. The inshore otter trawl fleet had annually taken part in a cod fishery on the southwest coast during the winter, taking large amounts of cod until the fishery was closed in 1994 to protect what was left of the Gulf of St. Lawrence cod stock. This stock annually migrated ahead of the advancing ice coming from the north to the spawning grounds in the area of the Port au Port Peninsula and Bay St. George (FRCC 2003).

The number of inshore draggers around the Province increased over the years and in 2000 (following the opening of the offshore shrimp fishery to inshore vessels) they numbered over 300.

The new fishing gears and vessels introduced to the region in the 1950s and 1960s gave fishermen the opportunity to seek and pursue fish on grounds that were previously inaccessible, and the larger vessels allowed them to find new fishing grounds farther from shore. They were now able to fish cod year round, pursuing them onto their overwintering and spawning grounds.

The design of the otter trawl has been improved since it was first used. The otter trawl can be configured to reduce by-catch of incidental and undersized fish. The shrimp otter trawl is a good example of reducing by-catch. The use of a Nordmore grate in the codend of the net has been successful in reducing the catch of finfish such as turbot, redfish, and cod (FDP 2002a). The use of the Nordmore grate in the Canadian shrimp fishery in the Northwest Atlantic is required by the DFO as a condition of license (Hickey et al. 1995). Regulations regarding mesh size are based on the premise that the larger the mesh size, more small fish will be allowed to escape. The configuration of the meshes has also been shown to be important. The use of square mesh netting, in the codend and extension of the otter trawl, has also been shown to allow a greater percent of small fish to escape than with diamond mesh of the same mesh size (Hearn 1984; Johnson 1985). The results from fishing trials in the inshore and offshore otter trawl cod fishery in Newfoundland in the mid 1980's had positive results in reducing the catch of undersized cod (Hearn 1984; Johnson 1985).

3.2.1 Changes in Related Technologies

Additional changes in fishing technologies involved improvements in vessel design and electronic aids used on the vessels.

The change in the vessels used in the fishery for cod in Newfoundland and Labrador to small inshore skiffs, longliners, and deep-sea draggers have in many cases replaced trap boats and schooners. The period of change started in the early 1940s and has continued through to today. The cod fishery my grandfather knew in the early 1900s was a small vessel powered only by oars and sails. Small vessels limited a fisherman's range to fishing grounds in the vicinity of where he lived. The introduction of the gas/diesel engine allowed the fishermen to travel well beyond their previous limits, and access to fishing grounds in areas they could not access before. In the case of the large draggers, this meant that their range of operation would be virtually unlimited and fishermen could now fish anywhere, anytime of the year. The offshore spawning and over wintering grounds of cod could now be targeted and eventually were.

In the early 1950s, along with the introduction of the monofilament gillnet to Atlantic Canada, the longliner was introduced to the inshore fishery in Newfoundland (Sinclair 1985). This was a vessel larger than the trap boats traditionally used by inshore fishermen, but still much smaller than the otter trawlers fishing the offshore waters. The first longliner introduced in the Province was in the area of Bonavista Bay in the early 1960s. The longliners that followed were between 10.7 and 16.8 m (35 and 55 feet) in length during the first few years they were used in the fishery. Over the years since then they have been redesigned and improved and now range in size between 10.7 and 20 m (35 and 65 feet) in length.

The fishermen in the early 1900s relied on their seafaring experience to navigate and had only a sextant and sounding leads to track their progress as they steamed to and from the fishing grounds. They were only able to return to the general vicinity of the fishing grounds where they had experienced good catches in previous days. The echo sounder was invented and used to locate submarines (particularly German U-boats) during the Second World War. However, it was discovered that the echo sounder could also be used to identify large schools of fish in the water column. In its infancy, the sound pulse emitted by the echo sounder into the water, was reflected back from objects in its path and showed up on the paper display in the echo sounder as clusters of individual marks (single fish would appear as ^). Today electronic monitors provide real time images of fish. The area that could be probed by the echo sounder was limited to an area beneath the vessel. The fishermen could locate fish before they set their nets, whereas previously they set their nets and hoped for the best. The echo sounder was refined, and improved, and from this technology the sonar (acronym for sound navigation and ranging) was invented. The sonar emits sound pulses that may be aimed at various locations, other than directly under the vessel. There were other improvements in these instruments, including multi-frequency, which allowed for better discrimination of the size of the schools of fish and detailed ocean bottom condition. Electronic fish finders used today allow fishermen to identify individual fish at great depths. Sounders have been modified so they can be attached to the fishing gear and send information (catch rate, net configuration, and bottom conditions in front of the otter trawl) from the net to the fishermen on the vessel. Information from gear-mounted sounders confirms that the net is fishing correctly to maximize fishing efficiency and give an accurate indication of the catch realized during any portion of the set.

Navigational aids were also developed and these technologies allowed fishermen to accurately plot their positions and navigate with a greater degree of accuracy. The use of the aids increased the profitability of fishing by reducing steaming time and increasing productivity during fishing. The radar, which emits electronic waves that are reflected back to the sending unit on the vessel in much the same way as the sonar or echo sounder, enabled the fishermen to locate objects on the ocean surface and land masses in the dark and during periods of restricted visibility (e.g. fog). This increased the safety of operating vessels at sea under less than optimum conditions. The Decca navigation system was developed and eventually installed on the coastline around North America. The unit on the vessel measured the time difference of signals sent from three shore stations. The data was then used to determine the vessels location by using navigation charts prepared with the Decca information. This gave the fishermen a reasonably accurate idea of his position. The next development in electronic navigation was the Loran A and C systems. These systems operated much like the Decca system, but were much more accurate. The use of the Loran systems also required the use of charts prepared with the Loran data. The next significant development was the satellite navigation system. This system consisted of several satellites placed in orbit around the earth by the United States military. The satellites transmitted signals to onboard receivers that interpreted the data and displayed the position of the vessel in latitude and longitude. This system has now been refined and improved, and is commonly referred to as the Global Positioning System (GPS). With GPS fishermen can now record the best fishing locations, return to within metres of these locations on their next trip, and set their nets back on the most productive grounds. Combined with the echo sounder and sonar, the aggregations of fish can then be located, and fishing started on the most productive areas.

The information collected by the various electronic units are now capable of being stored in a central computer on the vessel to be analyzed by the fishermen and used during future trips to ensure the best chance of good catches.

This means that with the improved technologies the fishermen could find the fish when they aggregated (e.g. when spawning) whereas DFO concentrated on stratified random sampling to determine fish populations or densities. The DFO did not look for fish but attempted to report on the overall biomass of the stock by randomly fishing in many areas. Using a single method to determine the status of a fish stock is not as accurate as using several methods. DFO now uses several methods that include the stratified random sampling (bottom trawl surveys), hydro acoustic estimates, sentinel surveys, commercial logbook data, and tagging experiments (DFO 2003b). Multiple data series over a long period improve the accuracy of biomass estimates and our ability to forecast sustainable quotas.

The improvements in electronic technologies were also available to DFO to conduct stock status assessments. Therefore the accuracy of the information they now have available should improve model predictions and recommendations made to fisheries managers.

3.2.2 Evolution of Technologies

The improvements in fishing technology over the years should have been matched by improvements in DFO's ability to manage the Northern cod fishery. This includes the monitoring and control of the landings from the participants in the Northern cod fishery, especially the offshore otter trawl fishery (McCay and Finlayson 1995). The recorded landings in the late 1960s were what was reported. Given the opportunity for under-reporting, due to high-grading and dumping at sea, as well as by-catches in other fisheries, we may never know the actual catches of Northern cod during the period of overfishing.

Since the Northern cod fishery was closed in 1992 DFO has been improving its management, and enforcement of the fishing industry. A good example of these improvements can be seen in DFO's "Policy - New Emerging Fisheries" developed in 2000. The policy states:

> "Management of new fisheries requires an integrated approach that would blend science and business principles and effective involvement of government, industry and other parties to ensure fisheries are ecologically and economically sustainable. It requires decisions on roles and responsibilities with regard to management, enforcement and science components within each exploratory harvest plan."

This integrated approach is applied before any new fishery can become a commercial fishery. The processes that must be followed in developing the fishery are; preliminary feasibility stage, commercial and stock assessment stage, and commercial fishery stage. This process is to ensure that the fishery is developed only after it is shown that the resource can be harvested in a sustainable manner. If existing fisheries were required to meet the same criteria, they would have a better chance of being sustainable.

Fisheries science, habitat protection, and monitoring and enforcement of fisheries have been highlighted by DFO through recent increases in funding during the past year for all of these factors.

3.3 Other Factors

The level of recruitment to any stock of fish is primarily controlled by the spawning stock biomass. Recruitment is a factor of the ability of the fish to spawn, and the survivability of the young. The mortality can be natural or through fishing activity. Natural mortality is caused by such factors as disease, longevity, and predation (fish, bird, and mammal) and environmental factors such as extremely cold ocean conditions.

Studying the diets of predators can approximate predation. Scientists use this information when determining the total mortality of a fish stock in the preparation of stock status reports and then in determining the total mortality that would allow a stock to remain constant or grow. If these estimates are wrong, the impression could be that the stock is healthy, when in fact it is not. The detection of these errors, in addition to others, could be years later and therefore it may be too late to take corrective measures before the stock is reduced to a point it can no longer support a commercial fishery.

The level of predation by seals on cod is controversial. The estimates used are from inshore observations and none are available from the offshore areas for recent years. A recent estimate of the harp seal population was 5.4 million animals in 1998 (Winters et al. 1998), and the most recent estimate has risen to 5.9 (range 4.5 to 7.5) million animals in 2005 (DFO 2005a). Seals prefer cod under 25 cm in length and sometimes eat only the belly section of the fish (Rumboldt 2003). Rumboldt (2003) indicates that in all NAFO areas combined seals consume 108,000 mt of cod less than 25 cm in length, and therefore consume approximately 300,000 cod each year. DFO estimates the consumption of cod by harp seals at 37,000 mt (DFO 2003b). Further, Rumboldt (2003) indicates that because recruitment is principal to the regeneration of Northern cod, consumption by harp seals of cod less than 25 cm in length is having an impact on resurgence of cod stocks. DFO science estimates that the consumption of cod by seals in NAFO Division 2J3KL to be 37,000 tonnes annually (DFO 2003a). DFO acknowledged that past estimates of the consumption of cod by seals have been too low as has their estimates of the size of the seal population (DFO 2005a). Thus, under estimates of natural mortality may have also contributed to the decline in the Northern cod Stock. The current quota for the harvesting of harp seals is set at approximately 240,000 animals per year, or a total of 975,000 harp seals for the period 2003 – 2005 (a maximum of 350,000 harp seals in any given year)(DFO 2003a). This approximates the MSY for the seal population, and will be reviewed in 2005 when a new population count is completed.

