Royal Commission on Renewing
and Strengthening Our Place in Canada

Fisheries Resources and Science in Newfoundland and Labrador: An Independent Assessment

By:
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The views expressed herein are solely those of the author and do not necessarily reflect those of the Royal Commission on Renewing and Strengthening Our Place in Canada.

Abstract

The fisheries in Newfoundland and Labrador waters began in the early 1500s, were prosecuted mainly for Atlantic cod (*Gadus morhua*), and increased markedly, and unsustainably, in the last half of the 20th century. The terms of union of Newfoundland with Canada relinquished full authority for research and management of the marine fisheries to the Government of Canada in 1949. Since then, a combination of circumstances which included the inability to control foreign and domestic fisheries, inadequate science, inappropriate policies, ineffective management, and the inability to react to local environmental and fisheries conditions and knowledge, has led to a major decline in the status of most fish stocks in the Newfoundland and Labrador marine ecosystems, and most recently to a regime shift to a crustacean-dominated biological community. The best known example of decline is the northern Atlantic cod, but this is only one of many species that is likely at all time historic low levels of abundance, including potentially valuable commercial species such as the redfishes (*Sebastes spp*.), the haddock (*Melanogrammus aeglefinus*), and the American plaice (*Hippoglossoides platessoides*), pelagic fishes, especially capelin (*Mallotus villosus*), and also species of lesser or no commercial importance. In the early years of the 21st century, the fishery has become dependent on snow crab (*Chionocetes opilio*) and northern shrimp (*Pandalus borealis*). Increased abundance in these species during the 1990s comprises a marine ecosystem regime shift likely caused by a change in oceanographic climates compounded by a reduction in predators, in particular cod. The state of fisheries science at the federal and provincial levels is inadequate to diagnose such ecosystem states and to support sustainable and durable fisheries. During the 1990s, the federal government substantially reduced funding and personnel for fisheries research, and there is no overall plan for future fisheries, especially the historically important northern cod and Grand Banks fisheries. Fisheries science at Memorial University remains a minor undertaking, despite the history, culture, and economy of the province it serves. A number of recommendations are made to enhance the abilities of Newfoundland and Labrador to renew and strengthen its position within Canada. Recommendations under local jurisdiction include the development of a Newfoundland and Labrador Fisheries Science Centre at Memorial University. Other recommendations that involve external co-operation include actions aimed at adopting a world leadership position in conservation and fisheries for the Newfoundland and Labrador marine ecosystems. To this end, the Government of Canada should be urged to reform its fisheries science program within an independent Northwest Atlantic Fisheries Research Institute based in St. John’s, to restore funding and research vessels, and to engage an ecosystem-based approach to fisheries science and management by taking custody of the full Grand Banks ecosystem, protecting spawning and juvenile areas by closures to all fishing and industrial exploration, and protecting forage species, in particular capelin. Finally, Newfoundland and Labrador should develop its own vision of its own future in the fisheries, a successor to the FRCC should be given broader fisheries ecosystem authority, and local operational authority and responsibility for fisheries by primary stakeholders within fishing communities should be enhanced.

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Terms of Reference

The terms of reference for this review were to provide an overview of:

1) the nature and extent of the renewable resources in waters adjacent to Newfoundland and Labrador (NAFO areas 2GH, 3KLMNOP, 4R);
2) chief factors influencing stock biomass, population dynamics and resources available for harvesting;
3) what is known about the causes and effects of the collapse of the northern cod and other species (e.g. capelin, but selecting only key cases to illustrate trends);
4) current scientific effort used to assess fisheries resources, and the process by which scientific knowledge and judgement is applied to resource management decisions;
5) any other information and analysis considered pertinent to the task of assessing and regulating sustainable fisheries resources;

and to,

6) draw conclusions and recommendations about the significance of recent knowledge about fisheries science for Newfoundland and Labrador's continuing place within Canada and its ability to renew and strengthen that relationship.

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Summary of Recommendations

Fisheries science remains poorly developed in Newfoundland and Labrador, at both the federal and provincial levels. A strengthened fisheries science presence in Newfoundland and Labrador is fundamental to the development and future of the fisheries, and to an improvement in the position of this province to renew and strengthen its relationship within Canada. The following recommendations stem from this report:

1. that Memorial University establish an academically-based Newfoundland and Labrador Fisheries Science Centre, with fisheries faculty taking an ecosystem-based research approach to oceanography, stock assessment, and groundfish, pelagic, and crustacean fisheries science;
2. that a course on the history and culture of Newfoundland and Labrador be made mandatory in the Newfoundland and Labrador high school curriculum;
3. that Newfoundland and Labrador, in consultation with the public and industry, develop a focused vision for marine fisheries ecosystems and their biological, economic and social dimensions, with firm objectives to be included in a master plan;
4. that Newfoundland and Labrador urge the Government of Canada to reform federally-funded fisheries science into independent Institutes of Fisheries Research (in Newfoundland and Labrador, the Northwest Atlantic Institute of Fisheries Research), that would be independent of management, and that science vessels be reinstated under their control and that their number not be reduced further;
5. that in order to pursue "ecosystem-level" science, in keeping with Canada's commitments under recent international agreements to rebuild depleted fish stocks, and to enhance the abilities of fisheries science to inform management on options for a sustainable and enduring fishery in Newfoundland and Labrador waters, several specific actions are recommended:
    a) unified management of the Grand Banks be pursued that would bring science, management and enforcement of the full coastal and Banks ecosystem under a single and more rational program than currently exists;
    b) that long-term marine ecosystem management plans be developed (preferably by the FRCC or its successors), which would include at least the following:
        - **i.** determinations of conservation-based harvest levels within the ecosystem context,
        - **ii.** recognition of the climate-based nature of the fisheries and potential for change over time,
        - **iii.** rebuilding collapsed stocks and ecosystem processes,
        - **iv.** allocation of rebuilding groundfish resources and appropriate gear types (e.g. inshore versus offshore fishery; abolition of destructive fishing practices),
        - **v.** appropriate scientific monitoring to inform an ecosystem-based approach to management (e.g., surveys of multiple trophic levels),

vi. a system of limited or no-take fishing and oil and gas exploration and development zones to protect habitat and spawning and juvenile fish,

vii. closure rules for unsustainable or uneconomic fisheries (e.g., capelin),

viii. habitat protection and restrictions against pollution (both land and sea based).

c) that an Atlantic Fisheries Conservation Board be set up to replace the current Fisheries Resource Conservation Council. The AFCB would have responsibilities for all fisheries resources, would be comprised of independent experts from industry and governments, including several full-time scientific employees (seconded or retired), would take an “ecosystem” approach, and would advise management directly. The AFCB would report to the federal minister only for administrative purposes.

d) that locally-based fisheries councils be set-up that are close to the fisheries, involve local expertise, and can take responsibility for designated local management and enforcement functions such as bycatch allocation, seal control, and methods to limit poaching and enhance conservation.

Introduction

Newfoundland and Labrador marine ecosystems form part of the wider North Atlantic large marine ecosystem (Sherman and Skjoldal, 2002) (Fig. 1). The Newfoundland and Labrador marine ecosystems are characterized by a wide and relatively shallow continental shelf transected in places by deeper trenches. Ocean circulation is dominated by the southerly flowing and very cold (to –1.7^{0}C) Labrador current, which results in seasonally highly stratified water columns off most of the northeast coast, and to the south, strong fronts caused by intersection of the Labrador current with the northeastward flows of the warm Gulf Stream off the southern Grand Banks. This combination of broad continental shelf, steep shelf breaks and adjacent deeper waters, and strong but divergent flows, has made much of this region highly productive. However, the northern reaches of this ecosystem, off northern Labrador, are near the northern extremes of the distribution of many of the most abundant commercial fishes such as Atlantic cod (*Gadus morhua*), the redfishes (*Sebastes spp*.), and haddock (*Melanogrammus aeglefinus*), and productivity (growth and reproduction) is typically at the low end of the range for these species.

The North Atlantic is a young and productive ocean, at present broadening slowly with the drift of the continents, and hence is biologically poor in species number but rich in biomass. Since the last ice age, which receded approximately 10,000 years ago, the dominant fishes in most continental shelf regions were likely capelin (*Mallotus villosus*) and cod. The historical abundance of each of these species was likely of the order of 2-4 million metric tonnes (t) (perhaps higher for capelin). The dominant marine mammal was the harp seal (*Phocus groenlandica*), whose recent population has been approximately 5-6 million animals. There is a decline in species composition from northern Labrador to the Southern Grand Banks. The only abundant large gadoid in the north is Atlantic cod, but in the southern regions, haddock were formerly common. Capelin dominates the pelagic fish community over most of the Newfoundland ecosystem, and is the major forage species for fish-eating fishes, marine mammals and seabirds. The seasonal migration and distribution patterns of many of these fish-eaters likely developed and became vitally linked to the patterns of the capelin. It is difficult to overstate the ecological importance of the pelagic fishes, particularly the small silvery capelin. In the southern regions of the Grand Bank and in the region off the South Coast of Newfoundland, capelin give way to another major pelagic species, the sand lance (*Ammodytes dubius*), and to the north off Labrador, there are Arctic cod (*Boreogadus saida*). Atlantic herring (*Clupea harengus*) form a dominant component of the pelagic fish biomass in more southerly regions, and in the warmer Icelandic and Norwegian Seas, but the waters on the Grand Bank and Northeast Coast are too cold for herring to reach such abundance. The dominant crustaceans are snow crab (*Chionoecetes opilio*) and pandalid shrimp (*Pandalus spp*.). In ecological terms, the Newfoundland and Labrador marine ecosystems are simple high-latitude systems, characterized by relatively few species, direct and short food chains, and high levels of abundance and biomass.

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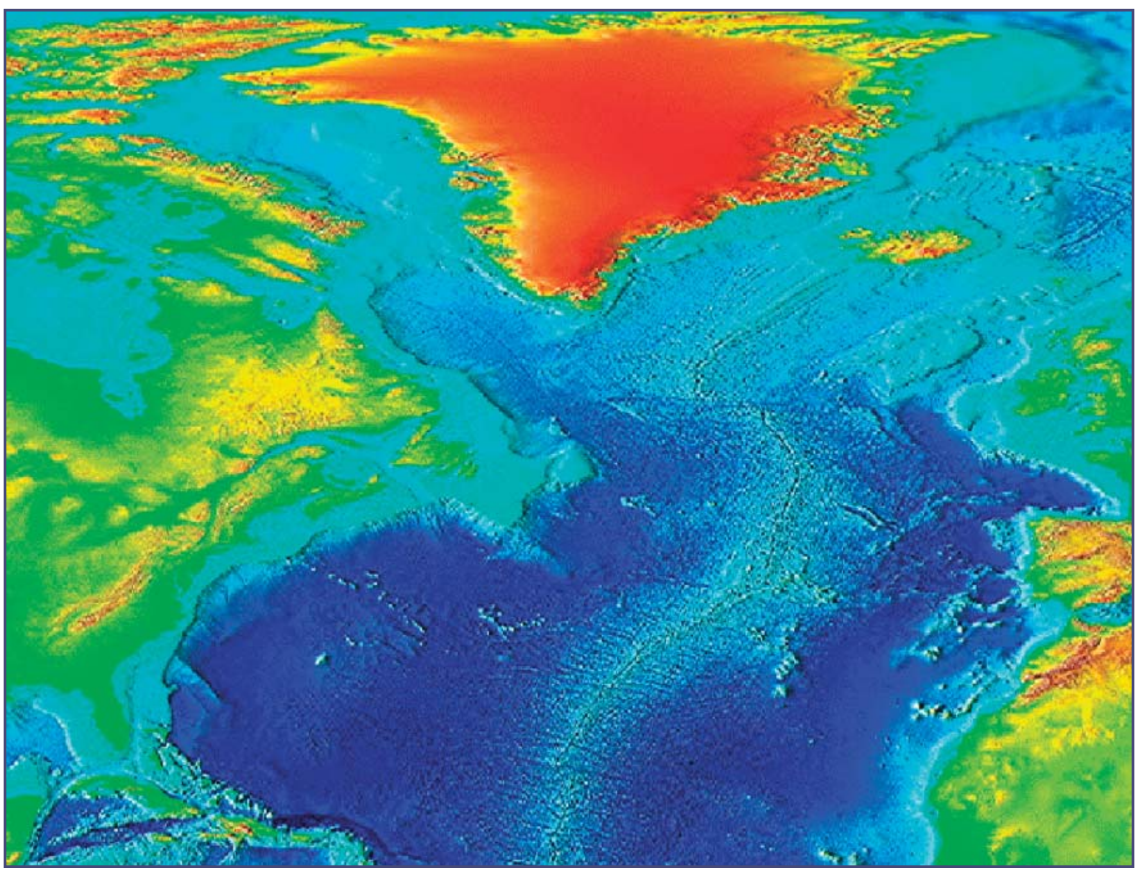
A Brief History of the Newfoundland and Labrador Fisheries

Fisheries in Newfoundland and Labrador coastal waters were prosecuted for the past nine thousand years on a subsistence level by a succession of native North American peoples (Major, 2001). Their harvests were almost all along the coastline, and most of their catch was likely Atlantic salmon (*Salmo salar*), Arctic char (*Salvelinus arcticus*), and marine mammals. After the early Norse explorations of the 10th and 11th centuries, it was not until the mid-late 15th century that the first persistent commercial fisheries were prosecuted by Basques in the form of seasonal fishing and whaling stations (the best known being Red Bay, Labrador). Portuguese, French and English adventurers followed, in search of adventure, marine resources and the Oriental spice trade. What they found were enormous shoals of Atlantic cod in the coastal waters around Newfoundland, and this “discovery” led to the modern European era of the cod fishery. By the late 15th century, the Newfoundland cod fishery had become a predominant economic activity in the northwest Atlantic that would be sustained for nearly 500 years (Innes, 1940; Cushing, 1988; Harris, 1990; Hutchings and Myers, 1995).

Figure 1.
The Northwest Atlantic Large Marine Ecosystem
(and the mid-Atlantic to the south).



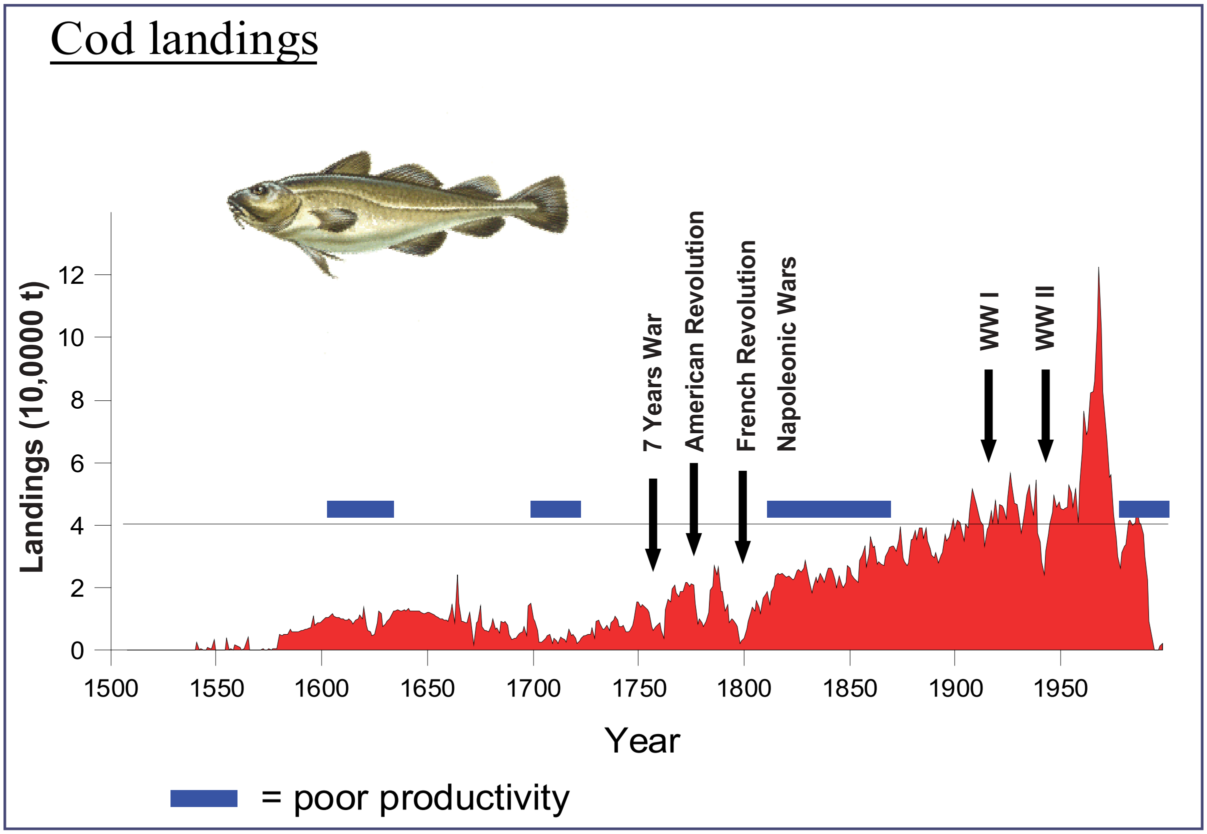
Cod were initially caught with single baited lines, then multi-hooked baited long lines or bultows, with these methods changing little until the 19th century. In the first three centuries of this modern fishery, the main limit on catch was likely to have been effort, whose main regulator may have been the vagaries of European politics (Fig. 2). These included the national policies and wars of France, England, Spain, and the emerging United States and Canada, but also on local responses to various political events. As late as the 19th century, a key restraint was the provision of bait, mostly Atlantic herring (*Clupea harengus*), but also capelin and Atlantic mackerel (*Scomber scombrus*). Provision of bait was used by English authorities to limit the French fisheries which relied on it (Prowse, 1895). During the late 19th century, the introduction of new gear that did not use bait, in particular the cod-trap, changed this situation. Initially, many wanted to ban the trap, which was thought to be too efficient and would destroy the cod. The 19th century also ushered new fisheries into this ecosystem, in particular for harp seals, and the numbers of people that settled in Newfoundland and were dependent on the fishery steadily increased.

The 20th century brought changes to society and the fisheries scarcely imaginable a century earlier (e.g., Hutchings and Myers, 1995). Vessel changes from sail and oar to steam then diesel, and rapid introductions of side and pair trawlers, stern otter trawlers, cotton and then mono-filament gill-nets, and Japanese cod-traps, led to extravagant increases in fishing power. In the last half of the 20th century, the traditional Newfoundland cod fisheries declined precipitously after an onslaught of fishing by newly arrived European-based trawlers in the 1950s and 1960s. At the same time, new technologies and changing markets spurred new fisheries. Former subsistence and bait fisheries for herring and capelin were greatly increased as reduction[1] fisheries for fish meal. Fisheries for redfish, haddock, and flatfishes increased as markets for fresh fish displaced salt fish, which had been the sole product of the Newfoundland and Labrador fisheries for hundreds of years. In the 1970s, political pressures led to the closures of the traditional fisheries for marine mammals (seals and whales). Cod continued to decline, and moratoria on cod fisheries were in place in all Canadian Newfoundland waters by 1993 (Rose et al., 2000). Entirely new fisheries were developed on burgeoning populations of shrimp and snow crab, and these prospered in the 1990s.

The Cod Fisheries

The Newfoundland cod fishery began in earnest in the mid-16th century (Fig. 2). The early rise in the fishery can be attributed mostly to the French, whose vessels almost certainly outnumbered those of England and Portugal for many years (Major, 2001). Catches increased rapidly in the last quarter of the 16th century to levels exceeding 100,000 t per annum. Despite numerous French and English disputes, the razing of St. John’s and many other English settlements in the late 17th century, and a general lack of support for settlement by either side, catches remained around 100,000 t for much of the 17th century. However, in the early 1700s, catches declined for a period of almost two decades, in concert with severe cooling of the ocean (Innes, 1941). The cod fisheries had collapsed, and resulted in the first massive out-migration of Newfoundlanders as a consequence of a failing fishery (Major, 2001). During the latter half of the 17th century, there began an increasing trend in landings which generally continued until the mid-20th century. Catches peaked in the mid-1960s at over 1 million t per year. For over 200 years annual catches had exceeded 200,000 t. **In total, approximately 100 million t of cod have been taken from Newfoundland waters since 1500. It is of great significance that approximately one-half of the 100 million t was taken between 1500 and 1900, the other half between 1900 and 1993.** Cod stocks declined abruptly in the 1970s, and after a brief respite, declined again in the 1980s and 1990s. Stock levels were almost certainly at their all-time low in the mid-1990s even after all fisheries were closed in 1993. The southern Newfoundland fishery (3Ps) reopened in 1997 with a quota of 10,000 t, and currently has a quota of 15,000 t. The northern cod (2J3KL) has had a very limited index fishery since 1999, with a quota of 5,500 t in recent years. The northern Gulf cod (3Pn4RS) has had a similar fishery of 7,000 t in recent years. The Grand Banks cod (3NO) is still under moratorium.

Figure 2.
Newfoundland and Labrador cod landings from 1500 to 2000 (equivalent to fresh landed weights). See Appendix I for data sources.



From 1500 to 2000, variations in the cod landings can be attributed to several factors. The rises and falls of the cod harvest in historic times were likely unrelated to any large-scale depletion (Pope, 1995). No doubt local variations in landings occurred, likely resulting from year-to-year changes in cod movements and distributions, and perhaps some localized depletion. However, most of the fluctuations can be attributed to other human activities and circumstances, such as wars, market changes and politics, or ocean climate changes that influenced either availability or productivity or both. The chronology of European and

American wars is evident in the catch series, with major declines corresponding to the 7 Year War, the American Revolution, the French Revolution and Napoleonic Wars, and WWI and II (Fig. 2). Environmental influences on productivity are also evident. The poor catches of the early 1700s coincided with very cold conditions across northern North America (D'Arrigo and Jacoby, 1992) (Fig. 2). All of the "cold" periods of the past 500 years coincide with periods of reduced or non-increasing landings relative to other factors known to influence landings (the mid-19th century shows stable landings but this was a period of great increase in settlement and fishing effort, see Sette, 1929; Mannion, 1990; Hutchings and Myers, 1995).

Although stock abundances cannot be inferred directly from the cod landings data, there is little evidence in historical times to suggest either growth or recruitment overfishing.[2] However, beginning in the 20th century it is likely that both types of overfishing occurred, and this is particularly the case following the huge harvests of the 1960s. Although there is only a single event of this magnitude in history, and hence any statistical arguments are groundless, the subsequent decline in landings inarguably related to those high harvests (e.g., Rose et al., 2000; Rice, 2002).

The influence of technology on the landings history is easy to describe but difficult to quantify. Technology changed little from the 16th to 19th centuries. The introduction of the cod trap in the late 19th century may have contributed to the more stable landings of the first half of the 20th century, but this was also a period of high productivity (Fig. 2). The situation is clearly complex and there is no single factor that can account for all catch variation. Although we cannot assume that catch relates directly to abundance, there is evidence that catch did relate to availability of cod to the largely coastal fishery in some periods (e.g., early 1700s). However, the dominant peak in cod catch in the 1960s can be attributed with some authority to the advent of factory trawlers in Europe and their arrival in Newfoundland and Labrador waters. As a direct consequence of this new and unsustainable fishery, more than 5 million t of cod were taken during the 1960s alone.

The reconstruction of the historical catches contains several uncertainties. In general, the farther back in time, the greater the uncertainty. Catch records prior to the late 17th century are sporadic and hence should be considered rough estimates only. However, the present series suggests relatively large catches as early as the 17th century. In contrast, Hutchings and Myers (1995) derived a catch series for northern cod that suggests that catches were comparatively low (averaging <10,000 t) throughout the 17th century. However, Cushing (1988) suggested that annual catches in Newfoundland waters in the late 1600s were of the order of 200-250,000 t. Pope (1995) also suggested that catches were of the order of hundreds of thousands of tonnes between 1660 and 1700, and disputed the data compiled by Hutchings and Myers (1995). The series compiled here from the English and French fisheries is in close agreement with the higher estimates given by Pope (1995) and Cushing (1988) for specific years of the late 17th century. There is more general agreement that the catches of the early 1700s were very low. Conditions for people dependent on the cod fishery in northeastern Newfoundland were desperate in the 1710s (Innes, 1940). Cod fisheries also failed in the winters of 1714-15 in northern Norway with similar effects on fishing communities (Clarke, 1967).

Pulse Fisheries and Commercial Extinctions

Commercial extinction of a species or local stock occurs when it is no longer economically worthwhile to fish. This is not true or biological extinction, but rather occurs at higher population levels and is dependent on the economic conditions of the fishery. Haddock was commercially extinct by 1960 in Newfoundland waters. Once abundant populations in the southern regions were reduced to remnant states that have not regained their former abundance and support no fishery (Fig. 3). There remains a tendency in the fishing industry to conduct pulse fisheries that target relatively strong year-classes whenever they occur, fishing them down to a state of depletion, foregoing any opportunities for these stocks to rebuild. Such strategies are not in the interests of conservation, but appear common in Atlantic Canada. The recent strong year classes of “dwarf” haddock (poor growth) on the eastern Scotian shelf in an ecosystem that has undergone dramatic declines in productivity, have been subject to recent industry lobbying to “get them now”, and hence repeat cycles of pulse fishing, with little allowance for rebuilding.

The redfishes also became commercially extinct in the northern ranges off Labrador and the northeast Newfoundland shelf in the 1960s (witness the spike just prior to the cod spike, Figs. 3,4). This was almost entirely a Russian fishery (Trevin and Panechuk, 1963). There has been no recovery. Southern populations have fared somewhat better, but population and catch levels are still thought to be relatively low, and the single remaining population of *Sebastes mentella* has not been bolstered by any significant recruitment since 1980.

Herring was fished for food and bait for centuries, and data recording this goes back well into the 19th Century (Fig. 3). Catch levels never exceeded 25,000 t and were apparently sustained. However, the reduction fisheries of the 1960s led catch levels upwards to > 100,000 t per annum, with a peak of over 150,000 t in 1968. Since then, herring have not become commercially extinct in all areas, but catch levels are well below those of historical times.

Extinctions

Two sea birds have become extinct during the period of European-based fishing activities. The Great Auk was slaughtered for eggs and food without restraint by explorers and fishing parties at its nesting grounds, particularly at Funk Island off the Northeast Coast of Newfoundland. By the mid-1800s, the Great Auk was extinct in these waters, with total extinction being perpetrated in Iceland some years later. The Labrador duck was last observed in New York state in 1878, presumably on its southern migration. No fishes or marine mammals have become extinct.

Figure 3. Landings of all species in Newfoundland and Labrador from 1500 to 2000 (landings in 100,000 t).

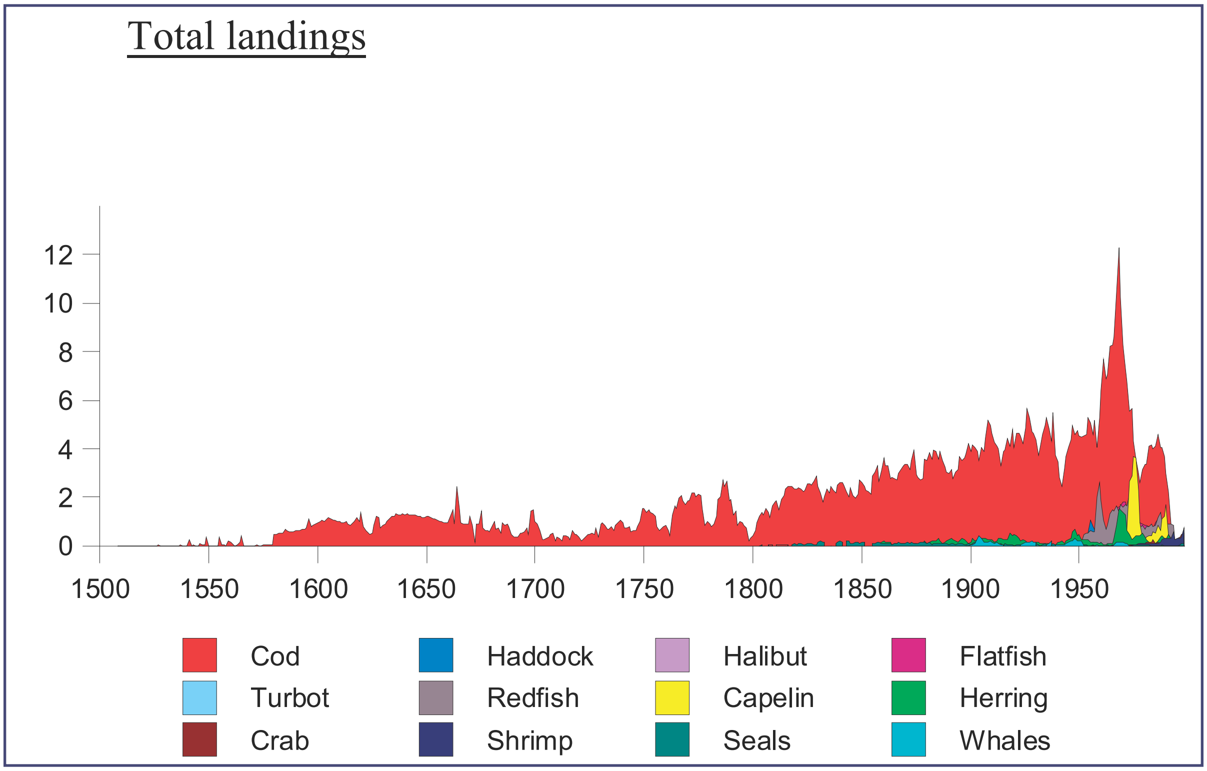
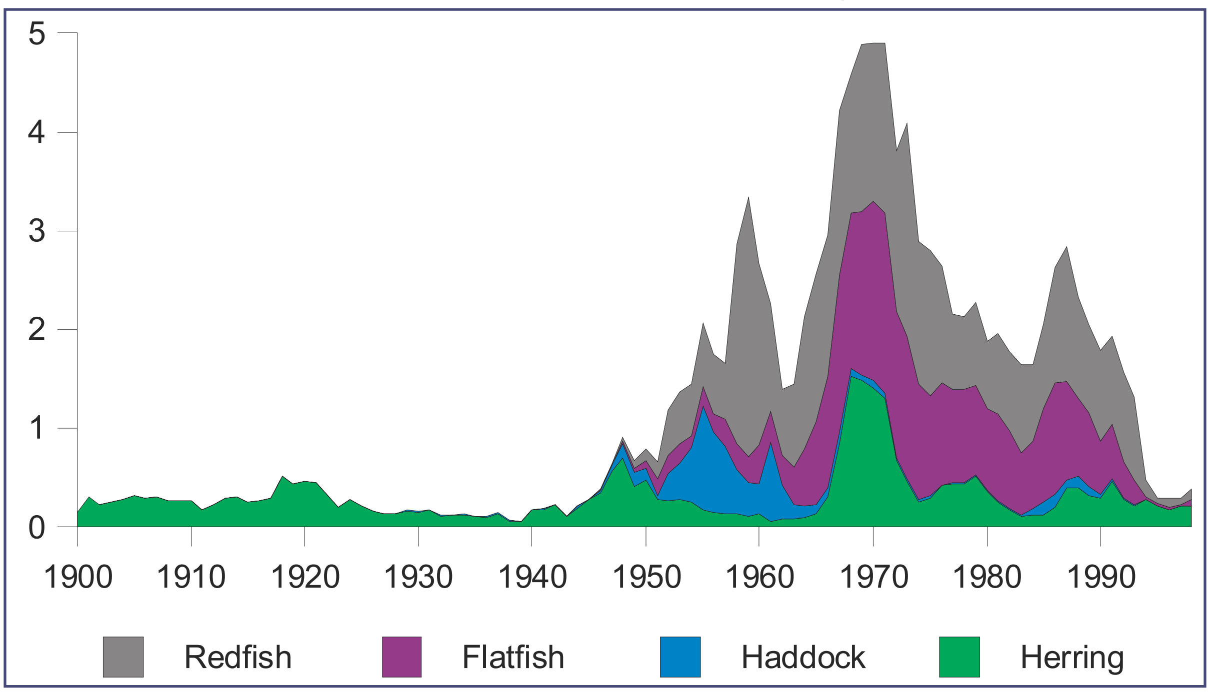


Figure 4. Landings of species newly or pulse-fished in the 20th century in Newfoundland and Labrador waters (landings in 100,000 t).



Other Historical Fisheries

Seal harvest data have been recorded beginning in the early 19th century at the commencement of the commercial hunt (Figs. 4,5). Seal harvest peaked in the mid-19th century at approximately 600,000 animals and declined thereafter until 1972, when a moratorium was imposed on the seal hunt. Since reopening the hunt in the late 1990s, the Newfoundland catch has risen to approximately 300,000 animals.

Whales were commercially harvested from Newfoundland and Labrador whaling stations beginning in 1898 (Fig. 3). The total catch fluctuated greatly until a ban on whaling in 1972.

Catches of capelin were historically very low in Newfoundland waters. The annual subsistence harvest was likely no more than 20,000 t for human consumption and fertilizer (likely 0.01-0.02 per cent harvest rate based on an historic abundance of 1-2 million t). However, during the 1960s and 1970s, the Russian catch increased dramatically, with a peak in the mid-1970s of over 350,000 t (Fig. 3). Capelin fisheries have declined in the 1990s in concert with very poor growth and marked deviations in capelin distribution to the south (Frank et al., 1996; Carscadden et al., 2000). The present fishery is market driven and recent markets have been poor (five cents per pound in 2002).

Fisheries for pandalid shrimp and snow crab are not historical fisheries in Newfoundland and Labrador. These fisheries began only in the late 1960s and 1970s and have since increased substantially. Landings have increased to more than 70,000 t for shrimp and 50,000 t for crab in the late 1990s.

Fisheries Yield

Overall yield from this ecosystem generally increased until the mid-20th century and since then has been steadily declining (Fig. 6). The composition of the yield changed from historical exploitation of the upper trophic levels (seals and cod), with minor bait and food fisheries for capelin and herring, to mid-trophic levels in the mid-20th century (cod, haddock, flatfish, redfish), to lower trophic levels and pelagic and demersal planktivores and detritivores in the late 20th century (herring, capelin, shrimp, and crab). In the 1990s, shrimp and crab comprised over 60 per cent of the total yield. At present, total yields are less than half of historical long-term averages over the period from 1750 to 1950.

The Newfoundland and Labrador ecosystems have been subjected to a version of “fishing down the food web” (Pauly et al., 1998), although in this case it appears to be more a “fishing out the middle”. Such reduced ecosystems may decline in robustness, to environmental and human perturbation.

Figure 5. Seal landings in Newfoundland and Labrador from 1500 to 2000 (landings in 100,000 seals).

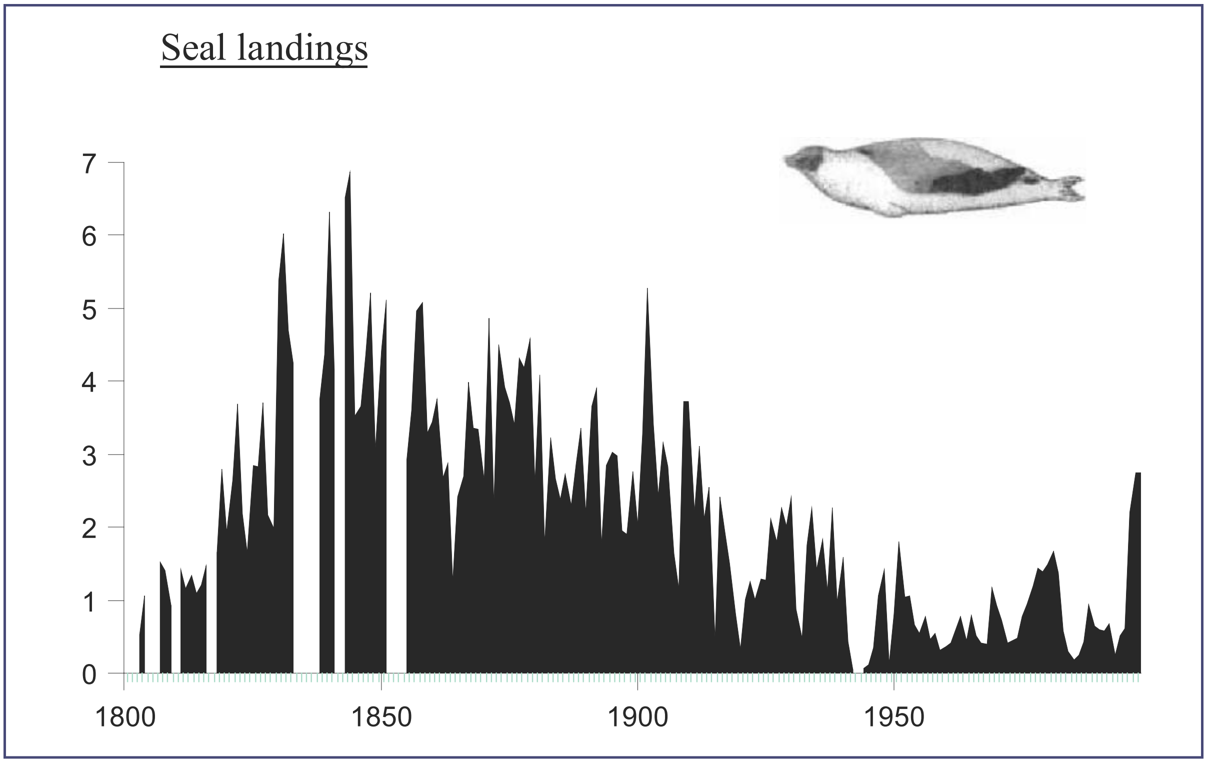
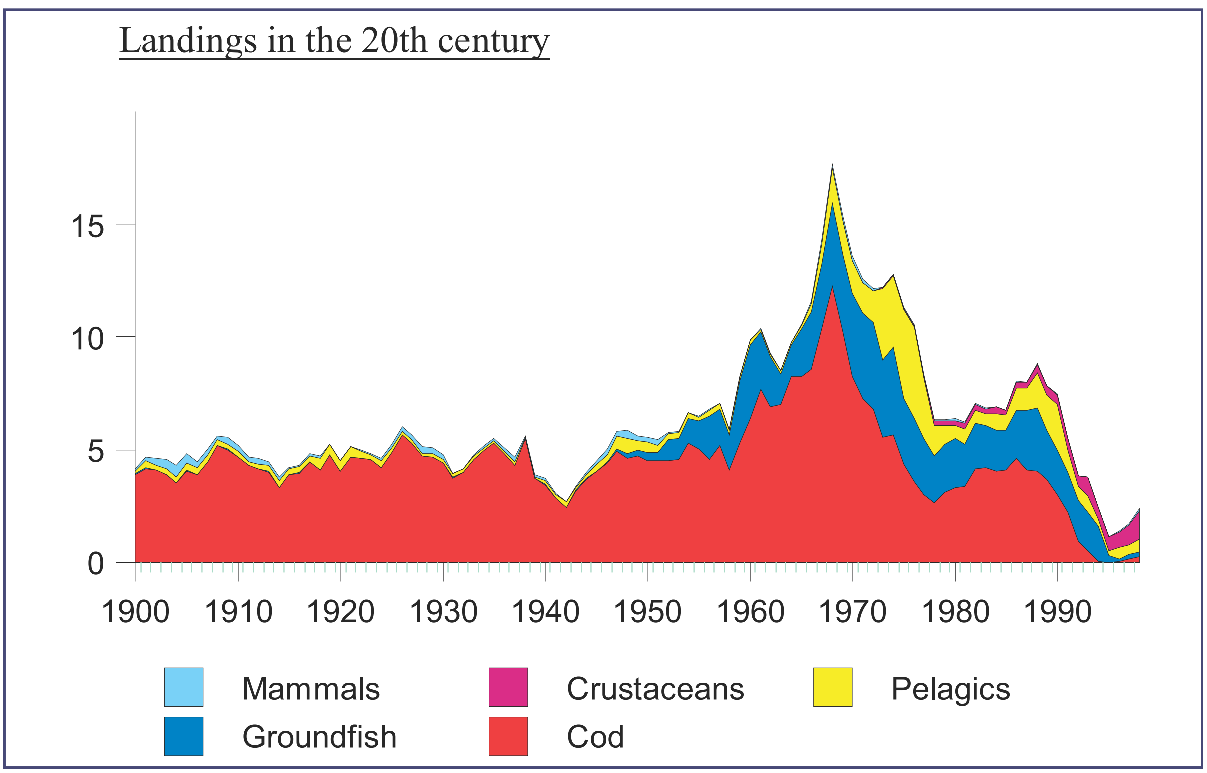


Figure 6. Newfoundland and Labrador landings from 1900 to 2000 (landings in 100,000 t).