Oceanographic changes, in particular water temperatures, during the 1960s to 1970s (Harris 1990, Drinkwater and Mountain 1997) may have contributed to recruitment failures and overall mortality in several cod stocks and limited the annual inshore migration of the Northern cod. Where cod remained offshore year round they were vulnerable to the large offshore trawler fleet for an extended period of time.

3.4 Changes in Abundance of Northern Cod

Since the early 1960s, The size of the 2J3KL cod stock has been declining due to various factors. These factors are outlined in a paper entitled "Towards a Cod Recovery Strategy" that was complied by the DFO and the DFA for public consultation in February 2005 (DFO-DFA 2005). The following factors were listed: natural mortality, fishing mortality, reproductive capability, and fish condition and individual growth. Each of these factors had a role to play in the decline of the stock.

The level of natural mortality through predation is believed to have increased through the increase in the seal population (DFO-DFA 2005). In fact the level of seal predation *"is such that it could be contributing to the lack of recovery ...."* (DFO-DFA 2005) This is the strongest indication by DFO scientists that seal predation is a larger factor than previously believed by this group.

The fishing mortality has been shown to increase through the 1900s, especially with the introduction of the otter trawling method, as previously described (Section 3.1.3). The impact that this change has made on the cod stocks is a major part of the decline in the stocks (COSEWIC 2003) but is impossible to quantify. That is, it is not possible to say that it is the largest contributor, but can only be described as one of the leading factors.

Chapter 4

4.1 Evaluation of the Technological Changes

The idea of comparing the ability of different fishing gears to harvest fish is not new. The process involves taking into account various factors such as size of the fishing vessel and type of fishing gear, as well as harvester knowledge and experience, and is difficult, if not impossible to accomplish (O'Brien et al. 1999). The types of fishing gear used by fishermen have changed their ability to harvest fish. They can now fish in areas previously inaccessible, catch fish in greater quantities quicker than they could before, and increase the number of days at sea each year. Attempting to determine how the improvement in technology has affected the size of the fish stocks (esp. Northern cod) can only be done using circumstantial evidence, as there is not direct evidence or studies available.

The annual landings from the northern cod stock have been recorded for many years and give an indication of how the landings for each year have increased from 1900 to the 1960s. Figure 7 indicates a gradual increase in Northern cod landings, from NAFO Divisions 2J3KL, from less than 300,000 mt in1900 to approximately 400,000 mt in the late 1950s. This increase is similar to that described by Steele et al. (1992) which they attributed to an increase in the number of fishermen involved in the fishery. Following this period the yearly landings increased dramatically to peak at over 800,000 mt by the mid 1960s, while there was only a marginal increase in the number of fishermen participating in this fishery (Harris 1990) and therefore could not be considered a factor contributing to this large increase in landings. During this period the effort by the foreign fishing fleets increased with the introduction of the otter trawl to the fishery in the north Atlantic (Harris 1990).

The otter trawl increased the fishermen's ability to catch fish. The problem is to quantify the extent to which the ability to harvest more fish so it can be compared to their ability to harvest fish with fishing gear used prior to the introduction of this new fishing technology.

The different types of fishing gear have different abilities to catch fish, and the total amount of fish that they each can catch. The handline is limited to one fish per hook used on the line, and the number of times the fisherman can retrieve and set the hook during the fishing day. The gillnet is limited to the number of fish that will be caught in the meshes before the net becomes visible to fish or sinks to the bottom. The cod trap is limited by the size of the trap, the number of times the trap can be hauled, and transportation of the fish to the dockside during the day. Perhaps most importantly, these gears require active movement of the fish onto the fishing grounds. As well, the processing capacity of the local fish plant limited the amount of fish that would be bought from each fisherman. The otter trawl is only limited by the number of times it can be set and retrieved during a day and the storage capacity of the vessel's fish hold. The otter trawl fishery is less labour intensive because of the machinery that can be accommodated on the larger vessels. If the fish are abundant, the net can be set and retrieved in a two to three hours. The size of the net will determine the amount of fish it will hold, and catches of over 50,000 kg (approximately 100,000 lbs) per haul were not uncommon in the early 1960s. The next factor that limited the amount of fish caught on the otter trawl vessel was the amount of fish that could be iced and stored during the day. For a vessel that could carry 150,000 kg (approximately 300,000 lbs) of fish, this could be accomplished in two or three days. The turn around (time required to unload, clean, restock the vessel) was generally two days, allowing each vessel to complete approximately 30 trips per year. In the case of the foreign factory freezer trawlers they could fish until they were full, and then offload to a mother vessel that would transport the product to the home country. These trawlers restocked at the ports in Newfoundland (usually St. John's) and returned to the fishing grounds repeating the cycle. These vessels were also commonly refitted in Newfoundland, and sometimes, did not return to their homeports for years at a time.

4.2 Current Stock Status

The latest Stock Status Report for Northern cod (DFO 2004a) was issued in 2004 by DFO and is an update of the full assessment conducted in 2003. The report gives a bleak picture of a stock, which, in the 1960s, was estimated to constitute a biomass of over 3 million mt (DFO-DFA 2005). The biomass dropped to less than 500,000 mt in the 1970s, recovered to slightly over 1 million mt in the 1980s, and then declined to less than 150,000 tonnes, or less than 5% of the biomass in the 1960s (DFO 2003a). The current estimates place the biomass at less than 1% of the 1980s (DFO 2004a). Another estimate puts the spawning stock biomass (SSB) for 2J3KL cod from 15,000 mt to over 20,000 mt (DFO-DFA 2005). Whatever levels of the biomass, or the SSB, the result is that the biomass and the SSB are at very low levels, based on historical levels (DFO-DFA 2005).

The 2004 stock update indicates female cod mature by age 5 and are on average 50 cm (20") in length. Whereas, prior to 1982, only 5% of the cod age 5 years were mature (DFO 2004a). Currently, the spawning stock biomass consists of a large number of small, early maturing fish, which appear to be more susceptible to recruitment failures than a population of large and small fish. The large fish mature later, have higher overall fecundities, and have the potential to broadcast their spawn over a larger spatial range and time scale to buffer against varying environmental factors. This reduction in length at maturity indicates the size of the spawners decreasing and populations of smaller fish are not capable of reproducing at the rate populations did in the early 1900s.

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was established as part of the requirements of the Species at Risk Act (SARA). Its evaluations of the status of various species of fish outline the scientific basis for the list of fish species at risk (COSEWIC 2003). The mandate of the COSEWIC is to provide *independent* advice about the status of species at risk. COSEWIC also develops and reviews scientific information to determine if a species is under risk of extinction (COSEWIC 2003). Because of their low abundance, COSEWIC reviewed the status of cod stocks in eastern Canada (COSEWIC 2003).

COSEWIC's role is to consider the state of the stock in question and then recommend that it be listed as either; endangered or threatened, special concern, or not at risk (COSEWIC 2003). Consultations with the public were held recently and the committee now has until late 2005 to complete its assessment and make a recommendation as to the designation of the Atlantic Cod under one of the four categories. If, for example, the cod is then designated as endangered or threatened, the fishing for any species that have cod as a by-catch, and or sentinel fisheries (which are used to collect scientific data during the moratorium on cod fishing) could be restricted or closed.

Fisheries and Oceans Canada, and the Department of Fisheries and Aquaculture, Government of Newfoundland & Labrador, formed the Canada – Newfoundland and Labrador Action Team for Cod Recovery. This committee was set up in 2003 and the objective was to develop a plan for the recovery and future management of cod stocks in NAFO areas 2J3KL, 3Ps, and 3Pn4Rs (DFO-DFA 2005). The committee held public consultations and has prepared a report in which it outlines the status of various cod stocks, potential factors that could affect rebuilding, and set goals and objectives to promote the recovery of cod stocks. Fishing mortality was one of the many factors that contributed to the decline in the Northern cod stock. The areas where directed fisheries for cod have opened to limited fisheries have still not recovered as expected and it is believed that the harvesting levels were in excess of what the stocks could withstand (DFO-DFA 2005). There is no indication in the report that the type of fishing gear used to harvest cod was more, or less, to blame. However, there is concern that in the future, the type of fishing gear that could be used to harvest Northern cod should ensure that damage to critical habitat is reduced as much as possible (DFO-DFA 2005). Therefore the design of the otter trawl, particularly with respect to contact with the ocean floor, should be considered and where practical efforts can be made to minimize damage to critical habitat.

4.3 Management in the Future

The management of any future cod fishery must look at past experiences and take into account various factors. These include capacity, quota and allocations, the method of harvesting, the time of year for harvesting, and the locations for harvesting. Season and location will largely dictate the type of fishing gear to be used. The management of the Northern cod fishery must be structured so the resource is harvested in a manner that allows the spawning stock biomass to maintain the stock at 'safe' harvest levels. The method of harvesting would not be a factor if each type of fishing gear had a minimal impact on the habitat and ecosystem where the fishing takes place. It is the total amount removed from the stock that has to be controlled.

The selectivity of the gear must allow the harvesting of a cross section of the biomass to ensue that not only the small fish grow to a point where they contribute to recruitment and spawning, but also to allow large breeders to be a significant component of the biomass. The type of fishing gear could be restricted so that cod could only be harvested in certain areas at limited times during the year. If critical habitat is identified, such as spawning grounds, fishing in these areas could be restricted. This approach has been taken in Marine Protected Areas (MPA) in Gilbert's Bay and the Eastport area (DFO 2002a). DFO anticipates that MPA's, Coastal Management Areas (CMA), and Large Ocean Management Areas (LOMA) will be established in Atlantic Canada during the next 5 years. This is the foundation of the ecosystem management for marine areas which DFO is now implementing (2002a).

The mesh size used in gillnets allows the fisherman to direct for a certain size of fish but is not able to catch a large range of sizes. The nets must be hauled on a regular basis to ensure the quality of the catch and care must be taken not to lose any more nets than possible. If they are lost, a retrieval process and or program must be part of the conservation aspect of the fishery. The Marine Institute has been examining the effectiveness of using pots to harvest cod for the past 6 years (Walsh and He 2000). The results are encouraging and catches have at times been comparable to other types of fixed fishing gear used. Further work is required and is now ongoing (Walsh and He 2000). The pot has the ability to catch and retain the fish alive, so quality is no longer a problem if the gear is left unattended for extended periods, as it is with gillnets.

The otter trawl can be designed to select fish above a certain size, eliminate fish under a certain size, or reduce by-catch of other species. It will not, however, eliminate the catch of fish of any particular size, or all by-catch. Fishing trials have been conducted using a separator grate in the yellowtail flounder otter trawl to reduce the by-catch of Atlantic cod. The results were positive with over 55% of the cod being released from the trawl (Hickey et al. 1995). The size of the catch per tow can be limited to ensure the quality of the catch simply by putting an opening in the extension or codend of the trawl. When the net has been filled to the area where the opening is, fish will spill out through the opening. Through experience, the placement of the opening can be adjusted so the optimal amount of fish is retained, thereby reducing damage to the fish retained from being crushed by the weight of the fish when the trawl is hauled. There have been many projects conducted in the Newfoundland and Labrador region by both DFO and DFA to modify otter trawls to configure the trawl to have greater discrimination when fishing for a certain species of fish. These include the yellowtail flounder (FDP 2002b), cod (Hearn 1984, Johnson 1985, FDP 2003), shrimp (FDP 2002a), and turbot (FDP 2002c) fisheries. All have met with some degree of success; however more work is required to make the trawls even more selective.

The locations for harvesting cod could be restricted so that fishermen do not have access to the identified spawning grounds. This would ensure that the mating and spawning fish are not disturbed, as well as the spawning grounds. The full effects of this type of interference in the reproduction phase of a cod's life are not fully understood however Robichaud and Rose (2001) suggests that the impact could be considerable. Rose (1993) observed spawning columns of cod and infers that to disturb this process of the mating cycle could have extended effects on the spawning unit. This is because the time for the fish to regroup, and resume the spawning process, could influence it, or contribute to its failure.

The otter trawl is very efficient in harvesting various species of fish, both demersal and pelagic. The trawls must be designed to minimize the impact they have on the habitat, and in conjunction with various management controls (e.g. quotas, closed areas, observer coverage) can be used in a conservation minded manner.

Chapter 5

5.1 Summary

1. Annual catches from the inshore cod fishery were relatively stable from the late 1800s until the early 1960s growing gradually as the population of the province increased.

2. With the introduction of mobile fishing gear catches increased in the 1960s peaking in the 1980s.

3. The otter trawl was introduced into the Newfoundland fishery in the late 1940s. The otter trawl fishery was developed and expanded over time, by both the foreign and domestic fleets, until the EEZ was introduced in 1977. At that time the domestic fleet expanded further to replace a large reduction in effort by the foreign fleet that was displaced because of the EEZ.

4. Annual catches, from the inshore and offshore Northern cod fishery, increased dramatically to over 800,000 mt in the 1960s, which coincided with the introduction of the offshore trawler fleet and dropped to less than 175,000 mt in the early 1970s.

5. The traditional inshore fishery, using codtraps and longlines, was expanded to include gillnets and otter trawls, as these technologies were developed for use on vessels less than 20 m (65 ft) in length starting in the early 1960s.

6. Annual catches increased slightly in the mid 1980s to over 250,000 mt. Catches for both the fixed gear (inshore) and mobile gear (offshore) dropped to less than 125,000 mt in 1991, and the moratorium on the Northern cod fishery (and other groundfish species) was introduced in 1992 - 1993.

7. Since the moratorium was introduced on the Northern cod fishery the cod stocks have not recovered to the point that they could support a large scale commercial harvest. This has lead to speculation that the stock will never recover to the level it was prior to the introduction of the offshore otter trawling technology.

8. Predation by seals is now recognized by the science community as a factor slowing the recover of the cod stocks in the northern areas and may have been contributed to the decline in the Northern cod Stock..

9. Water temperature and salinity levels fell during the 1960s and 1970s off Newfoundland and Labrador. How these physical oceanographic conditions influenced cod stocks is unclear. There has been a reversal of this trend recently, with both temperature and salinity levels rising since the late 1990s (DFO 2005b).This could assist with the recovery of the cod stocks.

Before the introduction of the otter trawl to the groundfish fishery, in the Northwest Atlantic in the mid 19th century, the harvesting capacity was less than the carrying capacity of the fish stocks to maintain there abundance. Following the introduction of otter trawls to the fishery, in combination with other fishing gears and environmental factors, the harvesting capacity now exceeded the carrying capacity of the groundfish stocks. This is shown by the dramatic decrease in the abundance of various groundfish stocks in the Northwest Atlantic. If the harvesting capacity in the Northwest Atlantic exceeds the carrying capacity of fish stocks then simply eliminating a particular gear type (e.g. otter trawls) in the future is not likely to reduce this overall harvesting capacity. Harvesters will adjust to using and improving the other fishing gears available to them. The amount of fish taken must be regulated. Improvements in the fishing gear must continue to be made to ensure they are as environmentally friendly as possible. By reducing the damage to the ecosystems we can be in a better position to maintain the fish stocks for future generations.

5.2 Conclusions

As soon as harvesting of Northern cod changed from an inshore fixed gear fishery to a mobile offshore fishery the initial decline of the resource was underway. When it became apparent that the stocks were not inexhaustible (as was thought prior to the latter part of the 20th century) there was an initial denial of the problem, then the collapse that some in the industry foretold. It was not until 1989 that DFO scientists became concerned that their predictions of the growth of the Northern cod stocks were overly optimistic and their estimates of fishing mortality were less than half of what was actually occurring due in part to misreporting of discards. Observations now show a correlation between the introduction of otter trawling and the decline of the groundfish resource in the Northwest Atlantic. It was not until 1971 that DFO started to monitor the state of the cod stocks through scientific observations, attempting to quantify the size of the Northern cod stocks, and recommend sustainable levels at which the resource could be harvested.

There was no attempt to quantify the harvesting ability of the otter trawl fleet in relation to the resource. There were no limits placed on where or when the trawlers could fish or how much fish they could take in any given area. There were no closures of spawning grounds to ensure the stocks could be left alone to reproduce. Therefore, the harvesters were able to focus their harvesting on spawning concentrations of Northern cod for many years, even while the scientific surveys started to indicate a decline in the resource. The advice from the scientists was to reduce the quotas on Northern cod, however the offshore harvesters quickly responded that there was no problem, though it now took them longer to fill their vessels. It was not until the inshore harvesters started to notice a decline in their cod trap fisheries in the 1970s, and the offshore otter trawlers needed to increase their efforts to maintain catch levels, that the problem was becoming evident. Still there was denial of a problem by managers and politicians. The resource had declined to an all time low and fisheries managers and politicians were still unable to admit the failures of the past.

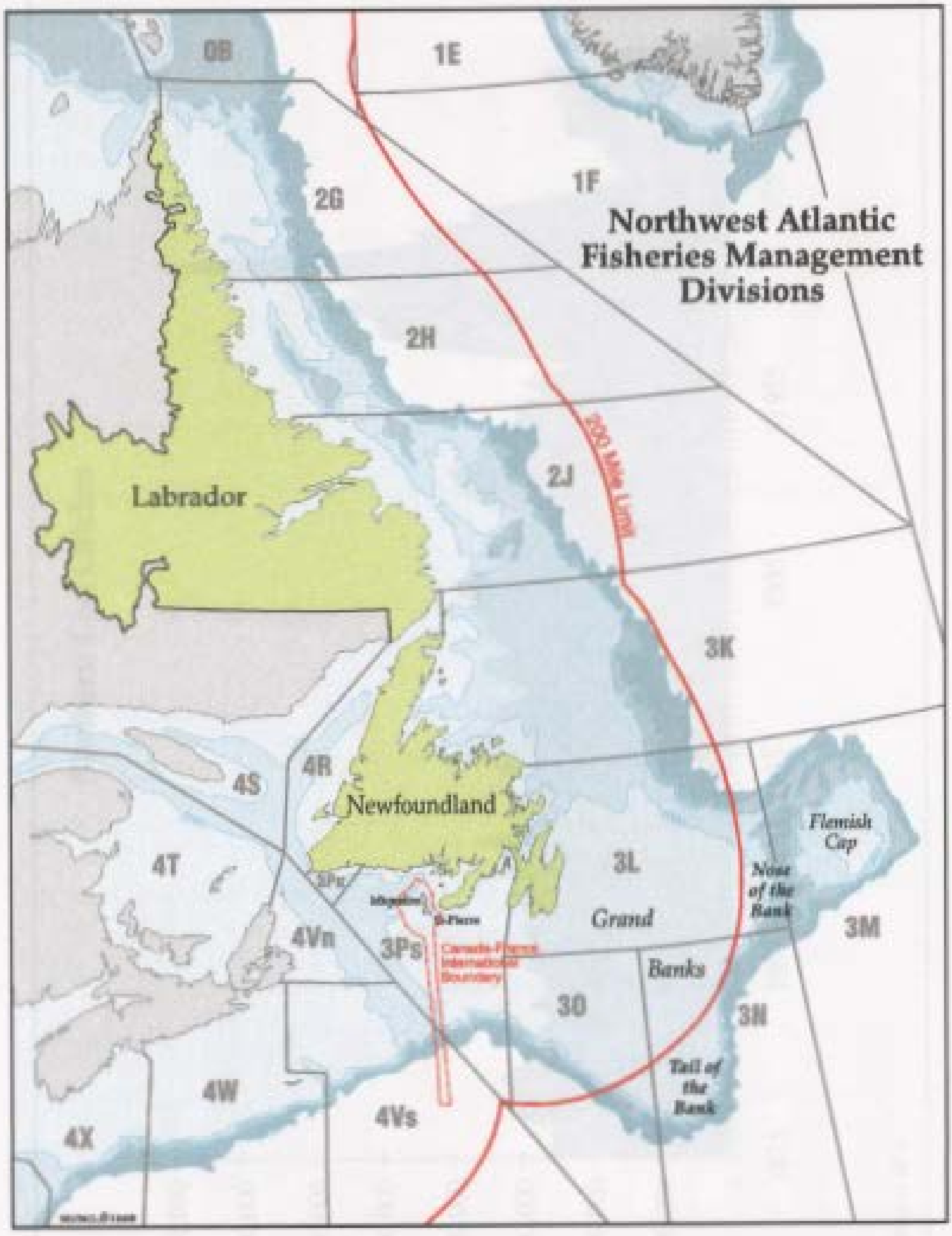
Many factors are considered by the managers when regulating the fisheries, and the scientific recommendations are not always the deciding factor when setting the harvesting quotas. The Minister of Fisheries and Oceans Canada makes the final decision based on many factors including the scientific information made available to him, but also takes into consideration political, social, economic, and historical access factors. The Minister has the absolute discretion in setting the quotas. DFO has now implemented their Ocean Action Plan which identifies collaboration with industry as a priority in fisheries management. However, as long as the Minister has the power to set the quotas, the advice of the stakeholders can be overridden.