The decline of the Newfoundland cod stocks and other species

There are four cod stocks in Newfoundland and Labrador waters. Most, if not all, are comprised of biologically distinguishable sub-stock components (Fig. 6). The four stocks are:

1. NAFO subdivisions 2J, 3K, 3L, the "Northern" cod
2. NAFO subdivisions 3N, 3O, the "Grand Banks" cod
3. NAFO subdivision 3Ps, the "South Coast" cod
4. NAFO subdivisions 3Pn, 4R (and 4S adjacent to Quebec), the "Northern Gulf" cod.

The Newfoundland cod stocks are not a single monolithic biological entity but are comprised of many biological sub-units of this species that have evolved with varying degrees of separation to local environmental conditions (Templeman and Fleming, 1962; Templeman, 1974; 1981; Lear, 1984; 1981; deYoung and Rose, 1993; Taggart et al., 1994; Brander, 1994; Ruzzante et al., 2001; Robichaud and Rose, 2001; 2002; Beacham et al., 2002). The NAFO-based management areas represent these units only roughly. Within most of the management areas there are or were several sub-units, some of which may have been over-fished in historical times. However, the major over-fishing of the cod stocks took place in the last half of the 20th century, and this coincides almost exactly, although coincidentally, with Newfoundland confederation with Canada. The increasing over-fishing and decline of the northern cod is the best known example of this 20th century debacle, but it is by no means the only one.

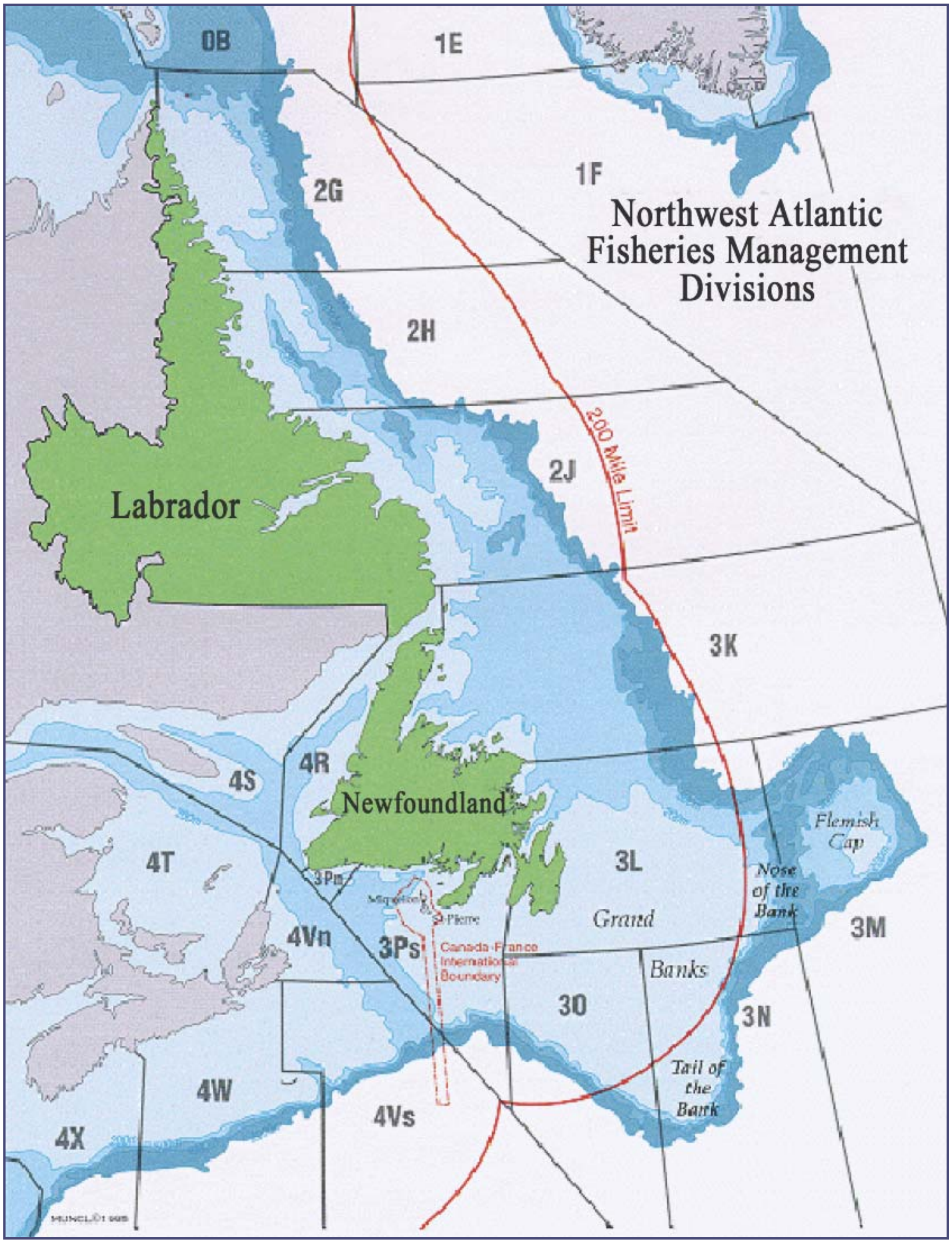
All Newfoundland and Labrador cod stocks declined in the late 1980s and early 1990s, although to differing extents. The 3Ps stock rebuilt relatively quickly in the 1990s, and currently has strong prospects for growth (SSR, A-02, 2002). The other stocks have shown disparate levels of lesser rebuilding. The northern Gulf of St. Lawrence stock enjoyed modest population growth despite elevated natural mortality, poor individual growth and poor recruitment over most of the 1990s (SSR, A4-01, 2002), but may have since declined. The northern cod overall remains at very low levels (1-3 per cent of historical levels), although the coastal substock component in Trinity and Bonavista Bays grew and recruited reasonably well despite high adult mortality with relatively strong year-classes in 1990 and 1992 (Rose, in press). The Grand Banks cod remain in a highly depressed state. The northern cod was by far the largest cod fishery in Canadian waters prior to the 1990s and hence this report will focus on that stock.

The Causes and Effects of the Decline of the Northern Cod

For 450 years, the northern cod fishery was a seasonal enterprise and largely restricted to coastal waters within sight of land. This was true of most Newfoundland and Labrador fisheries, with the exception of the Grand and St. Pierre Banks cod fisheries, where very shallow waters well offshore enabled handline fishing. Weather, gear and nature dictated conservation. However, after the Second World War, and the advent of large ocean-going factory freezer trawlers in Europe, the entire focus of the northern cod fisheries changed. For the first time in all the long history of this fishery, vessels could fish year-round in these waters, taking their catch directly back to Europe and Russia (most of these fisheries were prosecuted by Russian, East German, French, and Portuguese vessels). The fishing power and capacities of these fleets dwarfed all previous fisheries in Newfoundland and Labrador waters. The Russians and then Eastern Block allies located the then large redfish stocks off the Hamilton and other Labrador Banks in the late 1950s (Travin and Pechenik, 1963). These fleets proceeded to reduce these stocks to remnants of their former abundance, and these stocks have yet to recover to any appreciable extent, even after some 50 years. By the mid-1960s, the redfish, which a long-lived, slow-growing and low productivity species that cannot endure high levels of fishing pressure, were no longer commercially viable, and these fleets, which had by then located the over-wintering and spawning concentrations of the bank components of the northern and Grand Banks cod stocks, began to harvest these cod stocks with their large trawlers with a vengeance. The Hamilton Bank was lit up with the lights of these vessels, particularly in January, when cod are most aggregated and vulnerable to fishing. So began the demise of the over-wintering and spawning aggregations of the same cod that had supported the Newfoundland and Labrador fisheries for four-and-a-half centuries. Total annual catches exceeded half a million t during the mid to late 1960s (Fig. 2). The 1960s was a relatively warm period likely characterized by high cod production, certainly sufficient to enable the harvest of over 5 million t of cod in that decade. However, high productivity or not, such harvests were not even close to being sustainable, and by the early 1970s, all cod fisheries were in decline, as a direct consequence of this over-fishing (Rose et al., 2000; Rice, 2002). No fish stock on earth could have sustained such an incessant slaughter. Of all the calamities that have befallen the Newfoundland and Labrador cod stocks over five centuries, there is nothing to compare with this event.

In the mid-1970s, most Newfoundland and Labrador cod stocks were at the lowest levels observed to that time. Nevertheless, optimistic projections were made of the likely growth of these stocks in the absence of foreign fishing (Kirby, 1982). There was little thought of the long-term damage to stock productivity that may already have come into play by the over-fishing of the 1960s, and there were tacit assumptions that recruitment evident in earlier years would be matched in the 1970s. With a lower level of fishing, it was firmly believed that there would be quick and relentless growth in the stock (see Blackwood, 1996). At first, such euphoria gained some support, as in the late 1970s there were two strong year classes produced by the remaining fish in the northern stock (which were distributed to the north and comprised a spawning component on the Hamilton Bank, see deYoung and Rose, 1993). This event unfortunately appears to have given credence to and increased the momentum of the “quick growth” notions of that era, and led to an entrenchment of gold rush economics that in turn led to rapid expansion of Newfoundland and Nova Scotia-based fleets and plants. It was not to last long. By the mid to early 1980s, inshore fishermen were noticing that cod sizes were declining, and increased effort was needed to maintain catch levels (Hutchings and Ferguson, 2000). However, by this time, DFO science had become unofficially committed to the Canadian trawler fleet data, and catch rates of this fleet continued to increase. Such increases were interpreted as evidence of increasing abundance in the northern stock, which was incorrect (see Rose and Kulka, 1999). The increase in trawler CPUE (catch per unit effort) was directly responsible for the overly-optimistic output of the population models used to assess stock status in the mid to late 1980s (Baird and Bishop, 1986). During this period, there was dissension among scientists about the state of this stock (eg. Winters, 1986; Keats et al., 1986), but this went largely unnoticed at the time as a consequence of the "back room" nature of the stock assessments of that era, and the lack of a credible independent fisheries science program in Newfoundland and Labrador. It is also ironic that the DFO cod surveys of the 1980s indicated very modest increases in the northern cod stock, but these data were discounted in favor of the quickly increasing trawler catch rates. Unfortunately, an anomalously high survey result in 1986, which occurred for reasons still largely unknown, gave support to the optimistic view of northern cod and a short-lived continuation of what were unsustainable harvest rates. The trawler companies were not neutral during these controversies. As late as 1989, an official release stated "our captains are convinced that northern cod are as plentiful as ever offshore and our vessels have few problems catching their trip allotments throughout the year" (1989 memorandum to the DFO from National Sea Products, Lunenburg, N.S.).

Figure 7. Map of the Northwest Atlantic Fisheries Organization divisions and the general bathymetry.

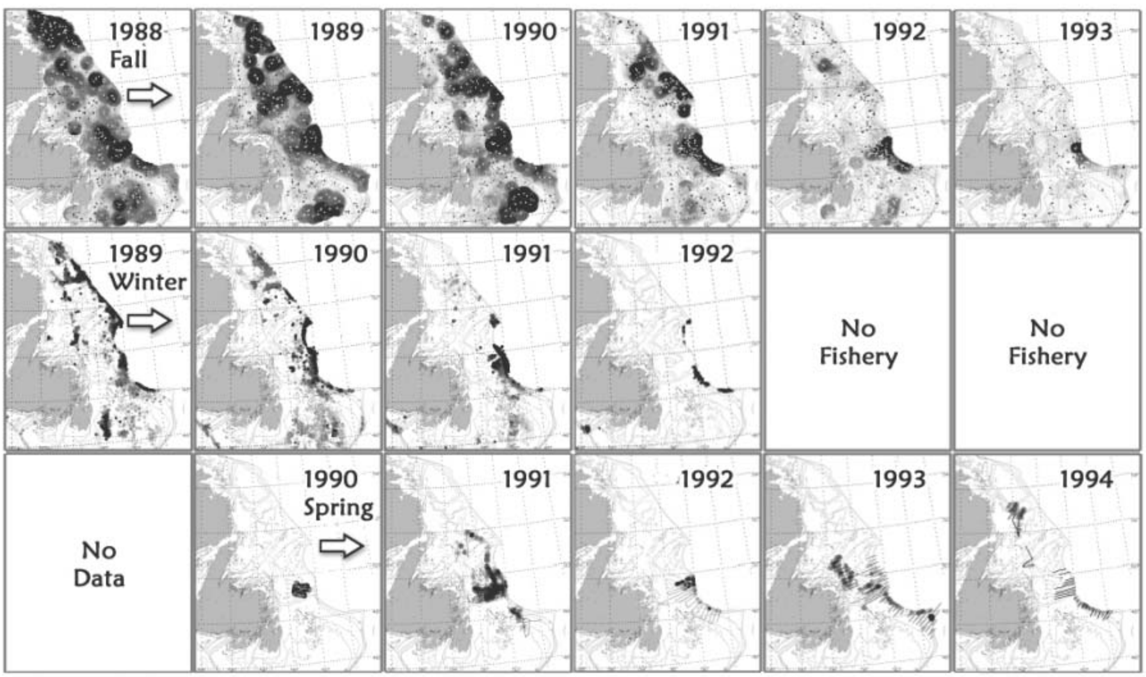


By 1989 and 1990, it was increasingly clear that the northern cod was in a serious state of decline. Equally as alarming, the ecosystem was changing towards much less productive conditions. Early evidence of this ecosystem change came in the form of swift and unexplained (to this day) declines in capelin growth, distribution and abundance (Frank et al., 1996; Carscadden and Nakashima, 1997), and declining growth and distributions in cod. In the spring of 1990, the northern cod were concentrated in the southern part of the range known as the "Bonavista Corridor" (Rose, 1993); (Fig. 7). What was interpreted as a warning of declining conditions and changing migration patterns for cod (Rose, 1993, deYoung and Rose, 1993) was somehow transformed to an indication of abundance in cod by the time it reached the Deputy Minister. By 1991, most of the extant fish were concentrated just north of the Grand Bank on the border of NAFO 3K and 3L (Rose, 1993). This southerly concentration of the fish and southerly migration led to the best inshore fishery in a decade in the southern portions of the northeast coast (deYoung and Rose, 1993). The remaining fish were sufficiently concentrated (Atkinson et al., 1997) to become even more vulnerable to both the trawler and inshore fisheries (Rose et al., 1994). Trawler CPUE continued to increase, right up until 1992 and the closure of the fishery (Rose and Kulka, 1999). Many other species followed suit, and these changes have been summarized in several recent papers (e.g., Rose et al., 2000; Rice, 2002; Drinkwater, 2002). Controversy ensued about the cause of the changes in cod (ironically not in capelin, whose changes attracted only limited research but were arguably more important to what was to come in the ecosystem). An early report suggested a commercial annihilation of cod (Steele et al., 1992), which was an extreme but not entirely unfounded view. How this could have happened was controversial. Cod distribution changes were interpreted as a fishing-down of the northern groups (Hutchings and Myers, 1994; Hutchings, 1996), or, alternatively, as a true distribution shift which then exacerbated the over-fishing by concentrating the remaining fish (deYoung and Rose, 1993; Rose et al., 1994). Rose et al. (2000) provided additional evidence from anti-freeze physiology, growth rates, and meristics (vertebral counts), that the distribution shift was real, and two recent reviews tend to support that view (Rice, 2002; Drinkwater, 2002). The early debates were followed by "who dunnit" controversies and finger pointing (e.g., Hutchings et al., 1997a,b; Doubleday et al., 1997). However, these controversies were more distractive than helpful. **The real issues were that scientific understanding of the cod fisheries had been inadequate and "signals" of change in the northern cod ecosystem were not sufficient to trigger any management action whatsoever.** In fact, the Newfoundland Inshore Fishermen's Association lawsuit to stop the trawler fishery on pre-spawning and spawning cod was fiercely rebuffed by DFO in 1989. By that time, many in DFO science had their heels firmly dug in. There was no effective opposition at the time either within or outside DFO science. It is important to point out that the barrage of scientific papers condemning DFO for mismanagement of the northern cod did not appear until the mid to late 1990s, in otherwords in hindsight (e.g., Hutchings and Myers, 1994; Walters and Maguire, 1996, and many other papers). There was far less foresight from science. Nevertheless, there is evidence that at least some of the early signals of ecosystem change and cod decline (and other species) were recognized by fishermen and science. However, this recognition was insufficient to influence management decisions, and some signals were grossly misinterpreted somewhere between the ocean and the offices of decision makers in Ottawa.

The destruction of the northern cod began and ended with foreign fisheries. In the early 1990s, the remaining cod that were concentrated in northern 3L on the northern fringes of the

Grand Bank were moving further east and towards the “Nose” of the Bank. In the spring of 1993, during a survey of post-spawning distribution, the only large aggregation of cod that was found was located outside the EEZ on the “Nose” of the Bank (Rose et al., 2000). The area was at the time being fished by foreign trawlers (G.A. Rose, personal observations). Under the current NAFO management regime, there was little if anything that could be done to stop the fishing of what may have been the last great northern cod aggregation by foreign trawlers. In a similar acoustic survey in the spring of 1994, not a single cod aggregation could be located, either inside or outside the EEZ. It is important to note that in 1991, when the northern cod was declining at an alarming rate, over 51,000 t of cod were reported caught on the “Nose” of the Grand Bank, primarily by the newly arrived Spanish trawler fleet (Shelton and Lilly, 2000). It is inconceivable that this amount of fish could be caught in such an area without an active movement of fish into the area (Rose et al., 2000).

Figure 8. The decline of the northern cod in the late 1980s and early 1990s. Top panels are the DFO fall trawl surveys. Middle panels are the winter trawl fishery. Bottom panels are spring acoustic cod densities.
Read chronologically down, then across. (from Rose et al., 2000).



In summary, although it is temptingly simple to describe the decline of the northern cod solely as a result of fishing (e.g., Hutchings, 1996; 1999), such an explanation is unhelpful in understanding how this could have occurred in fisheries thought to be well-managed and informed by state-of-the-art science. A simplistic explanation also provides no insight into the several stages of the decline (e.g., Rice, 2002), the ecological context of the decline, or how fisheries science and management should respond to environmental change, the current state of the stocks, or the future. The most recent scientific reviews have concluded that environmental changes were important to various aspects of the decline (e.g., Rice, 2002; Drinkwater, 2002), as was the lack of an ecosystem-basis for science and management (Shelton and Lilly, 2001; Rose et al., 2000). There is no argument from anyone that fishing caused most of the mortality. The details aside, the most striking feature of the 1980s was the failure of fisheries science and management to prevent over-fishing, clearly their mandate, and that is of most interest. It appears that scientific and management systems under the DFO and NAFO were unresponsive to impending changes both in the ecosystem and in the stocks as they were occurring, and despite some scientific warnings and even court challenges, and cheered on by some large fishing companies, allowed and even enhanced the playing field for over-fishing until the stock was nearly gone. **If we are to do better in the future, the entire system of science and management must be called into question, and likely reformed if Newfoundland and Labrador's place in Canada is to be strengthened.**

The Northern Cod Since the Moratorium

There was some notion that the northern cod might rebuild quickly after the moratorium on fishing (Lear and Parsons, 1993). This notion was challenged very early by deYoung and Rose (1993), who predicted that because of changes in the ecosystem, and the distribution of cod and reduced recruitment, that rebuilding would take a much longer time than indicated under the old production paradigm that assumed that removal of the fishery would result in an immediate increase in the stock. However, throughout the 1990s, predictions of relatively quick recovery continued to be recorded in the scientific literature. These were based on the simple rationale that fishing was the sole problem (e.g., Hutchings and Myers, 1994), hence removal of the fishery would result in quick rebuilding. Roughgarden and Smith (1997) indicated that the northern cod would increase to well over a million tonnes by 2000 in the absence of fishing, and Myers et al. (1997) made somewhat more conservative estimates but still predicted a relatively quick rebuilding. These quick-fix models were based on the notion that population levels of cod were determined entirely by fishing, and that no other factors were of much importance, and also that fishing had no long-term or "ecosystem" impacts that might influence the abilities of populations to grow. Hutchings (1999) retrospectively suggested that population growth had been slower than indicated by the earlier models that were clearly, by then, overly optimistic, because of bycatch or unknown fisheries. However, rebuilding was proceeding at a faster pace in coastal waters (Rose, *in press*) where unknown catches were likely to be higher (in addition to the legal fisheries), so this explanation seems implausible for northern cod. There was a generic problem, despite different assumptions and outputs, with all the population growth models. All were based for the most part on historical data on cod production, and an assumption that little had changed in the ecosystem that might impact cod rebuilding. In reality, there had been major changes in growth and condition in cod and other species, which slowed dramatically in the 1990s (Drinkwater, 2002). Distribution changes would likely impact recruitment (deYoung and Rose, 1993). Apparent mortality of fish at ages five and six years exceeded any observed historically. Moreover, both theoretical considerations (Frank and Brickman, 2001) and studies at sea on northern cod (Anderson and Rose, 2001) suggested that quick compensation of population numbers may not occur, as a consequence of reduced population richness and the lack of spawning fish in the remaining cod groups. These more ecological approaches are consistent with a decline in northern cod after the moratorium, without invoking additional fishing mortality, as earlier predicted by deYoung and Rose (1993). Furthermore, the most recent evidence indicates that a lack of capelin in this ecosystem is impeding both cod growth and reproductive potential (Rose and O'Driscoll, 2002) and perhaps leading to increased mortality at an earlier age (also see Rideout et al., 2000). To further compound the regime changes in this ecosystem, the growth of the harp seal herd (from 2 to over 5 million) from the 1970s to 2000 has likely depressed the pelagic fishes and made a recovery by the groundfishes problematic**. It is evident now that predictions that ignored "ecosystem" effects had little foundation, and although a detailed understanding of these changes and their effects on the northern cod and other species is still plagued with uncertainties, there can be no doubt that they have occurred.**

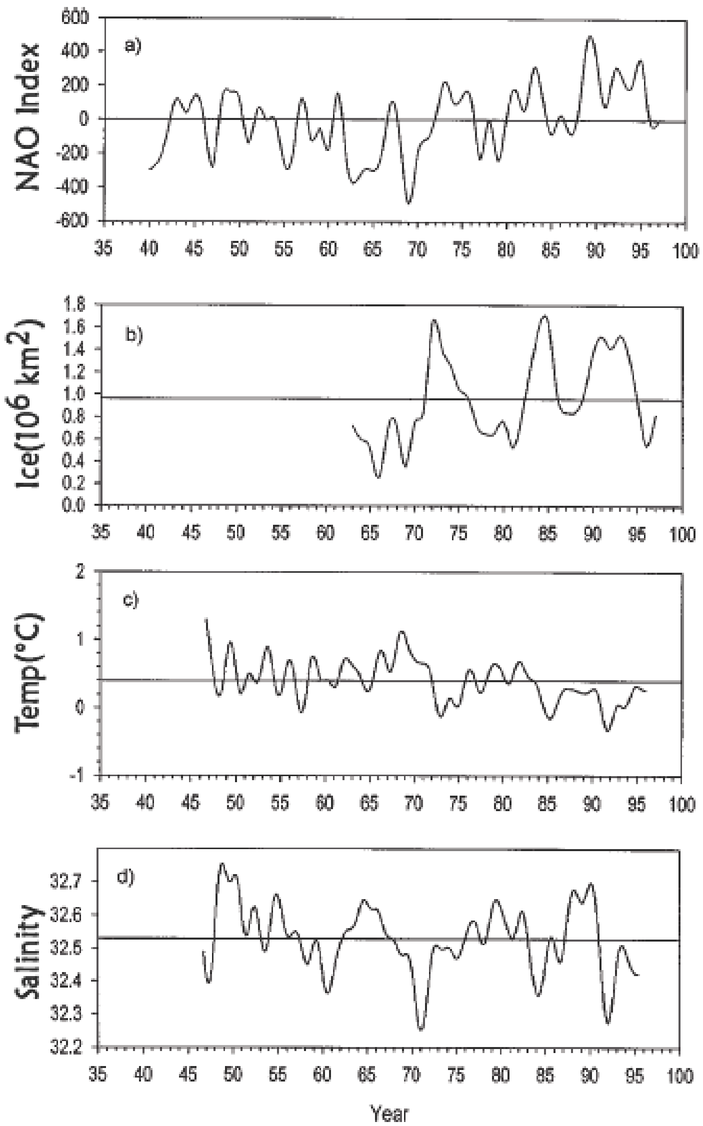
Ocean Climate

Studies by oceanographers indicate that the ocean climate changed in the late 1980s, and that the early 1990s were among the coldest years since detailed records were available (Colbourne et al., 1997; Drinkwater, 2002) (Fig. 9).[3] These conditions reflect the complex oceanographic dynamics of the North Atlantic ocean, with a primary index being the North Atlantic Oscillation (NAO), which measures the difference in pressure between the Azores and Iceland (Dickson et al., 1996). The NAO reached its highest recorded values in the early 1990s (Fig. 9a). A high NAO is typically associated with cooling conditions in the Labrador and northeast Newfoundland marine ecosystems (Fig. 9b,c). The effects that these cooling events had on many species were widespread and considerable (both direct and indirect), and reverberated throughout the ecosystem.

Effects on plankton are for the most part speculative because of the poor record of data on this part of the ecosystem. However, there are indications of major changes in the planktonic community (both species and abundance) between the late 1980s and early 1990s, based on CPR (continuous plankton recorder) data (Doug Sameoto, Bedford Institute, unpublished data).

Environmental changes and ecological anomalies in the 1980s and 1990s (Drinkwater and Mountain, 1997; Sinclair and Murawski, 1997) were involved in the decline in the northern cod (Rice, 2002; Drinkwater, 2002). It is important to note that the environmental changes affected many species other than cod. It is also important to point out that environmental influences provide no excuse for the overfishing or mismanagement of the cod stocks (often given as a reason why environmental effects should be ignored, e.g., Hutchings, 1996). Capelin exhibited slow growth, delayed spawning, and shifted southwards beginning in the late 1980s (Frank et al., 1996; Carscadden and Nakashima, 1997). These changes have been attributed to the cooler waters of the 1990s (Carscadden and Nakashima, 1997). Montevecchi and Myers (1997) documented an abrupt change in food for gannets, from mackerel (*Scomber scombrus*) to capelin, on Funk Island, off the northeast coast of Newfoundland, in 1990. Atlantic salmon (*Salmo salar*) exhibited changed migration patterns in the early 1990s (Narayanan et al. 1997). Arctic char feeding habits changed abruptly off Labrador, where capelin had become scarce (Dempson et al., 2001). Other species, such as American plaice (*Hippoglossoides platessoides*), declined under low exploitation (Bowering et al., 1997). Species as diverse as marine butterflies (*Oikopleura spp*.) and arctic cod, whose historical ranges were much more northerly, became widely distributed in the southern areas in the early 1990s (e.g., Drinkwater and Mountain, 1997). And as we shall see, pandalid shrimp and snow crab populations have surpassed any previously observed levels. **In summary, it is hard to find any aspect of the northern cod ecosystem that did not change in the late 1980s and early 1990s.** Although the fishery no doubt has contributed to and likely caused many of these changes, it is unreasonable and unhelpful not to recognize the important effects that ocean climate change has had on the events that played out in the marine ecosystems of Newfoundland and Labrador in the past decades. **It is arguably even more important to try to understand how ongoing changes will affect their future.**

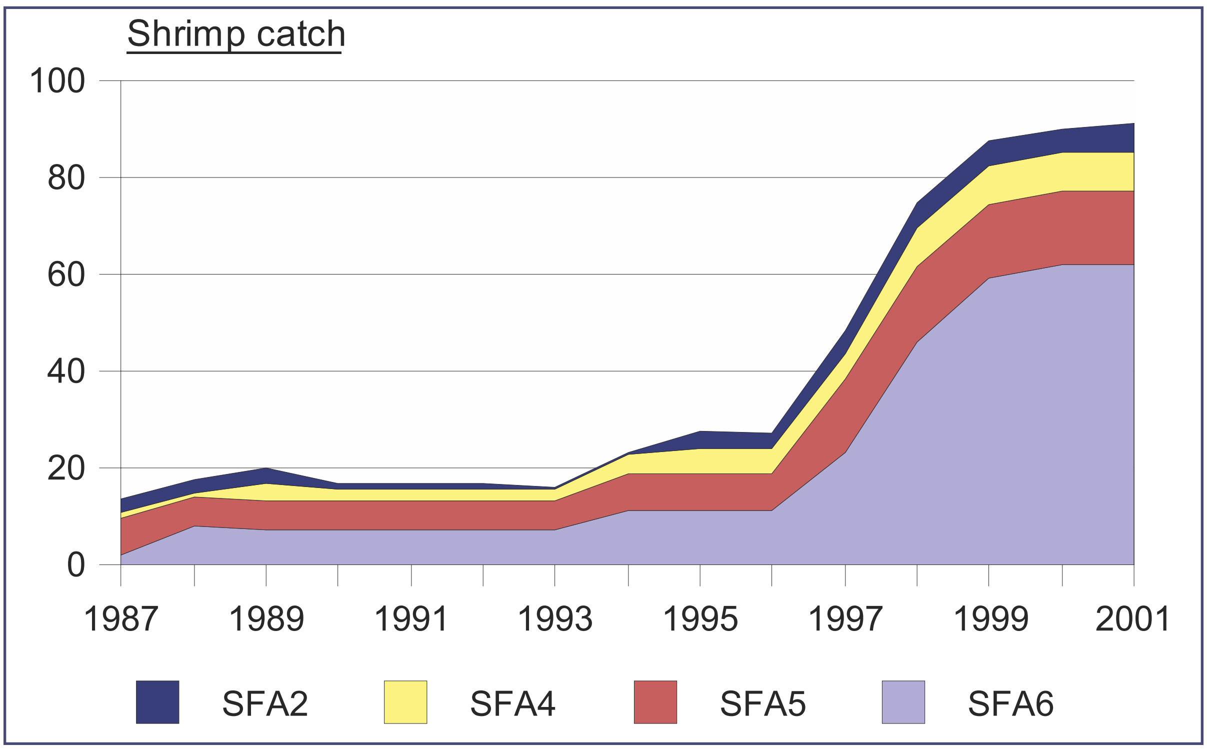
Figure 9. For the period 1940-1997, a) the annual average North Atlantic Oscillation (NAO), b) ice-coverage averaged annually for the Newfoundland and Labrador shelf, c) temperature and d) salinity from the inner Newfoundland shelf averaged over water column and filtered to remove the seasonal signal. Horizontal reference lines in b,c, and d are means.



The Rise of Pandalid Shrimp and Snow Crab

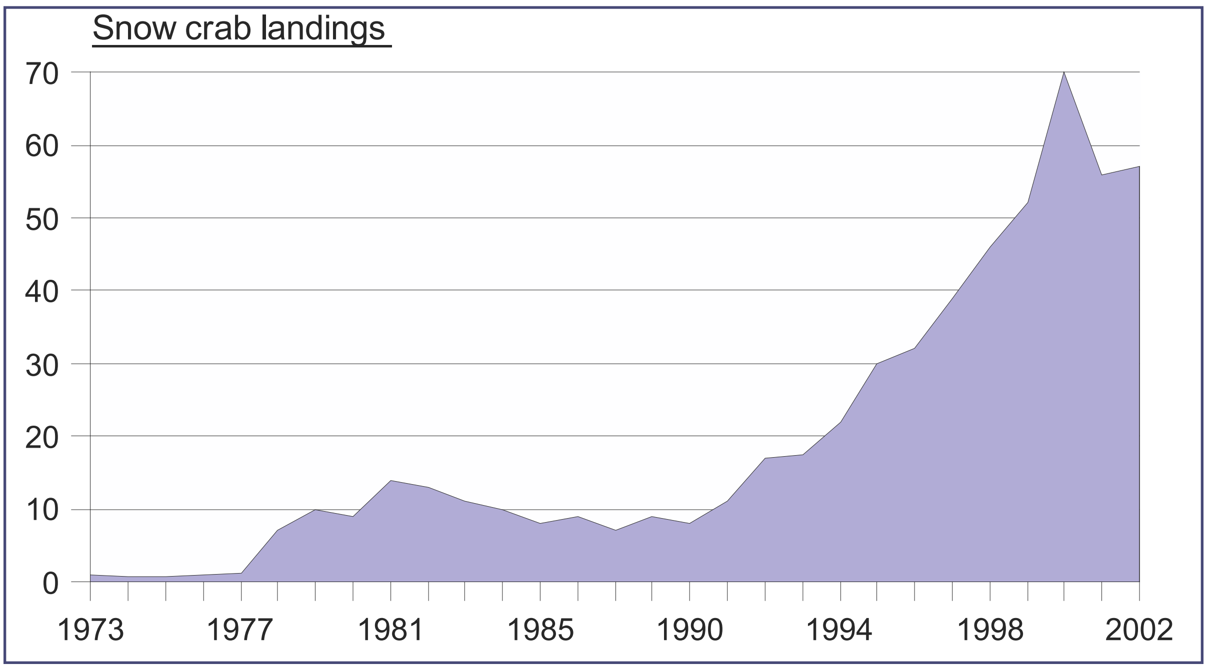
The declines of capelin and cod, particularly in the northern ranges of the northern cod (2J and 3K), were followed by relatively abrupt increases in the populations of pandalid shrimp and snow crab within the former range of the northern cod (see SSR C2-05, 2002). Fisheries for shrimp and crab were not traditional in Newfoundland and Labrador, but developed quickly in the late 1980s and early 1990s. Northern shrimp (*Pandalus borealis*) catches have increased from approximately 15,000 t to 90,000 t from the late 1980s until 2002 in the shrimp areas SFA2 to SFA6 (Fig. 10), which correspond to NAFO divisions 0B to 3K from Baffin Island to the Funk Island Bank (Fig. 7). The fishery is now limited by market conditions. There are early indications that shrimp have become smaller in 2001 and 2002, although it is not known if this is a result of overfishing the larger animals, or a growth decline. There is no evidence from the DFO surveys that the stock biomass is declining, in fact, biomass appears to continue to increase, despite the increasing harvests of recent years. There can be little doubt that shrimp biomass from the Hawke Channel to 3K (SFA6) has increased significantly in the 1990s. This increase is likely an effect of both cooler ocean conditions in the late 1980s and early 1990s that were favourable to shrimp production, and release from predation by cod. It is not possible at present to disentangle these effects, but historical experience and data from this and other ecosystems suggest that northern ecosystems will be dominated either by a pelagic-demersal fish group (e.g., capelin-cod), or by a crustacean group (shrimp and crab), and not by both at the same time.

Figure 10. Shrimp catch in SFAs 2 to 6, from Baffin Island (SFA2) to Hawke Channel and the Funk Island Bank (Hawke + 3K) (data extracted from SSR C2-05, 2002) (catch in 1,000 t).



The snow crab fishery began in 1968 in parts of Trinity Bay, initially as a bycatch in gillnet fisheries for groundfish. Since such humble beginnings the crab fishery has blossomed in the 1990s and now supports the largest fisheries by value and employment in most regions of Newfoundland and Labrador. Annual landings have increased from less than 1,000 t in the early 1970s to 50-60,000 t in recent years (Fig. 11). The fishery harvests only larger males (>95 mm) and hence has a strong conservation base. However, there are many uncertainties in any perceived state of the crab stock. Among these, it is uncertain if over-harvest of males could cause recruitment over-fishing, and only a weak understanding of basic biology and ecology and how crab production is related to oceanographic conditions and interactions with other species. There is a lack of targeted research in Newfoundland and Labrador aimed at answering such questions, and little fishery-independent data with which to assess the stock and judge future production to the fishery, and that is perverse given the importance of snow crab to the fisheries of Newfoundland and Labrador.

Figure 11.
Snow crab landings in Newfoundland and Labrador waters (NAFO divisions 2J3KLNO, 3Ps, 4R) (landings in 1,000 t).



There has been an association between CPUE in the crab fishery and general temperature conditions eight years earlier (SSR C2-01, 2002). Cold conditions result in high CPUE in later years, and presumably this indicates strong recruitment from the colder years, and lesser recruitment in warmer years. Since 1997, temperatures have risen considerably, and consistent with this, pre-recruit and biomass indices estimated from the DFO multi-species survey have fallen off since 1997. This relationship suggests a strong link between crab production and the state of the ecosystem, and supports arguments for ecosystem-based approaches to fisheries management.