The Northern cod stock has been under a moratorium since the early 1990s, is still at a very low level, and showing little, if any signs of recovery. If this fishery reopens in the future, the managers of the time must consider many aspects to control the catches at levels that are sustainable and minimize damage to habitat.

The improvements in fishing gear technology over the past 50 years have allowed harvesters to increase their catching power to surpass the availability of resources in many fisheries. The Northern cod is a good example of this. The idea that the fisheries resources can be protected by controlling the type of fishing gear used to harvest a species of fish does not work. The fishing gear will continue to be modified and improved to the point were the harvesting ability will be well in excess of the resources world wide. The impact of the fishing gear is now an important factor in allocating resources to the various fishing fleets. There is now acknowledgement that otter trawling has definite impacts on the habits and ecosystems. This must be examined in detail, and the otter trawl improved/modified to protect all the resources in the ocean. The ideal fishing gear would have no impact on the habit and allow for the harvest of the directed species without by-catch of other species. The otter trawl does not meet these criteria given its current design. Managers should consider that in order to access a resource, the harvester must prove that the harvesting method employed does not have any adverse effects on the habitat, or ecosystem, before it can be used.

The resources must be available for future generations if we are to be able to ensure a reliable food supply from one of our greatest resources, the oceans.

Figure 1: Northwest Atlantic Fisheries Management Divisions



Source: DFO

Figure 2: Northern Cod Catches 1875-1995

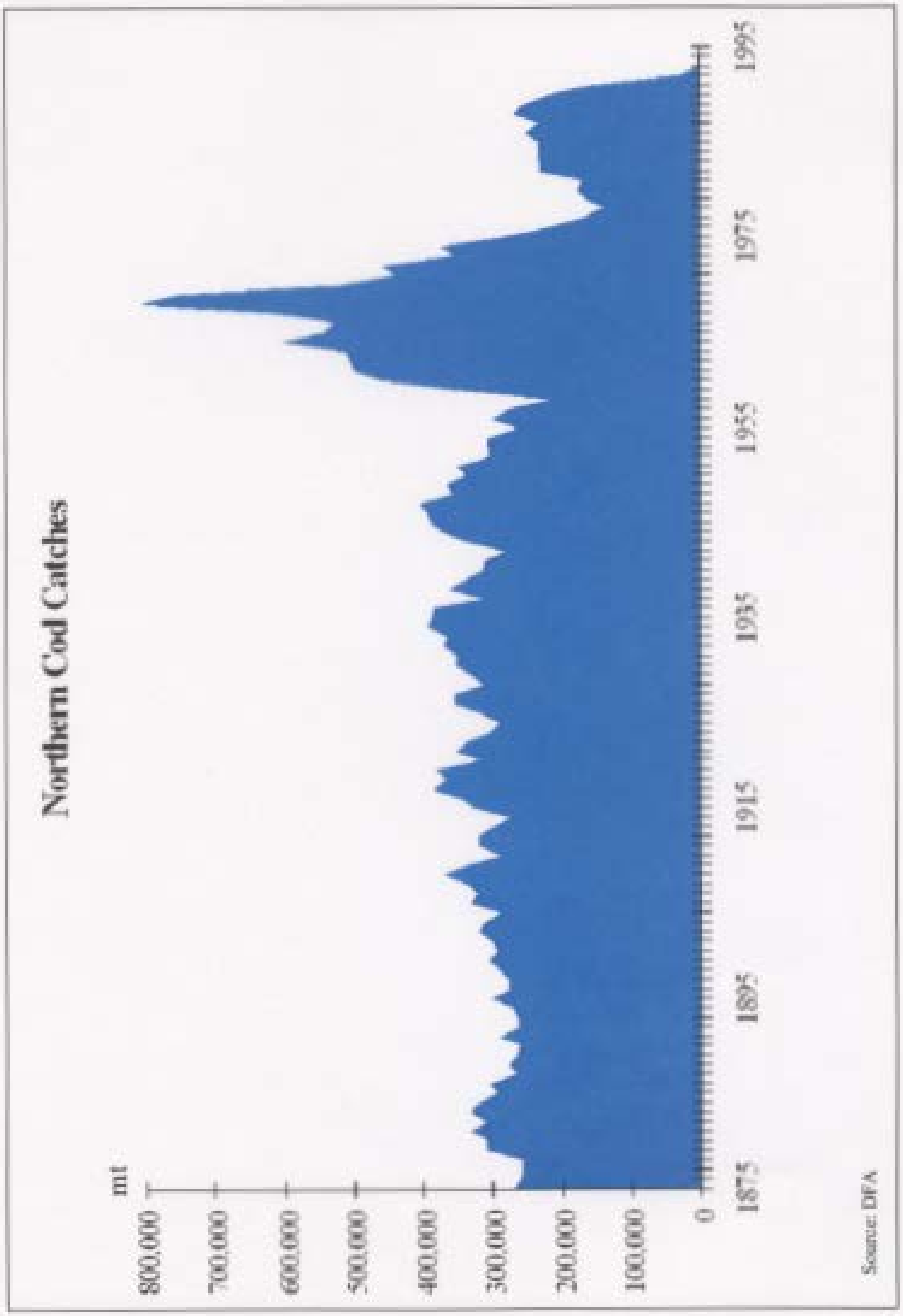
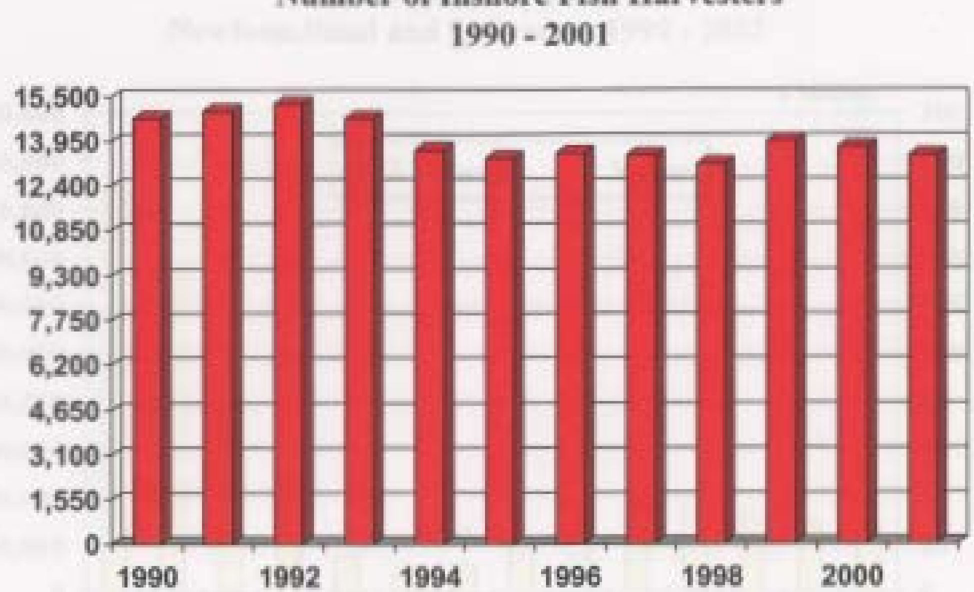
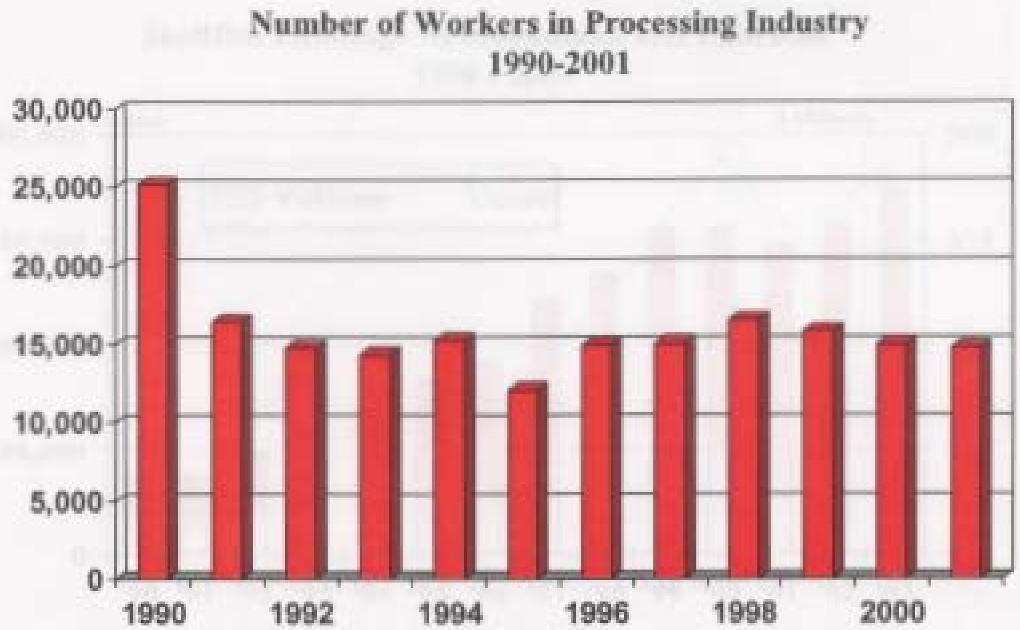


Figure 3:



Source: DFA, Special Tabulation, Statistics Canada; Newfoundland Statistics Agency

Figure 4:



Source: DFA, Special Tabulation, Statistics Canada; Newfoundland Statistics Agency

Figure 5:

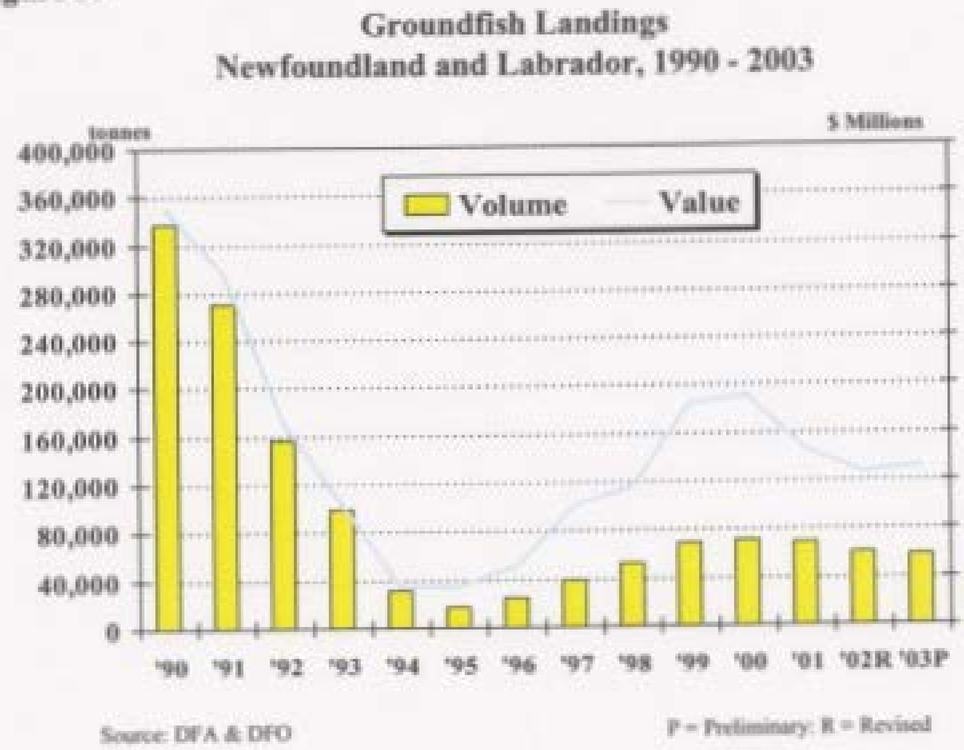


Figure 6:

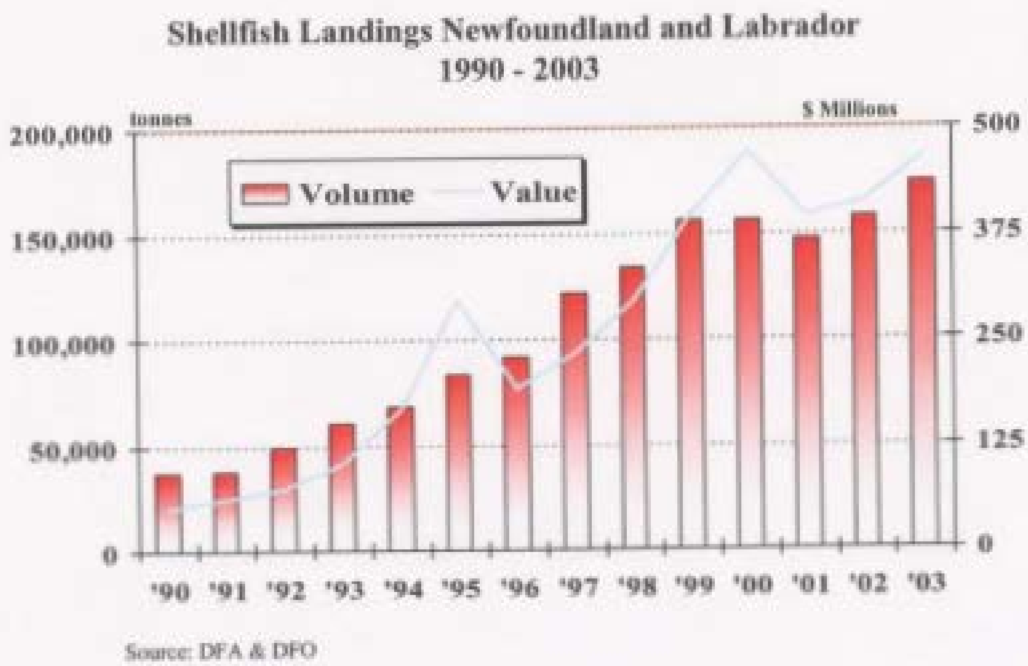
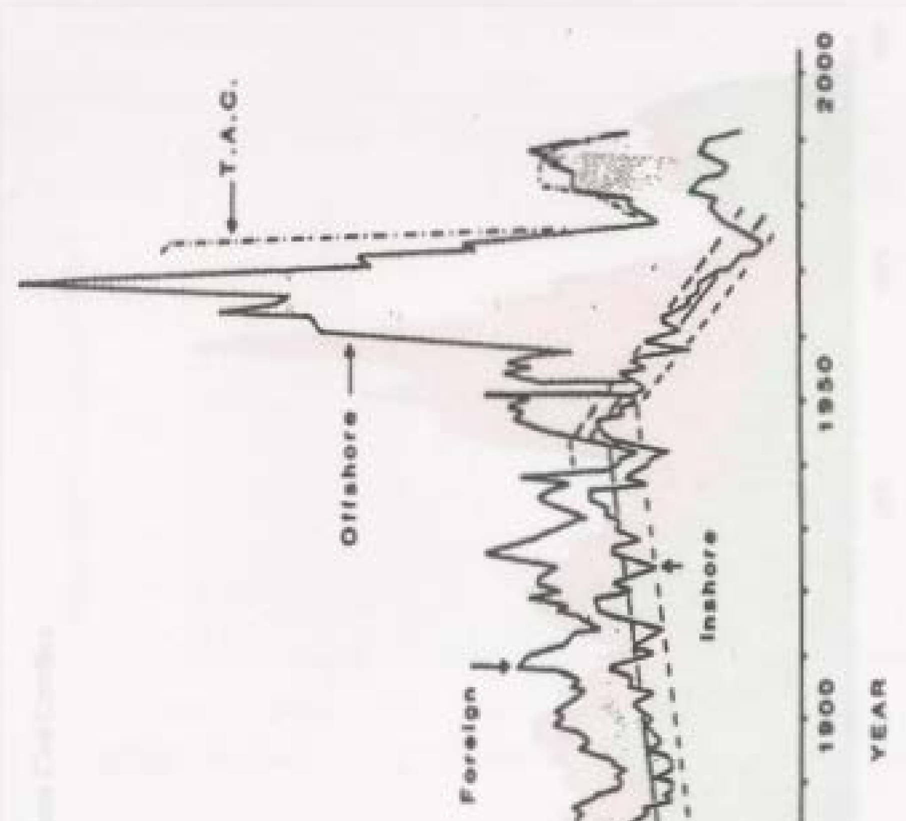
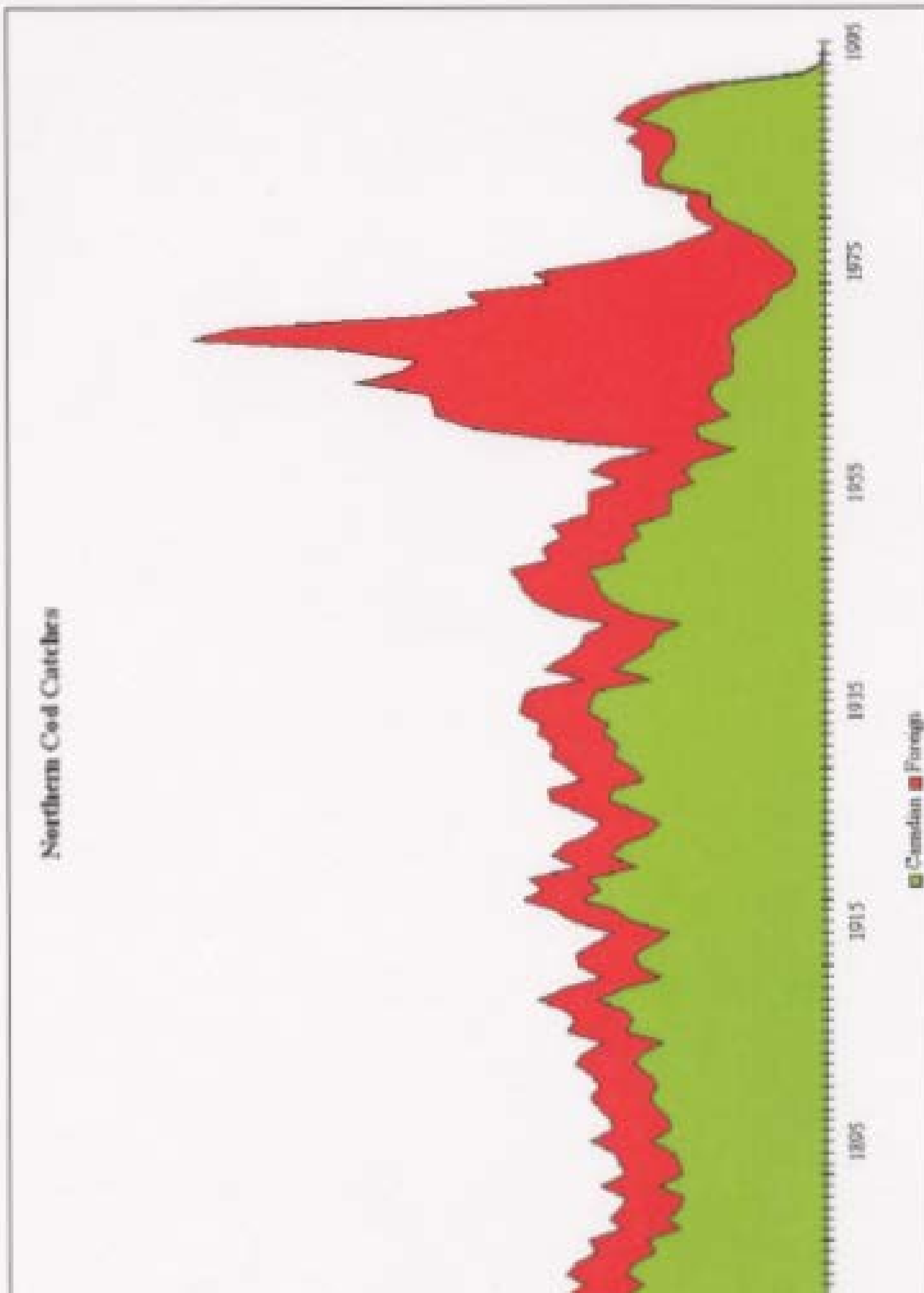