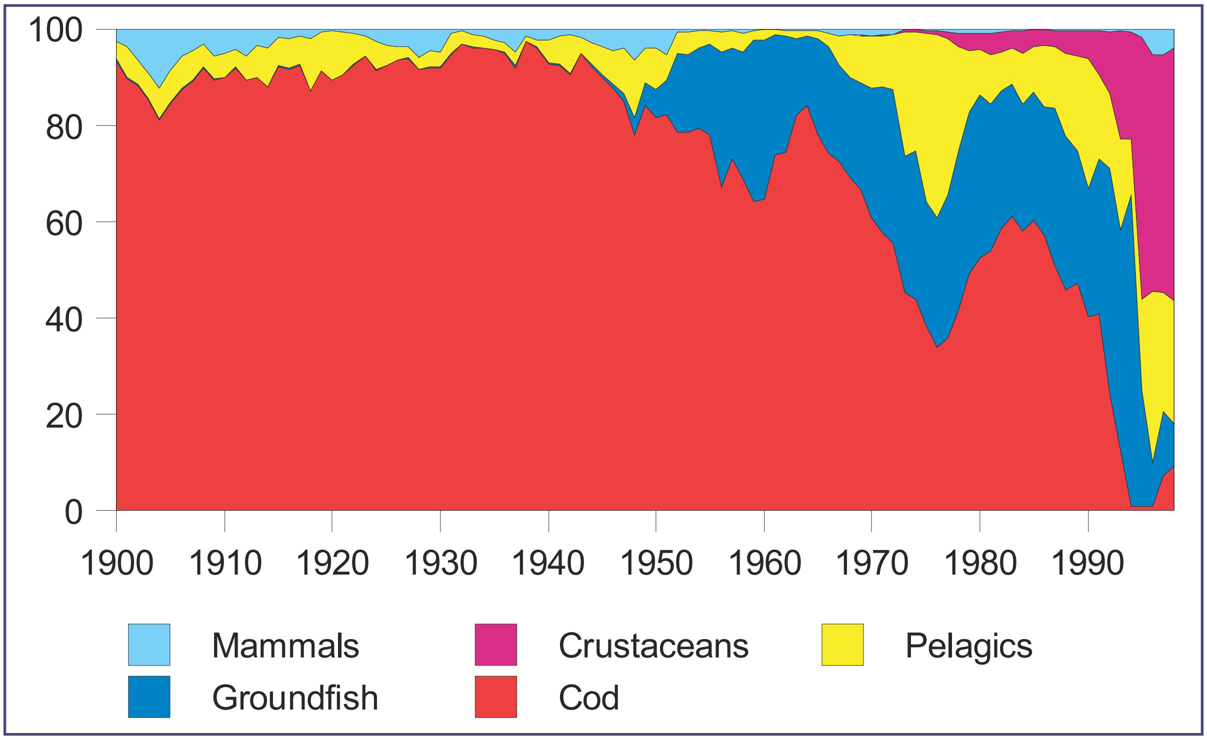
Ecosystem Changes

"Chance favours the prepared mind" – Louis Pasteur

The Newfoundland fisheries were dominated by cod for almost 500 years. No other fishery came close to the landings of cod. Modeling exercises have suggested cod biomass levels were historically in the range of several million tonnes (Pope et al., 1998). It is a reasonable assumption that capelin were at least as abundant as cod, and perhaps twice as much to 5-6 million tonnes. Although a complete reconstruction of the historical composition of the Newfoundland and Labrador marine ecosystems is impossible, nevertheless, there can be little doubt that capelin and cod were far more abundant than at present, and comprised dominant levels of biomass with far-reaching influence on most aspects of the ecosystem. The other fisheries prosecuted historically were bait and food fisheries for herring, capelin, and mackerel, which removed relatively small quantities. Until the 19th century, catches of all species were less than 250,000 t and likely had little effect on ecosystem structure or functioning. During the 19th century, new fisheries for harp seals were introduced, and the large harvests of the mid-19th century may have led to increases in capelin, herring, and cod populations, as these species are prey for seals. Any such increases would have made more cod available to the fisheries. During the 19th century, cod landings did increase steadily.

In the second half of the 20th century, the relative stability in the fisheries changed suddenly. During the two decades of the 1950s and 1960s, cod harvests doubled and the harvest levels of several other species that formerly were fished only lightly or not at all, were greatly increased (capelin, herring, haddock, redfish). Commercial extinctions followed in some areas. A similar pattern was played out with flatfishes in the following decades. In addition, the fisheries on marine mammals, the apex predators, were stopped. An ecosystem that was once harvested heavily at the top (seals and to a lesser extent, whales), moderately in the middle (cod), and trivially at the bottom (capelin and herring), suddenly was harvested not at all at the top, heavily in the middle (cod, haddock, redfish, flatfish), and somewhat more at the bottom. Moreover, this scenario played out in an ocean environment that was becoming cooler and less productive for the dominant species, especially cod (deYoung and Rose, 1993) and capelin (Carscadden and Nakashima, 1997). Such conditions may have favored cold-water species such as snow crab and pandalid shrimp. To compound this effect, the removal of the mid-level predators may have increased survival in crab and shrimp. The combined effects of these events has shifted the ecosystem into a state where overall yield has declined and the trophic pyramid has become an hour-glass, constricted in the middle. The top trophic levels have increased, the middle levels are decimated, and the bottom has changed in dominance. The stability and durability of this ecosystem state is unknown, although the relatively short life cycles of crustaceans suggests this state may be less stable than one dominated by cod and redfish, which have much longer life cycles.

Figure 12. The species composition of Newfoundland and Labrador fisheries landings in the 20th century (%).



Without regard to species, the overall yield from the Newfoundland and Labrador marine ecosystems to the fisheries has declined to less than half of historic levels during the latter half of the 20th century. The fisheries yield from this ecosystem was until recently dominated by cod. One outcome of the decline in cod might have been a replacement with another species with a similar ecological "niche". However, there is little evidence that another species has replaced cod. In contrast, it appears that a new and alternative "regime" comprised primarily of the crustaceans shrimp and snow crab, perhaps dominated by them, has replaced the capelin and cod systems. The shift between these 2 regimes appears to have taken place relatively quickly, within a few years in the early 1990s. A similar shift, but the other way, from crustaceans to a "gadoid outburst" took place in the Gulf of Alaska around 1970 (Anderson and Piatt, 1998). Our knowledge of marine ecology is insufficient to understand why these shifts might take place, or how long they might last, and there is no ability to predict these events. There is no certainty that ecosystem "memory" of previous states will result in a return to former conditions (Rice, 2002). Among possible reasons for ecosystem change are changes in ocean climate, the long term effects of fishing, or certain types of fishing, over-harvest of key components of the ecosystem, habitat damage or change caused by fisheries, and interactions among species. It is well known that cod eat female crab and shrimp, and that harp seals eat capelin, crab and cod, but more complex interactions, such as the possible effects of shrimp on capelin, are only speculative.

In addition to declines in cod, the yields of several other species, including haddock, redfish, the flatfishes, and herring have also declined. The declines in haddock, redfish, and herring directly followed pulse fisheries and do not appear to be related to environmental factors.

However, none of these species has recovered to their former abundance levels although it has been almost four decades since the initiation of such pulse fisheries. **The lack of rebuilding without appreciable fisheries is very worrisome, and highlights the potential long-term effects of excessive over-fishing on marine ecosystems.**

Trophic Structure

In addition to a decline in fisheries productivity, there have been fundamental changes in the trophic structure of the Newfoundland marine ecosystem during the past 50 years (Table 1). Classic pyramids of numbers and biomass (Clarke, 1967) once existed in these ecosystems (Fig. 13). Although it is impossible to determine the exact abundance levels of the components of the trophic pyramid, especially for historic times, these levels can be approximated to an order of magnitude in a scaling model. Historically, the numbers and biomass of indicator species harp seals, cod, and capelin conforms to a pyramid. There were likely on the order of 10^7 harp seals, as there are in the late 1990s. Cod numbers based on historical data and simulation models (Pope et al., 1998) suggest on the order of 10^9 cod. Pelagic (capelin, herring) and benthic (shrimp) numbers are more difficult to specify. However, it is likely that capelin alone were on the order of 10^{12} in average abundance (based on several million t of biomass which is similar to the levels in the 1980s, Carscadden and Nakashima, 1997). In the late 20th century, the abundance pyramid has been replaced by an hour-glass form, contracted in the middle. The current abundance levels, to orders of magnitude, of harp seals and the lower levels are similar to historic times (however shrimp are more numerous and capelin less so). The middle levels, which are comprised primarily of groundfish, in particular cod, are at least an order of magnitude less abundant than in historic times.

The earliest fisheries were for whales and codfish at the upper trophic levels. During the 19th century the chief removals from this system were still from the upper trophic levels (harp seals and cod). In total, approximately 100 million t of cod have been removed from this system since 1500. By the end of the 20th century, the cod had been reduced to a few per cent of their former abundance. It is likely that a revised food web now exists which is sustaining higher levels of top predators (e.g., seals) at the expense of mid-trophic level demersal fishes. Shrimp and crab are currently the chief components of the harvest, but their biomass is much lower than that of cod. At upper trophic levels, protection of species from harvest has led to population increases. In particular, harp seals doubled their numbers in two decades from 1977-1997 and have reached levels of 5-6,000,000 animals. In addition, fisheries on lower trophic levels are at all-time highs, despite the reductions of herring following overfishing in the 1960s and 1970s, and the reductions of capelin in the 1990s.

In conclusion, the Newfoundland marine ecosystems have undergone a regime shift in the 1990s, as a result of the primary effects of the fisheries and of oceanographic changes (Sinclair and Murawski, 1997), and secondary effects of species interactions caused by decreases in some species and increases in others. A system that appeared to be relatively stable over a period of 450 years, despite some climate changes during that period (but without year-round mobile fisheries), and characterized by dominant species harp seal, cod, and capelin, has been jolted into a state where the middle part of the food web has been severely diminished, and lower parts changed to an entirely different form. A major concern is that overall productivity, at least in terms of commercial landings, appears to have declined considerably.

A priority for fisheries research should be investigations of these ecosystem states, their durability, and the relationships between ocean climate and distribution and abundance of the dominant species of both the historical state (cod and capelin) and the current state (shrimp and crab) and what might cause such regime shifts between these or other states.

Figure 13. Historical (top) approximations of the biomass pyramid in the Newfoundland and Labrador ecosystems, and the more hour-glass shape of its current state (bottom).

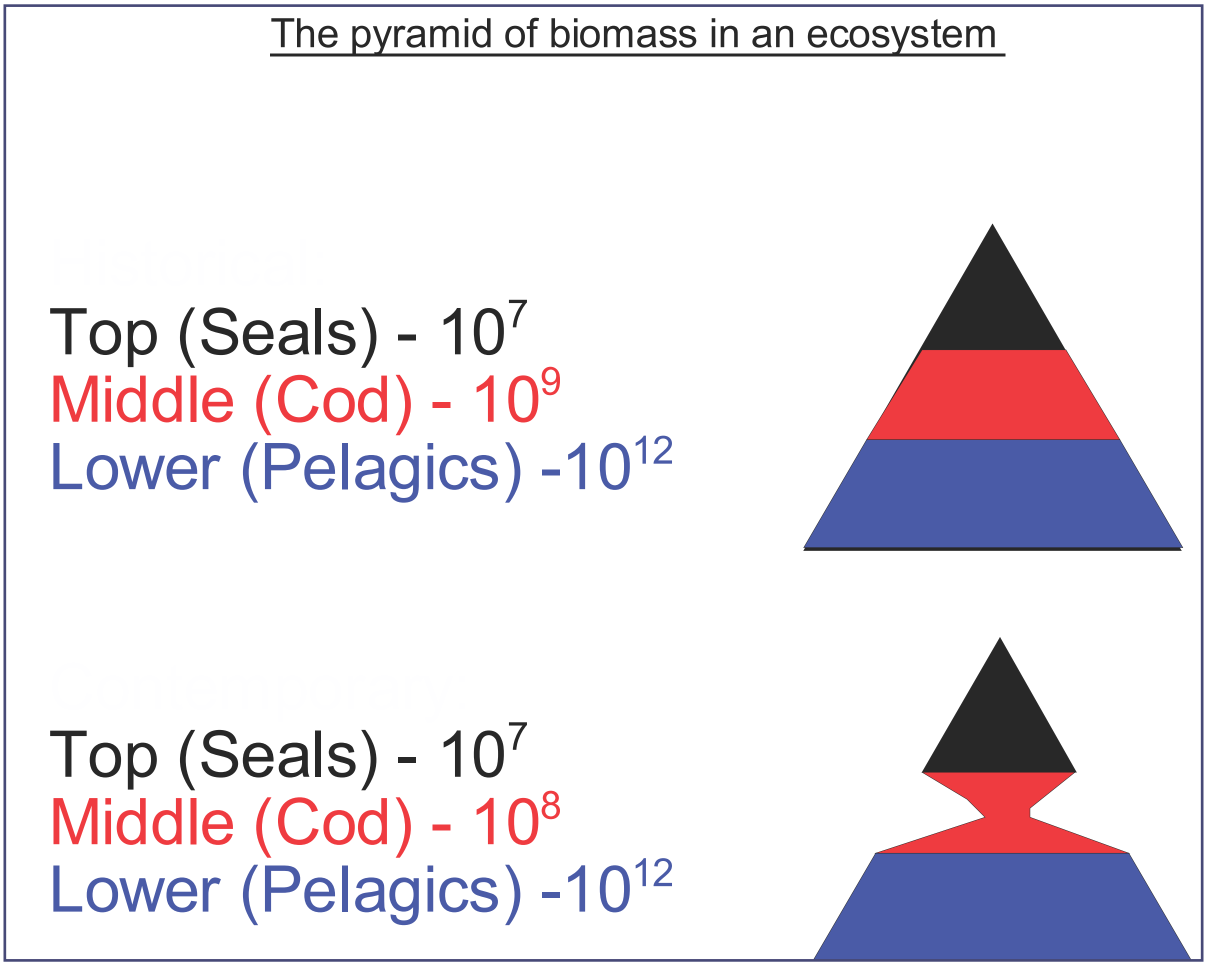


Table 1. Scales of the trophic structure above the plankton in Newfoundland marine ecosystems (see text for details).

	Top	**Middle**	**Lower**
Historic (to 1900)	10^7 (harp seals)	10^9 (cod, redfish, haddock, flatfish)	10^{12} (capelin, herring, shrimp)
Post 1950	10^7 (harp seals)	10^8 (cod, redfish, haddock, flatfish)	10^{12} (capelin, herring, shrimp)

Current State of the Renewable Marine Resources of Newfoundland and Labrador

The renewable marine resources of Newfoundland and Labrador are currently in a mix of conditions (Table 2). Most groundfish and pelagic fish stocks are at relatively low levels of abundance with respect to historical times. However, to the best of our knowledge, crab and shrimp are at all-time high levels and support lucrative fisheries. The current high values of marine fish landings are attributable almost totally to crab and shimp (Fig. 14). Harp seals are very abundant (approximately 5 million animals in the late 1990s) (SSR E1-01, 2000), and anecdotal evidence suggests that hood seal (*Cystophora cristata*) numbers are also high. On the other hand, most groundfish species are at either all-time lows or doing poorly. There are a few notable exceptions, such as cod in NAFO 3Ps, yellowtail flounder in 3NO, and turbot from Baffin Island to the Flemish Cap. Overall, total fisheries production in terms of dollar value is at an all-time high (ca. 0.5 billion dollars per annum).

Figure 14. Landed value of Newfoundland and Labrador marine seafood (1,000$).
Data from DFO and provincial DFA sources.

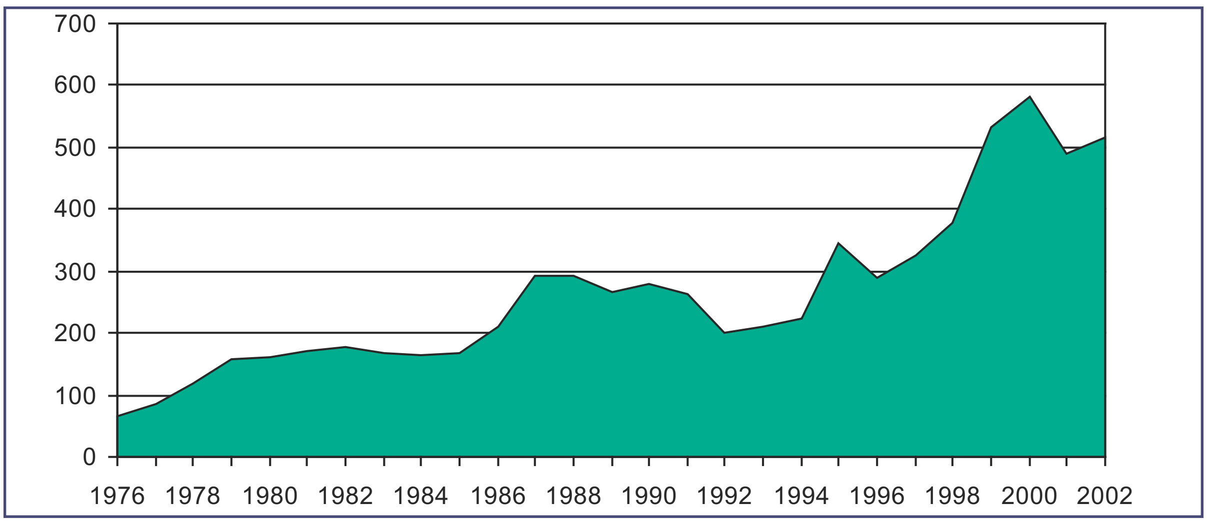


Table 2. Summary of the current state of fish stocks in Newfoundland and Labrador waters.