Figure 7: Landings of Northern Cod from 1800 to 2000 by
Inshore and Offshore/Foreign



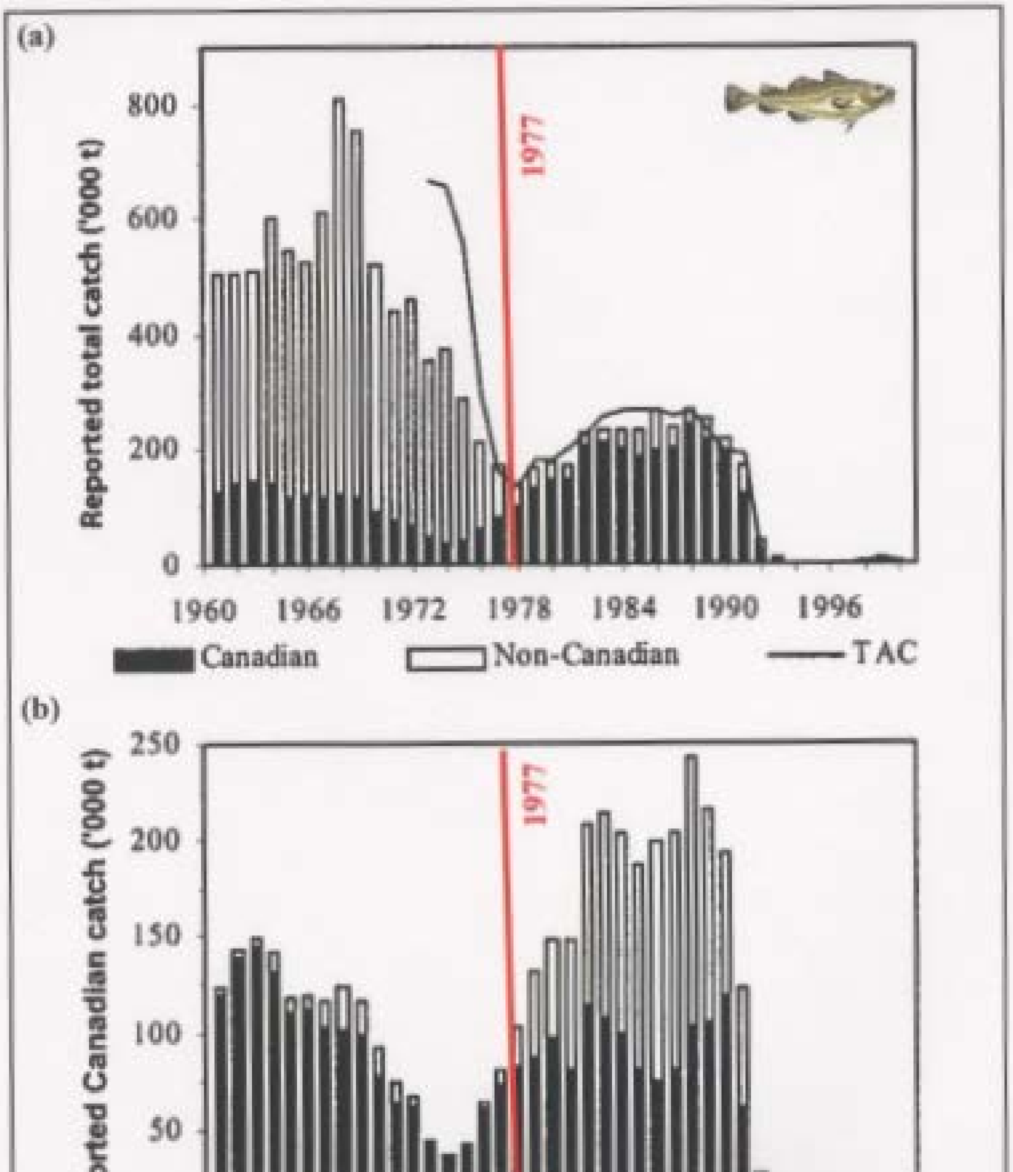
Source: Steele et al. (1992) The Managed Commercial Annihilation of Northern Cod. (P. 39)

Figure 8: Northern Cod Catches (2J3KL) Catches 1875-2001, Canadian and Foreign



(Source: DFA)

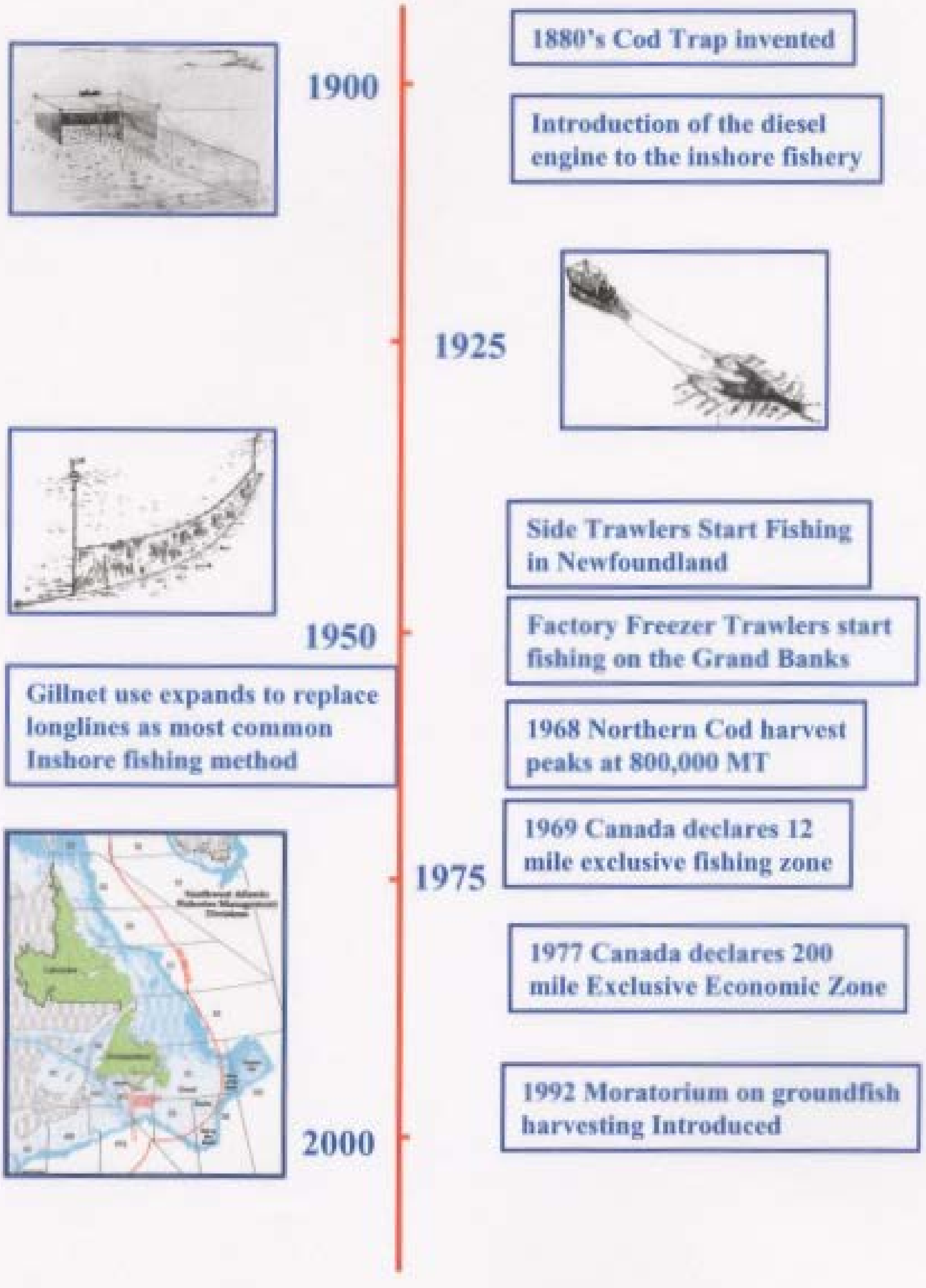
Figure 9: Summary of the reported total catch of Atlantic cod from 1960 to 1998 by (a) Canadian and foreign fisheries, (b) fixed and mobile gear. Vertical bar indicates the introduction of the 200 mile EEZ



(Source: DFO Science Advisory Secretariat)

Figure 10: Timeline of the Law of the Sea (Atlantic cod landings overlaid by milestones).

Figure 11: Timeline of Fishing Gear Development



Bibliography

Anderson, R. (1998). Voyage to the Grand Banks, The Saga of Captain Arch Thornhill. Creative Publishers, St. John's.

Baker, M. (2001). Fishing in the Global Village: Newfoundland and Labrador in the 21st Century. Canadian Issues (August/September 2001).

Blackwood, G. (1996). Past and Future Goals and Objectives in the Allocation of the Northern Cod Resource. Masters Thesis, Memorial University of Newfoundland.

Colbourne, E., deYoung, B., and Rose, G. A. (1997). Environmental Analysis of Atlantic Cod (*Gadus morhua*) Migration in Relation to the Seasonal Variations on the Northeast Newfoundland Shelf. Can. J. Aquat. Sci. 54 (Suppl.1).

COSEWIC (2003). COSEWIC Assessment and Update Status Report on the Atlantic Cod *(Gadus morhua)* in Canada. Committee on the Status of Endangered Species in Canada. Ottawa.

Craig, J. D. C., Colbourne, E. B., and Mailet G. L. (2001). Preliminary Studies of Density Stratification and Flourence on the Newfoundland Shelf. Science Advisory Secretariat 2001/085.

Day, D. (1995). Tending the Achilles' heel of NAFO: Canada Acts to Protect the Nose and Tail of the Grand Banks. Marine Policy: Volume 19.

DFO (1990). Independent Review of the State of the Northern Cod Stock. Ottawa: Supply and Services Canada.

DFO (1999). An Assessment of Trawling Technology in Canada. Program Planning and Coordination, Fisheries Management, Fisheries and Oceans Canada.

DFO (2000). Northwest Atlantic Harp Seals. DFO Science Stock Status Report E1-01 (2000).

DFO (2002). Northern (2J+3KL) Cod Stock Status Update. DFO Can. Sci. Advis. Sec. Stock Status Report A2-01 (2002).