NAFO region	Species	Status	Fishery	Notes
2J3KL	Coastal Cod	moderate	5 600t	
	Bank Cod	low	closed	Moratorium since 1992
	Redfish	low	closed	Poor recruitment for past 25 years
	American Plaice	low	closed	Age and length at maturity have declined
	Turbot	low	42 000t	Part of larger area (NAFO)
	Witch Flounder	low	closed	
	Winter Flounder	unknown		
	Capelin	low	35 580t	Lack of data in 2001
	Sand Lance	unknown	none	
	Herring	low	4 400t	
	Snow Crab	high	38 000t	Catches declining
	Lobster	moderate		Status unclear
	Pandalid shrimp	high	60 000t	Quota for 2J3K
	Lumpfish	unknown		
3NO	Cod	low	2 000t	NAFO bycatch
	Haddock	low	closed	No rebuilding
	Redfish	low	10 000	Quota for NAFO
	American Plaice	low	closed	Substantial bycatch
	Turbot	low	closed	
	Yellowtail Flounder	moderate	14 000t	Quota for 3LNO
	Witch Flounder	low	closed	
	Capelin		low-unknown	Closed
	Sand Lance	unknown	No fishery	
	Surf Clams	unknown	4120t	Quota for 3LNO
3Ps	Cod	moderate	15 000t	Moderate rebuilding
	Haddock	low	closed	1998 year class appears strong
	Redfish	low	8 000t	Unit 2 Redfish
	American Plaice	low	closed	Recent year classes appear stronger
	Turbot	low	closed	
	Yellowtail Flounder	low	closed	
	Witch Flounder	low	650t	
	Capelin	moderate	2 540t	
	Sand Lance	high	No fishery	Local knowledge
	Herring	low	4 100t	
	Lobster	moderate		Status unclear
	Snow Crab	high	7 600t	Catches declining
	Scallops	moderate	3 550t	Icelandic and Sea scallops
	Pollock	incidental		No fishery
3Pn4RS	Cod	low	7 000t	Status unclear
	Redfish	low	closed	
	American Plaice	low	1 000t	
	Turbot	moderate	1 000t	
	Witch Flounder	low	1 000t	
	Capelin	moderate	10 700t	Local knowledge
	Sand Lance	unknown	No fishery	
	Lobster	moderate		Status unclear
	Snow Crab	moderate	1 540t	Status unclear
	Scallops	moderate	1 200t	Status unclear
	Witch Flounder	low	1 000t	

There is particular concern about the current state of cod. Overall, the magnificent and economically dominant Newfoundland and Labrador cod stocks (which once made Newfoundland the richest place in North America, see Major, 2001) have been reduced over the past 50 years to a remnant state. For the formerly-dominant northern cod stock complex, there is only one component that has rebuilt well since the moratorium, and that is the relatively small coastal component centred in Trinity Bay (Fig. 15). It is overwhelmingly clear that there exist in Newfoundland waters what can be termed "coastal" cod populations, sometimes erroneously referred to as "bay" stocks (these fish may hold to one bay but that is not always true). Coastal fish tend to spawn in particular places, but may migrate along the coast to feed, but seldom offshore or to the Banks. Every scientific approach to the question of the existence of coastal fish has given a positive answer, from the ecological (deYoung and Rose, 1993; Rose, in press), to tagging (Templeman and Fleming, 1962; Templeman, 1971; 1981; Lear, 1984; 1986; Myers et al., 1997; Brattey et al., 2002), to genetics (Bentzen et al., 1996; Ruzzante et al., 2001; Beacham et al., 2002). The coastal component on the northeast coast has over-wintered and spawned primarily in Smith Sound, Trinity Bay since 1995. This population approximately doubled from the mid-1990s until 2002, which represents a strong rate of increase of about 0.2 per year (Rose, in press). However, in all other areas of the former northern cod stock area, there has been little increase over the past decade. There has been a four year cycle of sorts in offshore bank substocks of northern cod since the early 1990s. A relatively strong spawning event occurred in the Hawke Channel region in 1994 (Anderson and Rose, 2001), and the 1994 year class initially appeared to be relatively strong. These fish in turn spawned in 1998 (see Fig. 14). Following that event, there is evidence that the 1998 year class, and perhaps the 1999 year class, are the strongest in a decade, and they first spawned in 2002. If these recent year classes can survive beyond their first year or two of spawning, the reproductive potential of several Bank groups of northern cod may increase substantially in the next few years. It is far from certain that this will occur, however, because for the past decade the apparent mortality of fish greater than age five has been astoundingly high (Anderson and Rose, 2001; Lilly et al., 2001).

Another major concern is the status of capelin, formerly the major food of the northern cod (Turuk, 1968; 1979; Lilly, 1984). Although the status of capelin is uncertain (SSR B2-02, 2001), and evidence that year classes produced in Trinity Bay in the mid-1990s were relatively strong (SSR B2-02, 2000), there is a general agreement among fishermen and more recent surveys that capelin are at very low levels in most areas. During the past decade, cod in the key northern areas have had almost no access to capelin (O'Driscoll et al., 2001), and cod condition and reproductive potential has suffered as a direct consequence (Rose and O'Driscoll, 2002). Other species have shown similar declines in capelin their diets. Rowe et al. (2000) showed that murres (turrs) have far less capelin in their diets in the 1990s than in earlier times, and Arctic Char off Labrador found little capelin in the 1990s (Dempson et al., 2001).

Most of the species subjected to pulse fisheries in the second half of the 20^{th} century (e.g., American plaice, haddock, redfish), that could play roles in a revitalized fishery in Newfoundland and Labrador, have not rebuilt to any extent. There is also concern that current harvest rates of Greenland halibut will result in declines in this stock.

At present, the marine ecosystem and the fisheries are dominated by shrimp and snow crab. The ecosystem state has clearly changed or even flipped into a new state (e.g., Gunderson and Holling, 2002). Although the stability and durability of the crustacean regime are not known, there are reasons to expect that this regime will not be as stable or durable as a capelin-cod alternative regime. Cod and redfish (considered a part of the capelin-cod regime) are much longer lived species and should force a higher degree of relative stability on the entire ecosystem than is to be expected from the shorter lived crustaceans. Despite their current low levels of abundance, there is reason to believe that cod and capelin can regain their former dominance in the marine ecosystems of Newfoundland and Labrador. The genetic and distribution structures of the stocks are still relatively intact (Rose et al., 2000; Ruzzante et al., 2002). Capelin are capable of quick expansion of both range and numbers. Why these species have been slow to regain their dominance in the ecosystem is a key question for science. The same questions can be posed for haddock and redfish and other species. Seal abundance levels are high, and are likely impeding groundfish rebuilding (SSR A2-01, 2003). **The answers to such questions are no doubt complex, and the lack of them at present underscores our ignorance of marine ecosystem processes, but their importance to the future fisheries of Newfoundland and Labrador can hardly be overstated.**

Figure 15. Echogram across over-wintering aggregation of cod in Smith Sound in late 1990s. Aggregation is approximately 150 m deep and 1,500 m wide.

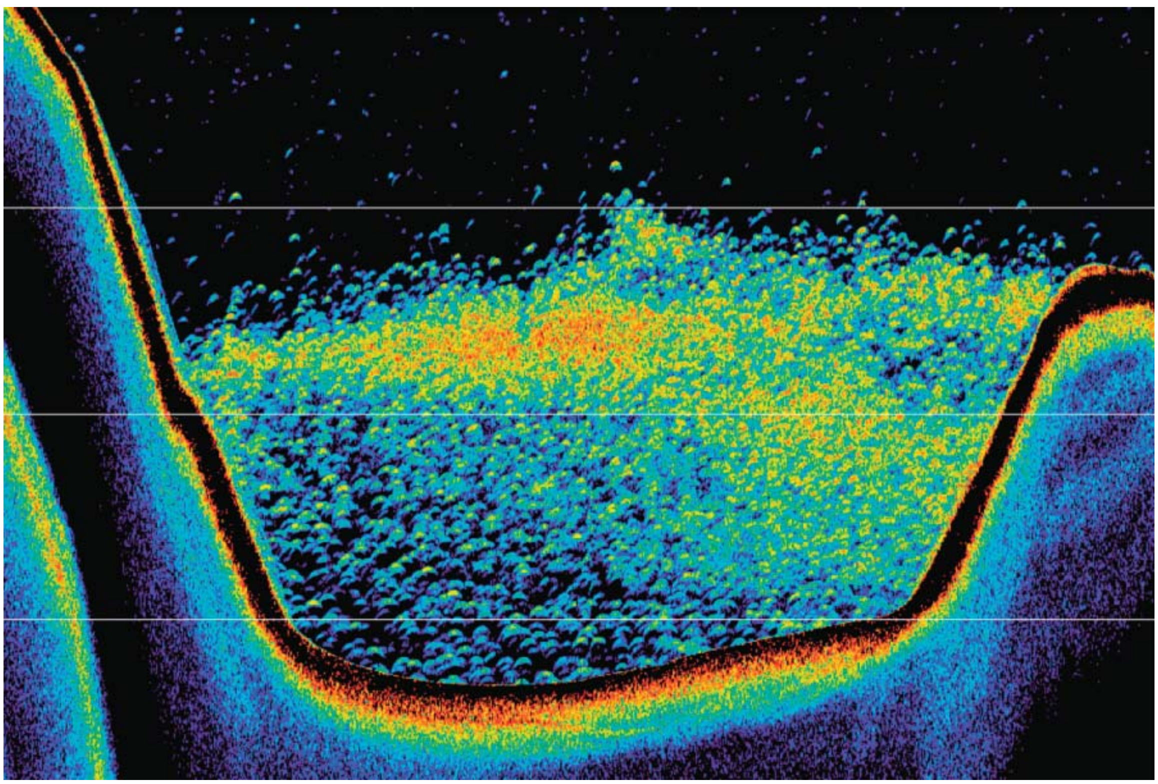
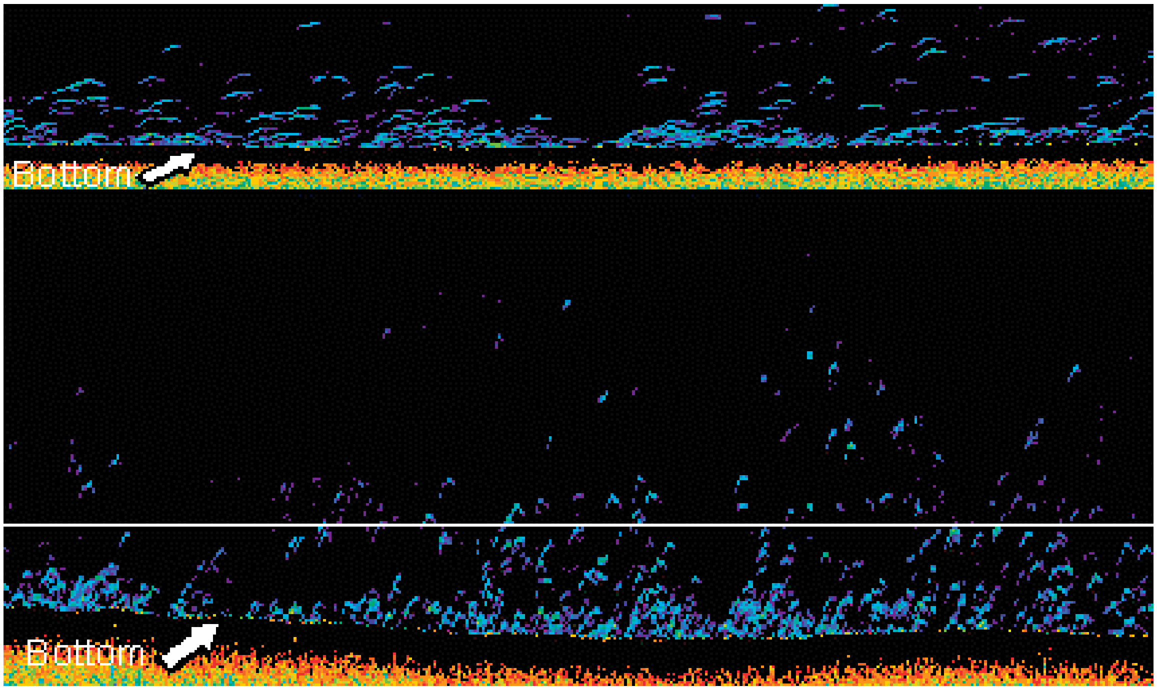


Figure 16. Post-spawning cod in the Hawke Channel in June, 1998. Most fish were four years old (1994 year class). Total depth 425 m, 8,000 m across. Top panel is expansion of bottom 10 m.



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Current Levels of Science and their Application to Management

A Brief History of Fisheries Science in Newfoundland and Labrador

Fisheries science is not well developed or supported in Newfoundland and Labrador. This is surprising, given the history, culture and the economic importance of fisheries to Newfoundland and Labrador over many centuries. Nevertheless, the history of fisheries science in Newfoundland and Labrador is characterized by neglect and oversight, beginning with the earliest Colonial regimes, and more recent relegation by both provincial and federal governments and Memorial University to a relatively unimportant status. Perhaps the low status of fisheries science relates to the generally-held low esteem of the fisheries themselves that may be found in the earliest records of settlement in Newfoundland (Prowse, 1895; Major, 2001). It has been the habit of the urban and gentrified elite to dismiss the fishery, and by implication, fisheries science. In rural areas, science remains too much an obscure abstraction. With respect to Confederation, there is no mention of fisheries science (which might be argued to have been an important point in the transfer of responsibilities) in the Terms of Union between Newfoundland and Canada (see Fitzgerald, 2002). Even more disconcerting, the entire text relative to fisheries received little more attention than did the sale and color of margarine (Fitzgerald, 2002). There appears to have been a general feeling that the fisheries were, and continue to be, an outdated and anachronistic endeavor and mode of employment and not to be treated as a serious economic and social institution (after all, Joey Smallwood told the boys to "burn your boats").

Prior to Confederation, Newfoundland had a small but able fisheries research presence. The Newfoundland Fisheries Research Board was founded in 1936, with most work on marine fisheries ecology. Some of this work, such as conducted by Sleggs (1932), Thompson (1939, 1943), and Templeman (1948) and later by Templeman (e.g., 1966 and many references), has not been much improved upon in succeeding decades. After Confederation, there was a five-year transition period after which all responsibilities for fisheries science came under the Canadian Fisheries Research Board, a quasi-independent federally-funded organization with an impressive research record in the rest of Canada. During the 1950s and 1960s, a gradual switch to quantitative stock assessment methods from the earlier more ecological work mirrored such changes in most jurisdictions of the North Atlantic fisheries. After the major declines in the fisheries in the 1960s and early 1970s, and the extension of the Exclusive Economic Zone (EEZ) to 200 nautical miles in 1977, there was a rapid expansion of the fisheries research and management capacities of the newly-formed Department of Fisheries and Oceans (which replaced the Fisheries Research Board of Canada). Scientific responsibilities became focused on stock assessment, and the ecological work of the former era declined. **Developments in more quantitative fisheries science led to a tacit assumption that science would inform management precisely how much fish could be harvested annually, based on surveys and modeling, and that this would ensure that the stocks were allowed to rebuild and not be over-harvested. There was also an unfailing faith in the marine ecosystems of**

Newfoundland and Labrador to rejuvenate themselves in a manner consistent with earlier and more productive decades. Both these faiths have proven to be unfounded.

During the era of the Fisheries Research Board of Canada, there were attempts to develop fisheries programs at Memorial University (then Memorial College) and the Fisheries College. At one point, Dr. Wilfred Templeman, the Director of the Federal Laboratory, was also a University Professor in Fisheries. However, none of these early efforts succeeded in establishing a major fisheries research presence at Memorial. The biology department at Memorial developed a very different focus which remains to this day, and the main ocean focus is on "marine biology", which is quite different from fisheries science[4]. In a similar vein, the Ocean Science Centre now concentrates on aquaculture, and various aspects of oceanography and marine biology, but not on fisheries. The Marine Institute conducts very applied research related to the fisheries (e.g., net construction, catching efficiency, fishermen training), but little basic research into the fisheries. The Fisheries Conservation Chair was established at the Marine Institute as part of Memorial in 1996, and has been a focus for fisheries research. However, this group has not been able to grow as hoped, and currently has only a single faculty member. There is the Masters in Marine Science program, which introduces but does not focus on fisheries science. Overall, the lack of fisheries science at Memorial is astounding, given the history and economy of Newfoundland and Labrador. Compare Memorial with the University of Washington in Seattle. UW has a College of Ocean and Fishery Sciences comprised of four schools in Aquatic and Fishery Science, Applied Physics, Marine Affairs and Oceanography, and a Sea Grant group that focuses on particular issues. Each school offers degree programs. The School of Aquatic and Fisheries Science has approximately 30 faculty and at present 10 post-doctoral fellows and dozens of graduate students. Most faculty work closely with scientists at the U.S. National Marine Fisheries Service laboratories in Seattle. Memorial has none of this, yet the history and future of Newfoundland and Labrador are far more closely linked to fisheries than is the State of Washington (after all, they have Boeing and Microsoft and a major agricultural industry). There has been a perverse and enduring reluctance at Memorial to take a leading role in fisheries science, despite a mandate to serve the interests of the province, and to work with various government departments to that end.

Universities in British Columbia and the Maritime provinces have had many of the same problems, but have fared somewhat better. For example, UBC and Simon Fraser universities have each recently put together impressive teams of academic faculty whose primary interests are not marine biology or general ocean studies (they also have these), but fisheries science and management. Although Dalhousie offers only a general marine biology program (and oceanography), there has been recent hiring in marine conservation areas, and several well known fisheries ecologists work there. Somewhat ironically, both UBC and Dalhousie faculty have conducted research on Newfoundland and Labrador fisheries (e.g., Walters and Maguire, 1996; Hutchings, 1996; Guenette et al., 2000). Surely the fisheries industry in Newfoundland and Labrador is worthy of at least as much attention from its own provincial academic institution.

During the late 1980s and early 1990s, there was a rapid expansion in the science capacity of the DFO and a growth in DFO involvement with Memorial faculty with interest in marine research on cod. During this period, the Northern Cod Research Program, which resulted from the Harris Panel report (1990) and the Ocean Production Enhancement Network (an NSERC Centre of Excellence in Fisheries Oceanography), brought new resources and people to bear on the problems with the Newfoundland cod ecosystems. There was progress, and hundreds of scientific papers were published. New evidence about stock structure and genetics (Ruzzante et al., 1997; 2001), migration and distribution (Rose, 1993; Rose et al., 1994; Warren, 1997; Atkinson et al., 1997; Colbourne et al., 1997), recruitment (Anderson and Dalley, 1997; deYoung and Rose, 1993; Anderson and Rose, 2001), feeding (Lilly, 1994; Deblois et al., 1995; 1996) and the decline and ecology of cod (Taggart et al., 1994; Hutchings and Myers, 1994; Hutchings, 1996; Myers and Mertz, 1997; Myers and Cadigan, 1995; Myers et al., 1997; Colbourne et al., 1997; Narayanan et al., 1997; Walters and Maguire, 1997; Kulka et al., 1997; Rose and Kulka, 1999; Rose et al., 2000; Rice, 2002; Drinkwater, 2002) were direct benefits of this increase in research. However, this level of research, like the stocks of cod, was not to be sustained, and the mid-1990s brought severe cutbacks in research. In the DFO Science branch, an entire research group was disbanded (e.g., the former CODE which focused on quantitative fisheries science), and many scientists retired or left DFO and were not replaced. Budgets were cut substantially, and access to ships curtailed. In the late 1990s, the former fisheries vessels were integrated with Coast Guard. This coincided with reductions in vessel affinities to fisheries science programs and reductions in time available to serve science priorities (Sandeman, 2002).

The Present State of Fisheries Science and its Application to Management

The state of fisheries science and its translation to management of the Newfoundland and Labrador fisheries must be judged harshly. The Government of Canada and its current Department of Fisheries and Oceans have not been effective at conducting the necessary science and executing effective management of Newfoundland and Labrador fisheries. This state of affairs also applies in other Atlantic Canadian waters and in British Columbia, hence the problem cannot be viewed as being exclusive to any province. The apparent attitudes at Memorial University towards fisheries science have added to these problems in Newfoundland and Labrador.

It is evident that many of the most serious problems with the fisheries and with fisheries science did not arise until after Confederation (some no doubt by coincidence). However, there is little assurance that science and management would have been more successful under a different regime (e.g., Newfoundland-based) in the last half of the 20th century. In one area under provincial control, that is education, particularly at the university level, the evidence suggests that fisheries science has been grossly ignored and undervalued. Successive provincial governments have either trivialized and degraded fisheries ("burn your boats") or been at least complicitous with federal governments in unsustainable expansions in fisheries capacity, with scant scientific justification. Hence, the clear failures of science and management cannot be viewed as solely a federal failure, but also as a failure of Newfoundland and Labrador to foster and protect its fisheries, in favor of short-term political interests, and not the least, to international and local circumstances beyond the control of either level of government.