DFO (2002a). Canada's Ocean Strategy, Our Oceans, our Future. Policy and Operational Framework for Integrated Management of Estuarine, Coastal and Marine Environments in Canada. Department of Fisheries and Oceans Canada.

DFO (2003) Media Room – Backgrounders: $50 Million Action Plan to Assist Fishers, Plant Workers and Communities Affected by Closure of Three Cod Fisheries.

DFO (2003a). Northern (2J+3KL) Cod Stock Status Update. DFO Can. Sci. Advis. Sec. Stock Status Report 2003/018.

DFO (2003b). Northern (2J+3KL) Cod Stock Status Report. DFO Can. Sci. Advis. Sec. Stock Status Report A2-01 (2003).

DFO (2004). A recent Account of Canada's Atlantic Cod. Retrieved April 2004 from the World Wide Web:WWW.dfo-mpo.gc.ca.

DFO (2004a). Northern (2J+3KL) Cod Stock Status Update. DFO Can. Sci. Advis. Sec. Stock Status Report 2004/011.

DFO (2005). Technical Briefing on the Harp Seal Hunt in Atlantic Canada. Retrieved April 2005 from the World Wide Web: http://www.dfo-mpo.gc.ca/misc/seal_briefing_e.htm.

DFO (2005a). Stock Assessment of Northwest Atlantic Harp Seals (*Pagophilus groenlandicus*). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2005/037.

DFO (2005b). 2004 State of the Ocean: Physical Oceanographic Conditions in the Newfoundland and Labrador Region. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2005/018.

DFO (ND). Atlantic Cod. Communications Directorate, Ottawa.

DFO-DFA (2005). Towards a Cod Recovery Strategy.

Drinkwater, K. F., and Mountain, D. G. (1997). Climate and Oceanography, Northwest Atlantic Groundfish: Perspectives on a Fishery Collapse, American Fisheries Society Symposium 22.

Dulvy, N. K. Jennings, S. Goodwin, N. B, Grant, A. and Reynolds, J. D. (2000). Comparison of threat and exploitation in status in North-East Atlantic marine populations. J. Appl. Ecol..

FDP (2002a). Reducing Capelin By-Catch in the Northern Gulf of St. Lawrence Shrimp Fishery – Project Summary: EACT-16.2002.DFO (FDP 367), Environmental Awareness and Conservation Technology, Fisheries Diversification Program.

FDP (2002b). Selectivity Experiments in Fishing Yellowtail Flounder, Using Square Mesh Codends and Rigid Grates. - Project Summary: EACT- 24.2002.DFO (FDP 434), Environmental Awareness and Conservation Technology, Fisheries Diversification Program.

FDP (2002c). Turbot Otter Trawl Size Selectivity – Vessels under 65' - Project Summary: (FDP 297), Environmental Awareness and Conservation Technology, Fisheries Diversification Program.

FDP (2003). Effect of the use of Chafing Gear on Codend Size Selectivity in Groundfish Otter Trawls - Project Summary: EACT- 26.2003.DFO (FDP 435), Environmental Awareness and Conservation Technology, Fisheries Diversification Program.

FRCC (2003). 2003/2004 Conservation Requirements for Groundfish Stocks in the Gulf of St. Lawrence. FRCC.2003.R.3, April 2003.

Genesis of Eden Diversity Encyclopedia (1997). Overfishing Cod. Retrieved November 2004 from the World Wide Web: http://www.dhushara.com/book/diversit/extra/cod/cod.htm .

Harris, L. (1990). Independent Review of the State of the Northern Cod Stock. Ottawa: Supply and Services Canada.

Hearn, D, (1984). Square Mesh Codend Experiment Aboard the F. V. Zandvoort: March-April, 1984. Data Series Report #20, Harvesting Operations Unit, Department of Fisheries, Government of Newfoundland and Labrador.

Hickey, W. M., Brothers, G., and Boulos, D. L., (1995). A Study of Cod/Flatfish Separation in Otter Trawls with the use of Rigid Grates, Can. Tech. Rep. Fish. Aquat. Sci. 2027.

HRDC (2000). The Atlantic Groundfish Strategy (TAGS). Retrieved April 2004 from the World Wide Web: http://www11.hrdc-drhc.gc.ca/pls/edd/TAGS_brf.shtml.

Hutchings, J. (2003). Interactions among collapse, recovery and extinction risk in marine and anadromous fishes.

Hutchings, J. and Myers, R. (1995). The biological collapse of Atlantic cod off Newfoundland and Labrador: An exploration of historical changes in exploitation, harvesting technology, and management.

ICES (2004). Cod in Subarea IV (North Sea), Division VIId (Eastern Channel), and Division IIIa (Skagerrak).

Johnson, B. (1985). Square Mesh Trials Summary Port aux Basques Area Winter 1985, Harvesting Operations Unit, Department of Fisheries, Government of Newfoundland and Labrador.

Keating, M. (1994). The Decline of the Fishery (1): The Killing Machine. Working paper – National Round Table on Environment and Economy February 1994.

Kelly, K. H., and Moring, J. R. (1986). Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (North Atlantic) Atlantic Herring. Biological report 82(11.38) TR EL-82-4.

Lear, W. H. (1998). History of Fisheries in the Northwest Atlantic: The 500-Year Perspective. Journal of Northwest Atlantic Fisheries Science, Volume 23.

Learning for a Sustainable Future (1995). The Disappearance of the Northern Cod. A Resource of Learning for a Sustainable Future.

Mason, F. (2002). The Newfoundland Cod Stock Collapse: A Review and Analysis of Social Factors. Electronic Green Journal, Issue 17, Dec. 2002.

Marine Institute of Memorial University (n.d.). Atlantic Cod, Offshore/Inshore Fisheries Development. Retrieved April 2004 from the World Wide Web– http://www.mi.mun.ca/mi-net/fishdeve/cod.htm

McCay, B. J., and Finlayson, A. F. (1995). The Political Ecology of Crisis and Institutional Change: The Case of the Northern Cod. Rutgers State University, New Brunswick, New Jersey.

McGuire, T. R. (1997). The Last Northern Cod. Journal of Political Ecology, Vol. 4, 1997.

MUN (2003). Management of the Northern Cod Fishery: Chronology – Key events and Publications.

MUN Negrijn, J. (ND). Atlantic Cod. The Fishery and Species, Offshore/Inshore Fisheries Development, Fishing Technology Unit, Retrieved November 2004 from the World Wide Web: http:www.mi.ca/mi-net/fishdeve/cod.htm

Mount Allison University (2003). About Canada - Canada's Fishery. Retrieved November 2004 from the World Wide Web: http://www.mta.ca/faculty/arts/canadian_studies/english/about/index.htm

O'Brien, C. M., Casey, J., and Rackham, B. D. (1998). Technical Indicators of the Temporal Development of fishing Power in the English Demersal Fisheries of the North Sea.

Palsson, O. K., and Thorsreinsson, V. (2003). Migration Patterns, Ambient Temperature, and Growth of Icelandic Cod (*Gadus morhua*): Evidence from Storage Tag Data.

Parsons, L. S. (1993). Management of Marine Fisheries in Canada. Can. Bull. Aquat. Sci 225: 763 p.

Powles, P.M. (1958). Studies of reproduction and feeding of Atlantic cod (*Gadus callasias L.*) in the southwestern Gulf of St. Lawrence. J. Fish. Res. Board Can. 15:1383-1402.

Robichaud, D., and Rose, G. A. (2001). Multiyear homing of Atlantic cod to spawning ground. Can. J. Fish. Aquat. Sci. 58: 2325-2329 (2001).

Rose, G. A. (1993). Cod Spawning on a Migration Highway in the Northwest Atlantic. Nature (Lond.) 366:458-461.

Rose, G. A., (2003). Fisheries Resources and Science in Newfoundland and Labrador: An Independent Assessment. Royal Commission on Renewing and Strengthening Our Place in Canada, Government of Newfoundland and Labrador.

Roy, N., (ND). What went wrong and what can we learn from it? Memorial University of Newfoundland.

Rumboldt, M. (2005). Harp Seal Distribution, Consumption Patterns and Impact on Groundfish Stocks (Term Paper: Fisheries Ecology 6001 - 2005).

Ryan, S. (1990). The Newfoundland Cod Fishery in the Nineteenth Century: Is there anything to be learned?

Scott, W.B., and Scott M.G. (1988). Atlantic Fishes of Canada. Can. Bull. Fish. Aquat. Sci. 219.

Shelton, P.A., Mace, P.M., Brodie, W.B., and Mace, J.-C. (2003). A Proposal for a More Flexible Framework for Implementing the Precautionary Approach on NAFO Stocks. NAFO SCR DOC 03/58.

Sinclair, P. (1985). From Traps to Draggers. St. John's. Institute of Social and Economic Research, Memorial University of Newfoundland.

Smedbol, R. K., and Wroblewski, J. S., (2000). Metapopulation Theory and Northern Cod Population Structure: Interdependency of Subpopulations in Recovery of a Groundfish Population. Canadian Stock Assessment Secretariat, Fisheries and Oceans, Canada.

Steele, D. H., Andersen, R., and Green, J. M. (1992). The Managed Commercial Annihilation of Northern Cod.

Terra Nature Trust (2004). Rough seas for orange roughy: Popular U.S. fish import in Jeopardy. Retrieved from the World Wide Web October 2005: http://www.terranature.org/orange_roughy.htm.