The first step to solving problems is to recognize them. What follows is a discussion of what are perceived to be underlying problems with fisheries science, and the approaches taken to fisheries science, in Newfoundland and Labrador. Possible solutions are then discussed that might enable Newfoundland and Labrador to improve its position and relationship within Canada. These discussions will in turn be followed by specific recommendations.

Centralization and Alienation of Science

Fisheries science has become an alien culture both within Newfoundland and Labrador and within Canada. It does not resonate well either within academic institutions or with industry or the public. At worst, it is mocked. Commentators on CBC's Fisheries Broadcast have referred to fishermen as the "real scientists", which is not only misleading and untrue, but intentionally demeaning to scientists. This does not happen to Physicists or Linguists or Engineers or any other discipline. Unfortunately, such attitudes only serve to perpetuate a rift between the legitimate knowledge base of fishermen and industry and the equally legitimate (but different) knowledge base of science. At the same time, the CBC belies age-old gentrified attitudes by over-reporting the largely negative views of rural Newfoundland and Labrador and the fisheries espoused by largely urban-based animal rights groups.

A major cause of alienation is that the centers of science and management are located thousands of kilometres from Newfoundland and Labrador and from any ocean, in Ottawa. Canada is a geocentrically-focused country whose capital and centers of power are centrally located. There are unspoken tendencies to address the needs of the central provinces (which are not fisheries management). The focus on land-based (and urban-based) issues is unfortunate considering that Canada has the longest coastline of any country and a long history of marine fisheries and seafaring activities. It is interesting to note that in the United States, the most populous and powerful regions are coastal and not central, which differs greatly from Canada, and this difference may be reflected in more aggressive marine policies. From the standpoint of fisheries science and management, centralization is a source of alienation of both institutions and individuals from local concerns and experiences. It also enhances the likelihood that federal institutions become overly bureaucratic and that lobby groups with better resources will be able to influence management policies outside of the local context. A good example of this occurred in the late-1980s, when local inshore fishermen were convinced that offshore trawling was decimating the spawning cod stocks, and took DFO to court on that count (they lost – which only proves the law is not always right). At the same time large trawler-based companies, some based in Nova Scotia, were effectively lobbying to keep the trawler fishery going and the quotas high. This sad state of affairs continued in spite of local evidence that the stocks were exhibiting signs of major stress and decline. The large vessel shrimp fishery lobby continues that tradition. Newfoundland and Labrador has done little to develop a counter-balance to this centralization by developing a strong fisheries science capacity in this province.

It is noteworthy that the European Union has recently stated a commitment to decentralize fisheries authority, and DFO's own Atlantic Policy Fisheries Review process described a similar demand for decentralization in many consultations.

There have been problems with fisheries science and its interpretation at the political level since Confederation, perhaps because of a basic disconnect between Ottawa-based fisheries personnel and the realities of the biology of the fish stocks and the fisheries. There are many examples of this. After the extension of jurisdiction to 200 nautical miles in 1977, which was clearly insufficient to conserve these fisheries ecosystems, projections were made of how the Grand Banks (NAFO 3NO) and northern cod (NAFO 2J3KL) would respond to the lack of foreign fishing within the new EEZ. The biological projections were based on faulty interpretations of the basic biology of the species, and an assumption that the devastation of the fisheries of the 1950s and 1960s would have no long-lasting effects. As a result of false assumptions, the Kirby Report (1982) stated that “there will be many problems in the future for the Newfoundland fisheries, but lack of fish will not be one of them.” This could not have been further from the truth, but was, unfortunately, followed by a gold rush attitude among provincial politicians and industry which resulted in the building of unsustainable fishing fleets (apparently to replace the foreign fleets), and plants to process the coming abundance of fish. Much of this new effort was not based in Newfoundland and Labrador, but in other Canadian provinces, particularly Nova Scotia. The problems with science on the northern cod did not end there. Federal scientists, convinced that the northern cod was growing, must take some responsibility for the massive over-fishing that took place in the 1980s.

A related source of alienation is the lack of consideration of the traditional and local knowledge of fishermen about the species they fish for and the local ecosystem which is, in a sense, their ‘back yard’ (Neis et al., 1999). There is no better example of this than the failure of science to take seriously the concerns of inshore fishermen about the state of the northern cod in the 1980s. Quantifying local knowledge is not a trivial matter (to go from individual opinion to consensual fact), but neither is it impossible. Surveys conducted by the FFAW (telephone) and the sentinel fishery surveys have proven very useful to science in recent years, and now form an important part of several stock assessments.

Inadequate Support for Fisheries Science

In Newfoundland and Labrador, most fisheries science is conducted by the DFO and most of that science is specifically targeted toward stock assessment. Despite the powerful messages of the Harris report (1990), which advised that a broader-based ecological approach be taken to fisheries science, and the signing by Canada of the Rio Convention (1992) to foster biodiversity which has ecosystem-based research at its core, there has in fact been a shrinkage in research that would serve such a broader approach. Prime examples include the lack of capelin research and surveys, with the unacceptable conclusion that “in future, it is highly unlikely that relative estimates of year class strength and an assessment of stock status will be possible” (SSR B2-02, 2001). Capelin is the most important forage species in Newfoundland and Labrador waters (Lilly, 1994) and is essential to cod growth, reproduction and survival (Rose and O’Driscoll, 2002). This importance of capelin is paralleled in Icelandic and Norwegian waters (Vilhjalmsson, 2002). Despite this, there is no regular survey of capelin abundance in Newfoundland and Labrador waters (a former survey was ended in the mid-1990s as a consequence of confusion about capelin status and funding cuts). Another example is the dropping of the juvenile survey that provided early information on cod, haddock, capelin, redfish and other species that presumably should be rebuilt (e.g. Anderson and Rose, 2001). A third example is the lack of feeding studies by DFO on the main consumers in these ecosystems (the Fisheries Conservation Chair has been analyzing cod stomachs since 1996). It is clear that to achieve a better understanding of both the state of the marine resources, and their likely future levels and performance, an increase in research that takes an ecological approach to fisheries is needed. At present, an "ecosystem approach" has little substance, and hence in many cases science cannot answer questions as to why the fish stocks are in their present state, and what is the likely outcome of the species and abundance changes that have occurred in Newfoundland and Labrador waters in past decades.

The abilities of DFO science to achieve its mandate of providing advice on stock status and the potential for fisheries is hampered by several factors, including a reduction in both personnel and funding for science at all levels. At the DFO, the number of research scientists has declined significantly over the past decade, through both retirement and leaving. In addition, there is less access to ships by DFO science for surveys and research than at any time since the 1970s (Sandeman, 2002).

There are also apparent disproportionate allocations of available funding within DFO science. At present, shrimp and crab represent some 85 per cent of the landed value of fisheries in Newfoundland and Labrador, yet the research effort on these species is minimal. There are a minimal number of crab and shrimp scientists in DFO. There is a much higher representation in salmonid biology, even though salmonids comprise only recreational fisheries, and in groundfish.

A further problem stems from the shifting of fisheries research vessels to Canadian Coast Guard management. The Coast Guard and fisheries have a very different "culture", and science is not the priority it was when vessels were under fisheries control. There are too many instances of science programs being reduced or cut because of vessel down-time or tasking to non-science objectives. **Putting scientists out on the water is necessary to achieving good fisheries science (Rose, 1996), and doing so has become increasingly difficult.**

An "Ecosystem-Based" Approach and Curtailing Foreign Over-fishing

There is near universal agreement that the best way to proceed with fisheries management and marine conservation is to pursue an "ecosystem-based approach" (Sinclair et al., 2002). To do so, the ecosystem must be defined, researched, and human activities conducted within them managed as a unit**. For the Newfoundland Grand Banks, this is at present not possible, because the EEZ does not take in the full continental shelf ecosystem.** The NAFO regime has as objectives the conservation and management of the Northwest Atlantic fisheries in areas outside of the Canadian EEZ and for transboundary stocks. The NAFO regime controls the fisheries on the "Nose" and "Tail" of the Banks (Fig. 1), and applies different rules, quotas and standards of conservation and compliance than does the Canadian regime inside the EEZ. This dichotomy of approaches, and the lack of a conservation-based management plan under NAFO, has resulted in depletion of the cross-boundary stocks in NAFO 3L, 3M (the Flemish Cap) and on the southern Grand Banks (NAFO 3NO) (see Table 2). A comparison suggests that the NAFO record is worse than the Canadian record. For comparison, the 3NO (under

NAFO) and 3Ps (Canadian) stocks are in similar ecological regions and affected by similar ocean climates and biological regimes. However, the moratorium in 3Ps led to a rebound in that stock and a fishery reopening in 1997, and the stock has continued to grow. In stark contrast, the NAFO managed 3NO, which is subject to NAFO "bycatch" fisheries that exceed likely stock production, has not rebounded and may even be in further decline. Almost all of the NAFO-regulated groundfish stocks remain in a state of collapse (Table 2). The yellowtail flounder stock on the Grand Bank is the only notable exception. It is clear that NAFO cannot meet its conservation or management objectives.

An alternative form of management should be found in order to pursue an ecosystem-based approach to the Grand Banks fisheries. One option would be a form of custodial management of the full Grand Banks ecosystem as espoused by the Parliamentary Committee on Fisheries. Delays in achieving this goal should not deter Canadian action to develop an evolving ecosystem-based approach to our fisheries.

Managing Canadian Fisheries (Within the 200 Mile EEZ)

Although the focus of this report is fisheries science, management decisions will impact how science can and should be done. DFO Science is currently charged with providing advice on fish stock status that can be used by DFO management to formulate harvest limits and restrictions for fished stocks. Despite the problems referred to in other sections, the science produced is typically of a very high caliber. However, there is little consistency in how that science is interpreted or utilized. Groundfish stock status reports that are not under NAFO are submitted to the Fisheries Resource Conservation Council (FRCC), which holds consultations with industry and the public, then submit their own report with recommendations to the Minister. NAFO stocks (those that inhabit the Grand Banks and are considered to be transboundary) are assessed through NAFO without consultations and it is Canadian policy to accept NAFO decisions outright. Pelagic, crustacean and marine mammal stocks are assessed locally but these results are submitted directly to Ottawa DFO Science and then to management. This lack of a unified approach to science and management belies any attempt to develop an "ecosystem" approach to our oceans and also creates many imbalances and discontinuities in the conduct of various fisheries. The first step towards an ecosystem-approach should be to get our own house in order.

Management of the fisheries is arguably more difficult than conducting science. Science can and does hide, but management cannot. Managers come under too much pressure from international interests, other government departments, industrial and local interests, and directly from politicians. As a consequence, and somewhat understandably, DFO management is often too willing to capitulate to political interests or to short term fishery interests that are not in the interests of conservation or rational fisheries. Recent examples include the imposition of recreational fisheries on northern cod and northern Gulf cod at a time when stocks were at very low levels, and exploitation already high (opposed by both the FRCC and DFO Science), and the unwillingness to impose meaningful closed areas on the northern cod Bank stock components to protect spawning and juvenile fish. These represent a continuation of perverse policies that did little to sustain fisheries resources, or to secure the future of the Newfoundland and Labrador fishing industry.

A related problem with DFO management may be the lack of consistent training in its personnel, who come from a variety of backgrounds. Unlike Science branch personnel, who must hold University degrees in fisheries or a related science, there are no mandatory requirements for training in fisheries management to gain employment with Fisheries Management. Such training is thought to be essential for DFO fisheries managers, and there are specific training programs in Fisheries and Wildlife Management which cover the basics of managing renewable natural resources. The University of Guelph has offered such programs since the 1960s, although not specifically targeted at marine fisheries, and Memorial University now offers a Masters in Marine Science which is focused on marine fisheries and could form the basis for training of management-level personnel.

An ecosystem approach to management involves a balance of conservation of the full system and its component habitats, species and processes. At present, the unwritten strategy has been to fish what is currently available to the fullest extent possible (under the guise of quotas in some cases). Although it is not the intent of this report to give a detailed or comprehensive account of alternative management strategies for fisheries, it is useful to consider several (Table 3). Options range from simply fishing what is there in abundance to the maximum level, to attempts to manage the ecosystem for long-term stability. The first option will likely result in an unproductive ecosystem, the latter is simply impossible. Somewhere in the middle may lie the best path to take, which involves medium-term stability (5-10 years) as a strategy, attempts to enhance ecosystem productivity and species diversity as much as possible, and imposes reasonable scientific demands. In the Newfoundland and Labrador marine ecosystems, there are currently many species that have depressed population levels compared to earlier times (e.g., redfish, American plaice, haddock, herring), and fisheries potential lies dormant. More diverse ecosystems may be more robust against natural vagaries, so rebuilding these fisheries has an additional rationale. For rebuilding, there is a need to protect spawning and juvenile fish, by restricting fishing and gear within certain areas, and to maintain the populations of all components of the marine ecosystems at reasonable levels. Achieving a scientific and management method that recognizes and promotes a balance between species diversity and fisheries productivity is a key challenge for the 21st century.

The Lack of a Plan and Perverse Agendas

Another major problem facing fisheries science and management in Canada, and that impacts greatly the fisheries of Newfoundland and Labrador, is the apparent multiplicity of approaches being taken to conservation science and management by the federal government. **There exists no overall plan or strategy.** On the one hand, the DFO has as its mandate the conservation of marine resources and fisheries (it shares this mandate with many other countries through NAFO for many stocks), and has most of the country's expertise at its disposal. With the aid of fisheries academics and Industry, DFO (and NAFO) regularly conduct stock assessments to advise management, most of which are peer-reviewed, then for Canadian-managed groundfish stocks subject to further review and consultation with industry and local knowledge by the FRCC. Despite this system, which while imperfect has several essential checks and balances, the Department of the Environment has untethered the COSEWIC group (Committee on the Status of Endangered Wildlife in Canada), whose mandate is to independently identify endangered species. COSEWIC conducts *ad hoc* assessments of the state of various fish stocks, at times using students, which are not subject to any normal scientific peer review, nor any consultations. Up until the passage of the Species at Risk Act, COSEWIC reports were not binding, and so had little impact. However, it now appears that the work of a single person (with no necessary background in the fisheries) could supplant the work of many experts within a major government science branch. There is great cause for concern in this process - that time-tested scientific methods based on acknowledged and unbiased expertise, caution, and peer review are being given short shrift. In parallel with COSEWIC views, which are at least legitimate, there are also concerns that other federal departments (e.g., External Affairs) and lobby groups from the fishing industry and animal rights groups with at times perverse agendas have undue influence on fisheries management. These Departments and vested interest groups may have agendas at variance with future fisheries, and what can be viewed as external power struggles are being played out with little input from Newfoundland and Labrador. There is an old Swahili proverb that states that "when the elephants fight, the grass gets trampled". It appears that once again, the lack of independent fisheries science within Newfoundland and Labrador results in local fisheries being controlled by Canadian and international agendas that do not coincide with those of the Newfoundland and Labrador fisheries.

Table 3. Possible strategies for fisheries in Newfoundland and Labrador. A medium term outlook is thought to be the most realistic and beneficial scope for long-term planning.

Strategy	Benefits	Risks	Science Implications	Management Implications
Maximize short-term harvest, TACs a guideline only	Conceptually simple – recognizes ecosystem variability	Overharvest may compromise long term productivity and species status	Short-term projections	No bycatch, No attempt to rebuild threatened species
Maximize ecosystem diversity	Ecologically attractive – a more robust system	Difficult to achieve Economically questionable	Requires an unrealistic level of science	Unrealistic, Attempt to rebuild all species, Many closed areas
Maximize economic value	Economically attractive – "farming the ocean"	Ecologically undesirable, Unrealistic management goals, Potentially wasteful	Short-term projections	Bycatch could be large, Attempt to rebuild only valuable species, Threatened species
Medium term (5-10 year) sustainability – TACs for medium term	Economically attractive – recognizes ecosystem variability	Few	Medium-term projections (realistic)	Manageable, Rebuilding of species where possible, Some closed areas.
Long-term sustainability – long-term TAC goals	Economically attractive	Won't work – cannot manage ecosystems	Long-term steady states (unrealistic)	Very complex, Lots of surprises

Oil and Gas Exploration and Shipping

The increase in oil exploration through seismic work and in oil tanker traffic raises considerable concern about the future of the marine ecosystems around Newfoundland and Labrador. For all intents and purposes it appears that the oil industry has had a "carte blanche" to conduct seismic work when and where they want, without regard to fisheries resources. This has occurred despite evidence that seismic shooting can negatively impact fish behavior up to 30 km from the shooting range and for considerable periods (Engas et al., 1996) and many outstanding questions about effects on juvenile fish. There is a clear need for both restrictions and research on the seismic activity in marine ecosystems to avert potential effects on sensitive life stages or distributions of marine animals.

In addition, there is great concern about the potential for a major oil spill in Newfoundland and Labrador waters (Carew, 2000), and also about the chronic oil leakages from ships and their effects on the marine environment, in particular but not exclusively on sea-birds (Wiese, 2002). Consideration of the wider marine environment must become central to the ecosystem-based focus of fisheries science.

In conclusion, there is little evidence that fisheries science has been well fostered in Newfoundland and Labrador, and as a consequence the public and industry have not been well served by fisheries science. This situation may deteriorate further with the interventions of the federal Department of the Environment and COSEWIC. **The days when successful fisheries can be prosecuted without science are over.** The fault is not simply or exclusively with the DFO or the federal government, but just as much with local Newfoundland and Labrador interests that do not appear to value fisheries science. There is a clear need for a new direction, based firmly on ecosystem and fisheries science, that will ensure that both fisheries and the marine environment upon which the fisheries depend are able to be sustained and to secure their place in the future economy and society of Newfoundland and Labrador.

New Direction

Fisheries science in Newfoundland and Labrador needs a new foundation and new direction. In conducting this review, it became clear that these needs must first be addressed here in Newfoundland and Labrador, and best with bold and courageous action. **We turn our backs on the ocean, and on our fisheries and marine heritage at our deep peril.** In discussing the options, there are several principles which must be adhered to:

1. federally-funded fisheries science must regain an independence from the political concerns of management;
2. a broadly-based and continuity-rich scientific program will be near impossible without a stronger local base that includes an enhanced university-based component that focuses on Newfoundland and Labrador fisheries;
3. funding for fisheries research must be sufficient to sustain sea research surveys and should be partly provided for by industry.

The independence of science from management and the political processes of the day is vital not only to the quality of the science, but also to its credibility both to local industry and more broadly on the international scientific arena.[5] **There can be no concessions on this point.** It is doubtful if the present configuration of the DFO can deliver the type of science required. Current DFO science seems incapable of dealing with either external (NAFO, animal rights groups) or competing (COSEWIC) agendas. The fault is almost certainly to be the structure of the organization, which constrains the best efforts of science and people. A solution may be to impose a complete separation of science from the current DFO, and to broaden its mandate. **Ideally, an Institute of Fisheries Research, similar to those in Iceland and Norway, would be mandated and funded by the federal government to provide both stock assessments and research on all commercial fish stocks and their ecosystems.** Under such a system, there should be no need for additional COSEWIC bureaucracy for commercial marine species, as endangered species concerns would be dealt with under the new Institute (with responsibilities to the Fisheries Act, the Oceans Act, and the Species at Risk Act). In such an Institute, most research scientists would hold adjunct status at Memorial and compete for independent funding for more specialized research projects.