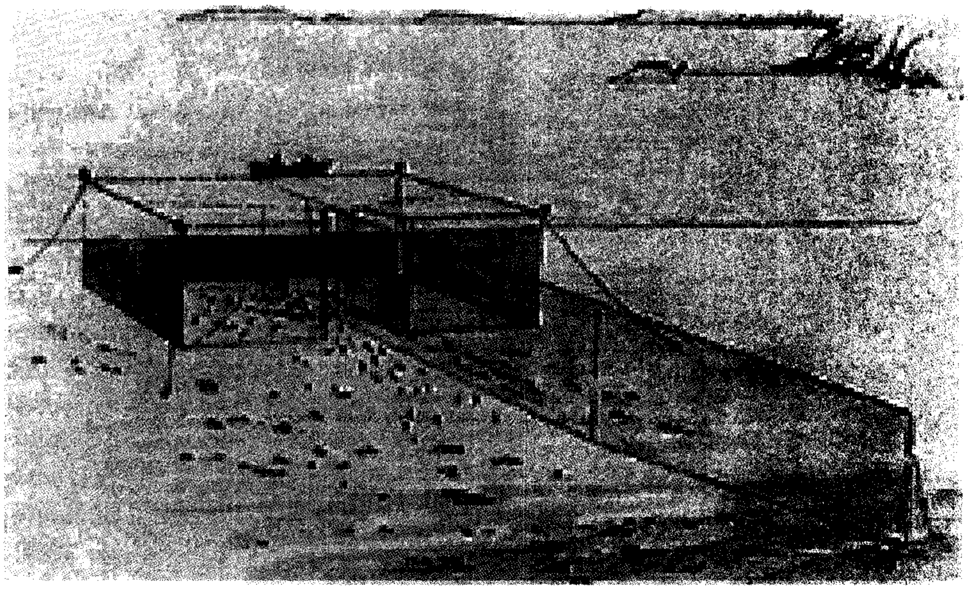
Vasconcellos, M., Heymans, S., and Pitcher, T. J. (2000). Historical Reference Points for Models of Past Ecosystems in Newfoundland. UBC Fisheries Centre.

Underwater World: Atlantic Cod. (2004). Department of Fisheries and Oceans, Ottawa.

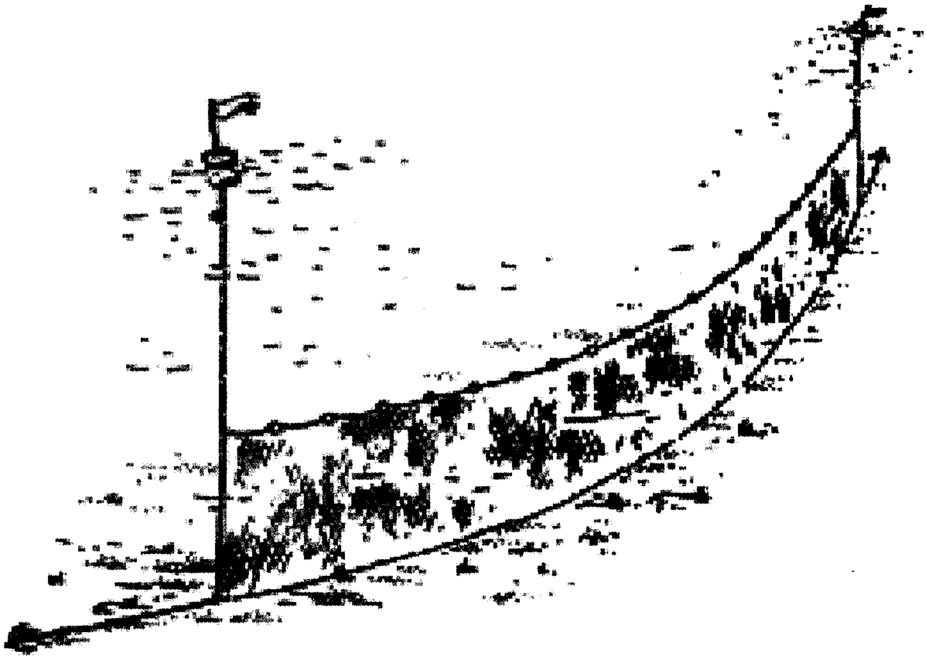
Walsh, P., and He, P. (2000). Design and Evaluation of Cod Pots for the Newfoundland Inshore Fishery. Phase II: Preliminary Sea Trials of Cod Pot in St. George's Bay, May 2000.

Winters, G. H., and Miller, D. S., (1998). A Simulation Model of the Response of Harp Seals to Alternative Harvesting Strategies. Government of Newfoundland and Labrador.

Appendix A: Fishing Gear



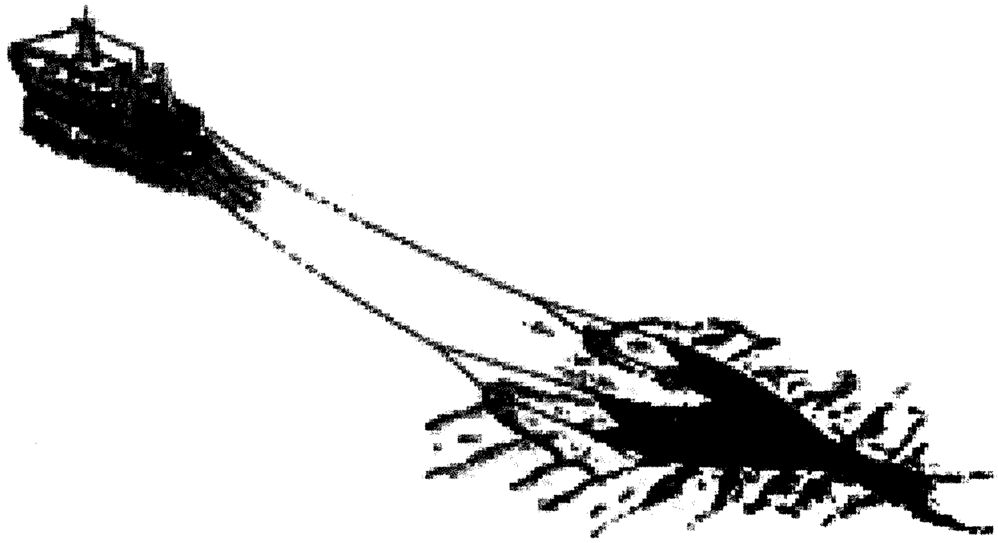
Cod Trap



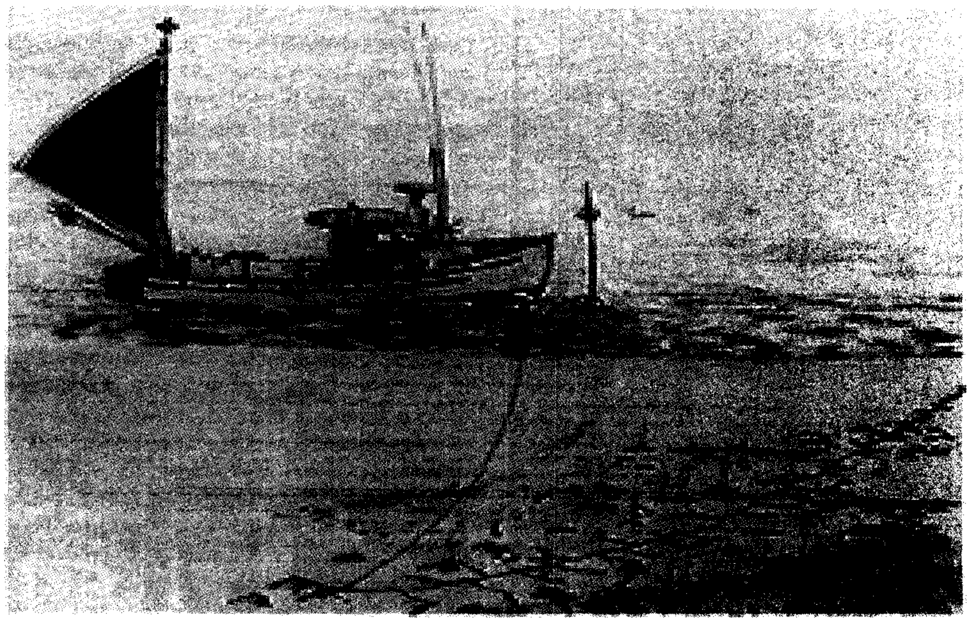
Gillnet

Source: DFO

Otter Trawl



Longline



Source: DFO

Appendix B: Historical Northern Cod Catches, 1932-1995

Historical Northern Cod Catches					
Year	Inshore	Off NF	OFF other CDN	Foreign	Canadian
1932	284,558			84,600	284558
1933	280,123			85,520	280123
1934	305,952			86,440	305952
1935	300,863			87,360	300863
1936	295,775			88,280	295775
1937	223,171			89,200	223171
1938	271,139			90,120	271139
1939	247,337			91,040	247337
1940	221,726			91,960	221726
1941	217,158			92,880	217158
1942	187,873			93,800	187873
1943	244,537			94,720	244537
1944	276,059			95,640	276059
1945	291,165			96,560	291165
1946	294,096			97,480	294096
1947	305,280			98,400	305280
1948	257,197			99,320	257197
1949	263,688			100,240	263688
1950	236,921			101,160	236921
1951	248,611			102,080	248611
1952	200,000			103,000	200000
1953	200,000			103,920	200000
1954	199161			104,845	199161
1955	169283			94,625	169283
1956	183033			117,386	183033
1957	162363			113,368	162363
1958	114376			102,702	114376
1959	159,492	2,259	2,256	195565	164007
1960	157,286	2,544	4,863	294104	164693
1961	119,363	2,499	2,177	374039	124039
1962	138,511	1,568	2,605	359858	142684
1963	144,548	2,963	1,484	360214	148995

1964	131,328	6,849	3,340	461152	141517
1965	110,527	5,575	1,789	427134	117891
1966	110,843	6,571	1,734	405357	119148
1967	101,859	11,786	1,834	496285	115479
1968	101,037	20,203	2,100	686694	123340
1969	97,224	16,453	1,908	638125	115585
1970	76,588	12,700	1,864	429075	91152
1971	62,539	10,891	1,116	364972	74546
1972	62,052	4,010	377	391856	66439
1973	41,648	2,279	35	310372	43962
1974	35,181	939	8	336570	36128
1975	41,213	688	587	245026	42488
1976	59,939	2,834	218	151229	62991
1977	72,623	5,699	691	93159	79013
1978	81,455	18,673	2,283	36182	102411
1979	85,822	35,569	9,252	36120	130643
1980	96,523	42,705	8,330	28230	147558
1981	80,038	55,353	11,644	23677	147035
1982	113,049	69,454	25,003	22268	207506
1983	106,423	80,448	27,581	17892	214452
1984	97,721	76,939	31,549	26262	206209
1985	79,883	82,214	30,550	38646	192647
1986	72,369	89,137	28,846	61154	190352
1987	78,747	94,010	26,631	35622	199388
1988	101,035	112,369	28,466	26807	241870
1989	102,869	83,294	28,513	38748	214676
1990	112,533	65,626	12,501	28028	190660
1991	74053	50827	8100	24782	132980
1992	6252	11780	2700	7523	20732
1993	3943	1	8	161	3952
1994	1303			0	1303
1995	160				160

Source: DFA