A vibrant and far-reaching fisheries science program also requires a strong university-based research program in addition to government-funded fisheries Institutes or Departments. Universities have the capacity to conduct short-term inquiries of a more specialized nature, the power of graduate students and post-doctoral fellows to conduct and inspire new research, cost-effectiveness, and also provide a conduit for young scientists to collaborate with and join government-based programs. Co-operation between government-based and university-based science is a win-win situation. There are many examples around the world of close and productive working relationships between government fisheries science and university fisheries research (e.g., Tokyo University of Fisheries - an entire university is devoted to fisheries in Japan - and the Japanese Federal Fisheries, the Universities of Bergen and the Norwegian College of Fisheries Science, Tromso and the Marine Research Institute in Norway, and the University of Washington and the National Marine Fisheries Service Laboratories in Seattle, Washington State). Why such relationships have developed only slowly in Newfoundland is hard to understand. Many university faculty might blame the DFO for this problem, and there has been much criticism about DFO science policies and actions with respect to lack of transparency, data secrecy, and outright perverseness (Hutchings et al., 1999). However, a major part of the problem likely lies with the university, and institutional and individual attitudes towards fisheries and fisheries science, that appear to have persisted for many decades. The institutional attitude seems to be that fisheries are not of sufficient scientific interest or scope to merit focus within the university. Hence, Memorial has only one or two faculty members dispersed among the many departments and Institutes who have formal training in fisheries science. In the most recent DFO science subvention program in 2002, in which DFO Newfoundland partnered with universities to conduct research, of five awards, only one was with Memorial, the others being with mainland universities. The simplest explanation for this state of affairs is that Memorial has few faculty for DFO science to partner with.

It is proposed that the most important single action that Newfoundland and Labrador could undertake to solidify and improve its fisheries science and relations within Canada would be to have Memorial University establish an academic Fisheries Science Centre. A model could be the Ocean Sciences Centre, which operates as a research facility within the university (primarily in aquaculture and fish physiology), with 8-10 research faculty. The initial focus of a Fisheries Centre would be to conduct research on the marine fisheries ecosystems of the North Atlantic, but also on other fisheries systems, and to offer graduate training and post-doctoral training. Students could come from Newfoundland and Labrador, other provinces, and other countries. With sufficient undergraduate student demand, the Centre could evolve to form a new department with degree granting status. The establishment of the Fisheries Centre is recommended whether or not the DFO is reorganized along the lines suggested in this report (ideally, a university Fisheries Centre would work seamlessly with federal and provincial fisheries interests). A new Centre should focus on Newfoundland and Labrador priorities on fisheries, and would enable a much stronger focus on fisheries science at Memorial, and a more effective interaction between government science and university science. The Centre could utilize existing facilities at the Ocean Sciences Centre and the new Bonne Bay research station, and would of necessity have close ties with the more applied research at the Marine Institute. There are several faculty at Memorial that could form the nucleus of such a Centre almost immediately, although new hiring in the fisheries area would also be necessary.

Fisheries science cannot be successfully conducted entirely within laboratories and offices (Rose, 1996). Surveys and at-sea research is essential, as is exposure of fisheries scientists to the marine ecosystems they are studying, if not to the fisheries. In Newfoundland and Labrador, access to vessels has been declining (Sandeman, 2002) and many important surveys and research have been dropped in recent years (e.g., the acoustic survey for capelin, the juvenile fish and ichthyoplankton survey) or substantially reduced. There is a need to have at least three fisheries research vessels operating year-round in Newfoundland and Labrador waters two with offshore capabilities, and one inshore). Of the three vessels that now operate in Newfoundland and Labrador waters for part of the year, only the CCGS Teleost is a modern fisheries research vessel, both the CCGS Templeman and CCGS Shamook are old and outdated for fisheries research. In addition, since the merging of fisheries research vessels with Coast Guard, there have been tendencies to down-play the importance of the science program, and to use the former fisheries research vessels for other tasks such as routine search and rescue. The fisheries research vessels should be extracted from Coast Guard and put under the control of DFO science or a new Institute of Fisheries Research.

Industry should play a larger role in supporting fisheries science in Newfoundland and Labrador. Industry involvement can take several forms. Funding should be offered for both basic and directed applied projects at Memorial and the DFO laboratory. In addition, Industry ship support could be used for surveys, as is done in Iceland, Norway, South Africa and New Zealand. Industry is well on its way to doing this. Funding has been available for NSERC Industrial Research Chairs at Memorial, independent surveys, and DFO collaborations. Such involvements should be encouraged, and would likely be more productive for Industry with an enhanced fisheries science capacity at Memorial, and an independent Institute of Fisheries Research.

A Rebuilding Plan for the Newfoundland and Labrador Fisheries

"Made Right Here" – a Newfoundland and Labrador slogan

A symptom of the lack of effective fisheries science (and management) in Newfoundland and Labrador is the lack of an overall comprehensive plan to guide rebuilding of the fisheries. There are no clear goals, few guidelines and little direction, and as a result many confusing and incompatible agendas receive endless and needless discussion**. Newfoundland and Labrador needs to refine its own future vision and to incorporate that vision into a master plan for its fisheries ecosystems and industry, as a basis of its future economy and society.** Such a plan will assist and influence federal planning and management. At Johannesburg, Canada committed to rebuilding depleted fish stocks, of which there are many in Newfoundland and Labrador waters. A key question is how does Canada intend to meet that commitment? A clear vision of the future of Newfoundland and Labrador and its marine ecosystem-based economy would no doubt help focus that commitment and guide its implementation. The master plan must be comprehensive in terms of conservation of the ecosystem, its components and fisheries, and address many of the most difficult problems facing the current fisheries and those of the future. It must be formulated with full public and industrial participation and consultation. This is not a time for faint hearts.

It is not the intent of this report to draw up such a plan, but rather to point out very clearly that one is needed, and to draw attention to what may be some of its key components. An effective plan will have to address issues pertaining to science, management and enforcement. Some of the key issues for science will be what types of science are needed and how much of it can we afford? Also who will do it and who will pay for it? There are key ecosystem-level questions about the recent regime shifts, the long-term impacts of fisheries, climate change, and the balance between high level predators (marine mammals), commercial groundfish, crustaceans and forage fish. Key issues for management, and there are many, will include foreign over-fishing on the Grand Banks, oil industry impacts and pollution, capacity limits through restrictions on licenses and allocations for fishing and for plants, the type of gear to be used in sustainable fisheries, the protection of forage fish stocks (capelin, herring, sand lance), the potential for reduction in seal herds, and management by restricting all fishing in sensitive spawning and juvenile areas both in the coastal and Banks regions. Planning can begin with single species, but should merge to form an "ecosystem" approach that takes into account ecological principles (as best we understand them), and the benefits of having a multi-trophic level balance and conservative harvests as a means to long term fisheries sustainability. History shows that it is neither acceptable nor effective to have such a plan fabricated in Ottawa. Newfoundland and Labrador needs to redefine and refocus its own version of its future.

Conclusions and Recommendations

It is the conclusion of this report that fisheries science has been inadequately developed in Newfoundland and Labrador to achieve goals generally associated with a sustainable and durable fisheries-based economy. The lack of local science has likely contributed to the current lack of fish. This situation began in an independent Newfoundland and Labrador, continued through Confederation with Canada, and has been exacerbated by a generic non-interest in fisheries science at the province's only university. Recommendations are divided into two parts, those that are entirely within local Newfoundland and Labrador jurisdiction, and those that require actions by external parties, in particular the federal government.

Newfoundland and Labrador

Newfoundland and Labrador must change its ways if it is to do better within Canada. We must better look after our own interests, notably the science, management and direction of our oldest and most important industry - the fishery. If we want to see why Newfoundland and Labrador has not fared as well as hoped since Confederation, we should first hold the mirror in front of our own institutions. In short, to increase the ability of Newfoundland and Labrador to renew and strengthen its relationship with Canada in terms of fisheries science, it is imperative that enhanced capacities for independent fisheries science be developed within Newfoundland and Labrador at Memorial University. This must be seen as the top priority if Newfoundland and Labrador is to improve its fisheries science and by doing so enhance its abilities to influence federal science and management. Otherwise, we should be content with having mainland interests make the decisions for us. The prospects of increasing fisheries science at Memorial under existing university structures have been limited. Hence, **it is recommended that Memorial University establish an academic Centre for Fisheries Science, with fisheries faculty taking an ecosystem-based approach to addressing areas of oceanography, stock assessment, and groundfish, pelagics, and crustacean fisheries science.**

Newfoundland and Labrador high school students might be expected to develop an interest in the science of the fisheries that are conducted on their doorsteps. Some do, but it is not enough. One reason may be that students are not exposed to the history and culture of Newfoundland and Labrador, which is inextricably entwined with the fisheries. Another is the generally negative view of the fisheries and their future. However, in one high school course on Newfoundland and Labrador history, much could be learned, almost by osmosis, about our historical and modern fisheries and their science and future. Is there any reason why fisheries science and models could not be studied in co-operating biology and mathematics classes? An ideal textbook for a course on the history and culture of Newfoundland and Labrador would be the recent book entitled *As near to heaven by sea, a history of Newfoundland and Labrador* by Kevin Major (2001). **It is recommended that a high school course on the history and culture of Newfoundland and Labrador be made mandatory in the high school curriculum.**

There is a need to clearly express a positive vision for the future of the Newfoundland and Labrador fisheries. **Hence, it is recommended that Newfoundland and Labrador, in**

consultation with the public and industry, develop a focused vision for its marine fisheries ecosystems and their biological, economic and social dimensions, with firm objectives to be included in a master plan.

External

Many actions that would likely lead to an improvement in fisheries science in Newfoundland and Labrador, and an improved position of Newfoundland and Labrador and its fishery within the economy of Canada, cannot be accomplished by Newfoundland and Labrador alone. This situation in no way lessens their importance. The independence of Canadian science under the DFO is imperative for effective fisheries management. However, the present configuration of science within the DFO is less than optimal. The lack of independence from management and political concerns can put science in a straightjacket, and recent declines in funding, personnel and ship service to science has reduced the local knowledge base significantly. Hence, **it is recommended that Newfoundland and Labrador urge the Government of Canada to reform federally-funded fisheries science into independent Institutes of Fisheries Research (in Newfoundland and Labrador, the Northwest Atlantic Institute of Fisheries Research) that would be independent of management, that scientific staffing be reinstated to levels of the 1980s, and that science vessels be reinstated under science control and that their number not be reduced further.**

Newfoundland and Labrador should embrace an "ecosystem" approach to fisheries and become a world leader in its development and implementation. The status quo of following trends in other jurisdictions, usually not to our benefit, is no longer acceptable. We have the ocean, the ecosystems, the fisheries, the marine mammals, the history and culture of a marine people, and an overall environment second-to-none on earth. What is lacking is the will to confront existing attitudes and power structures that traditionally have meant that Newfoundland and Labrador will neither control its own destiny nor prosper. It is clear that to put Newfoundland and Labrador in the forefront of marine conservation requires a change in attitude of most everyone involved in the fisheries, from the small boat harvester to those at Memorial University and in Ottawa. To accomplish this will require a tough political approach to management not seen since the days of the fishing Admirals (not that we want to see them back). One thing is clear. Such a change must start here.

An ecosystem-based approach requires that activities and developments taking place within ecosystems be managed. At present, such a unified approach is impossible in Newfoundland and Labrador waters, because the EEZ does not encompass the full continental shelf whose shelf break forms the most obvious boundary of the coastal ecosystem. The current system of dual management, that of Canada inside the EEZ, and that of the NAFO conglomerate outside the EEZ, on the same fish stocks, is not consistent with an ecosystem approach to fisheries. A unified management of the full ecosystem is mandatory in order to practice an ecosystem approach to fisheries. Hence**, it is recommended that Newfoundland and Labrador endorse and pursue a unified approach to the science, management and enforcement of the Grand Banks fisheries that is ecosystem-based and implemented by the coastal state (Canada).**

It is also important to note that present difficulties with NAFO provide no argument for not working towards ecosystem-based management in Canadian waters.

Successful management of the marine fisheries by model-based quota setting has a checkered track record. There are several reasons for this. Model fitting procedures and data interpretations often lead to "retrospective" problems in which models systematically overestimate stock size and underestimate fishing mortality. In addition, exploitation levels can be set too high (on the basis of misinterpreted historical data on sustainable harvest rates), or if the rates are appropriate, are overshot. Discarding and other poor fishing practices effectively may make modeling a paper exercise (e.g., see Shelton and Lilly, 2001, for northern cod). For all these reasons, a more robust and conservation-based approach is needed, and one that fits better into an ecosystem approach. Newfoundland and Labrador is in a strong position to take a leadership role in fisheries conservation by implementing new fisheries management measures that would buffer the stocks against errors in science and the vagaries of nature (neither of which is expected to cease). To do this, managers must become more familiar with new and alternative measures of management through fisheries management education and the setting of hiring standards for new employees with a focus on fisheries management. In addition, there are some particular management measures that could be used to help guide future fisheries and enhance the abilities of science to inform management on options for a sustainable and enduring fishery in Newfoundland and Labrador waters.

The current science-management system for Newfoundland and Labrador fisheries involves a mish-mash of different approaches. For groundfish stocks resident entirely within the Canadian EEZ, the FRCC sits between DFO science and the Minister, but not for other stocks. NAFO stocks are subject to an entirely different system, with no consultation, and with Canada accepting all NAFO decisions. Pelagics and crustaceans are not subject to FRCC review or consultation. The FRCC does not have an ecosystem mandate, or the authority to guide management directly. These factors impede the effectiveness of both fisheries science and management in Newfoundland and Labrador.

To address the inadequacies of the present system in a constructive manner, and to conserve our fisheries for the future prosperity of Newfoundland and Labrador, several specific actions are recommended:

a) that long-term marine ecosystem management plans be developed (preferably by the FRCC or its successors in consultation with Newfoundland and Labrador) to address at least the following:

   i. determinations of conservation-based fishery harvest levels within the ecosystem context,
   ii. recognition of the climate-based nature of the fisheries and potential for change over time,
   iii. rebuilding collapsed stocks and ecosystem processes,
   iv. allocation of rebuilding groundfish resources and appropriate gear types (e.g. inshore versus offshore fishery; abolition of destructive fishing practices),
   v. appropriate scientific monitoring (e.g., surveys of multiple trophic levels),
   vi. a system of substantial limited or no-take fishing and oil and gas exploration and development zones to protect habitat and spawning and juvenile fish,

vii. closure rules for unsustainable, uneconomic or undesirable fisheries (e.g., capelin),

viii. habitat protection and restrictions against pollution (both land and sea based).

b) that an Atlantic Fisheries Conservation Board be set up to replace the current Fisheries Resource Conservation Council. The AFCB would have responsibilities for all fisheries resources, would be comprised of independent experts from industry and governments, including several full-time scientific employees (seconded or retired), would take an "ecosystem" approach, and would advise management directly. The AFCB would report to the Federal Minister only for administrative purposes.

c) that locally-based fisheries councils be set-up that are close to the fisheries, involve local expertise, and can take responsibility for designated local management and enforcement functions such as bycatch allocation, seal control, and methods to limit poaching and enhance conservation.

Endnotes

[1] Reduction fisheries reduce fish into meal for animal feed or other protein

[2] Over-fishing can be defined as growth over-fishing, which reduces the yield of a fishery, or recruitment over-fishing, which reduces the abilities of a stock to self-recruit.

[3] Hutchings (1999) continued to argue that the early 1990s were not unusually cold.

[4] Fisheries science is an applied science that studies the effects of fishing and environmental variation on fish population dynamics and the ecosystem

[5] There are many other legitimate interests in marine resources, and this is not to deny them, nor proper political concerns of managing the fisheries, but neither these concerns nor the parties who have them should be in a position to influence science. The appropriate process is to have science provide research and analyses that lead to advice to management, and then through an additional process the consequences of various management alternatives suggested by the science be judged. Ideally, this additional process would involve an independent board similar to the present FRCC, but with a distinct difference in that this board would have authority to advise management directly. The Minister would not have such authority, and the influence of Ottawa-based DFO would diminish accordingly, in favor of local DFO management.

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Appendix I

Data for Historical Descriptions of Newfoundland Fisheries:

Historical data were collected from several sources (Table 1). Discrepancies in the data were resolved using a comparative method. For example, in many cases several independent data records existed for the same time period. A modal range was used to decide which record to use. This method worked well for all periods with the exception of the earliest data from the 17th century. The English fishery data were consistent, but there was disparity among historical treatment of the available French fishery data. Hutchings and Myers (1995) show very low catches through this period for northern cod. Alternative treatments of this same era by Pope (1995) and Cushing (1988) show substantially higher catches, based primarily on the French fishery. There was consistent agreement, however, that catches in the early 18th century were poor (considering the French catches or not). The early catches are almost certainly underestimated. They do not include any Portuguese or Basque data, which is unavailable, even though the Portuguese fishery was the first major fishery in these waters (one report of 150 vessels by 1550, cited in Cushing, 1988). Pope (1995) argues that these fisheries were minor compared to the French and English fisheries of this era.

There were sporadic occurrences of years for which no catch data exists (usually these were lost in a fire). However, the overall series for cod was strongly autocorrelated ($r = 0.85$ at lag 1). Hence, for some analyses the missing data were filled in by a moving average of catch in the two preceding and following years. Where data gaps were larger, linear extrapolation between data was used to estimate catches. This occurred only with data from the 16th and 17th centuries. As a consequence, the interannual variability in catch in these centuries is likely underestimated. French catches from 1793-1893 were estimated from a linear model based on vessel numbers (de La Villemarque, 1994) in relation to known catches in the late 18th century (de La Villemarque, 1991). Increasing efficiencies in the 19th century would indicate these catches are also underestimated.

Historical climate data from direct measures and reconstructed from tree ring analyses were taken from the literature. Tree ring data provide the longest continuous series of climate data available with which to compare to northern fisheries data (e.g., D'Arrigo and Jacoby, 1992).

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Appendix II

Table 3. Sources of historical fisheries data.

Century	Fishery	References
16th	French	De La Villemarque (1991, 1994), La Morandiere (1962), Cushing (1988)
	English	Cell (1969), Cushing (1988)
17th	French	De La Villemarque (1991, 1994), La Morandiere (1962), Cushing (1988)
	English	Prowse (1895), Ryan (1969), Forsey and Lear (1987)
18th	French	De La Villemarque (1991, 1994), La Morandiere (1962), Cushing (1988)
	English/NF	Prowse (1895), Ryan (1969), Forsey and Lear (1987)
19th	French	De La Villemarque (1994), Prowse (1895), Sette (1929), ICNAF (1951)
	English/NF	Prowse (1895), Sette (1929), Ryan (1969), Forsey and Lear (1987), ICNAF (1951)
	Portuguese (1896- only)	ICNAF (1951)
20th	French	ICNAF (1951), NAFO (1996)
	NF	ICNAF (1951), NAFO (1996), Nordco (1981), Winsor (1992), DFO (unpublished)
	Portuguese	ICNAF (1951), NAFO (1996)
	American	ICNAF (1951), NAFO (1996)

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