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High Seas Reform

Actions to Reduce Bycatch and Implement Ecosystem-Based Management for the Northwest Atlantic Fisheries Organization

Andrew A. Rosenberg, Robert J. Trumble, Jennie M. Harrington, Oleg Martens, and Marjorie Mooney-Seus

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Prepared for WWF-Canada by:

MRAG Americas, Inc., Tampa, Florida

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Table of Contents

Preface

WWF-Canada commissioned this report to recommend specific reforms and steps for the Northwest Atlantic Fisheries Organization (NAFO) to implement ecosystem-based management (EBM), reduce bycatch, and recover depleted fish stocks on the Grand Banks of Newfoundland. While specific to NAFO, the report builds on other recent global initiatives by WWF, and partners, in mapping out an agenda to implement badly needed reforms of global fisheries management.

- This report is a companion to WWF-Canada's report *Bycatch on the High Seas: A Review of the Effectiveness of the Northwest Atlantic Fisheries Organization* (see http://www.wwf.ca/AboutWWF/WhatWeDo/ConservationPrograms/Marine/BycatchReport.asp), which in particular highlighted the issue of excessive bycatch and its implications on NAFO-managed stocks.

- It builds on recognized, leading international policy and management approaches promoted recently in key fora, including the United Nations Open-ended Informal Consultative Process on Oceans and the Law of the Sea (UNICPOLOS) and the United Nations Fish Stocks Agreement (UNFSA) Review Conference.

- It echoes many of the recommendations of the WWF/TRAFFIC report *Follow the Leader – Learning from experience and best practice in regional fisheries management organizations* (see http://www.panda.org/about_wwf/what_we_do/marine/publications/index.cfm?uNewsID=69480), which reviewed the performance of regional fisheries management organizations (RFMOs) internationally and provided guidance on how they can be more effective in meeting their responsibilities to manage fish stocks, and associated ecosystems, more sustainably.

- It complements elements of WWF's comprehensive framework for EBM presented in the report *Policy Proposals and Operational Guidance for Ecosystem-based Management of Marine Capture Fisheries* (see http://www.panda.org/about_wwf/what_we_do/marine/publications/index.cfm?uNewsID=71920), acknowledged by the Food and Agricultural Organization (FAO) of the United Nations as valid operational guidance for EBM.

- It reinforces the need to adopt the recommendations of the Organization for Economic Co-operation and Development (OECD) High Seas Task Force on illegal, unreported, and unregulated fishing (IUU) (see http://www.high-seas.org/). The Task Force was a group of fisheries ministers and international NGOs (including WWF) that developed an action plan designed to combat IUU fishing on the high seas – a chronic problem inhibiting the recovery of Grand Banks fisheries.

It is intended that this report will provide useful guidance and management recommendations to those countries that are party to the NAFO Convention and who face an historic opportunity to reform fisheries management – perhaps the last chance to place the Grand Banks ecosystem on a path to recovery.

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Dr. Robert Trumble joined MRAG Americas in 2000 as a senior research scientist and became Vice-President in 2005. Dr. Trumble's work includes preparation and review of fisheries and habitat management plans, development of bycatch management and control schemes, preparation of environmental assessments, conducting workshops on fisheries issues, and managing observer programs. Dr. Trumble received a BSc in Oceanography, an MSc in Fisheries, and a PhD in Fisheries from the University of Washington.

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Jennie Harrington has been a fishery biologist with MRAG Americas since 2003, working on a variety of projects involving scientific research, compilation of data from fisheries around the United States, fishery information management systems, independent program reviews, and workshop organization and facilitation. Ms. Harrington has received a BA in Biology and Psychology from Middlebury College and an MSc in Zoology from the University of New Hampshire.

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Abbreviations

ABC	allowable biological catch
Blim	target biomass size of the entire population
CDS	catch documentation scheme (of CCAMLR)
CCAMLR	Convention on the Conservation of Antarctic Marine Living Resources
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
EBFM	ecosystem-based fisheries management
EBM	ecosystem-based management
EEZ	exclusive economic zone
EFH	essential fish habitat
EU	European Union
F	fishing mortality rate
FAO	Food and Agriculture Organization (United Nations)
Fmax	the level of fishing mortality (rate of removal by fishing) that produces the greatest yield-per-recruit from the fishery
F0.1	the fishing mortality rate at which the increase in yield-per-recruit in weight for an increase in a unit-of-effort is only 10 percent of the yield-per-recruit produced by the first unit of effort on the unexploited stock (i.e., the slope of the yield-per-recruit curve for the F0.1 rate is only one-tenth the slope of the curve at its origin)
GIS	geographic information system
IFQ	individual fishing quota
IUU	illegal, unregulated, and unreported (fishing)
MARPOL	International Convention for the Prevention of Pollution from Ships
MPA	marine protected area
MSC	Marine Stewardship Council
NAFO	Northwest Atlantic Fisheries Organization
NPFMC	North Pacific Fishery Management Council
NRA	NAFO Regulatory Area
RFMO	regional fishery management organization
SSC	Scientific and Statistical Committee (of NPFMC)
SSB	spawning stock biomass
SSBlim	target spawning stock biomass (predetermined threshold weight of all sexually mature fish in the population)
STACFEN	Standing Committee on the Fisheries Environment
STACFIS	Standing Committee on Fisheries Statistics
TAC	total allowable catch
VMS	vessel monitoring system

Executive Summary

The Northwest Atlantic Fisheries Organization (NAFO) manages most of the fisheries in the Northwest Atlantic outside of the 200-nautical-mile exclusive economic zone (EEZ) of Canada. The majority of these stocks have been severely overfished, few show signs of rebuilding, and nine are currently under moratoria.

Mounting international pressure prompted NAFO, at its September 2005 annual meeting, to create a working group to examine NAFO reform and recommend changes in the NAFO decision-making process to incorporate a precautionary approach and ecosystem considerations in fisheries management. A commitment to wider ecosystem-based management (EBM) would help reduce overfishing, rebuild fish stocks, and restore overall ecosystem health in the NAFO Regulatory Area (NRA).

The Effectiveness of NAFO Fisheries Management

NAFO has made progress in setting fishery management guidelines but has not fully implemented effective management measures in the NRA. NAFO's generally poor success in meeting its objectives demonstrates an inability to implement and enforce needed management measures. The severely depleted state of many of its managed stocks highlights the need for further action. Several factors have made it difficult for NAFO to meet its management objectives. These include:

- Lack of compliance with management measures
- Ineffective monitoring and enforcement
- Setting total allowable catches (TACs) above scientific advice and exceeding TACs
- Overfishing of unmanaged and newly managed stocks
- Fisheries on juveniles
- Illegal, unregulated, and unreported (IUU) fishing
- Bycatch of moratoria stocks
- Bycatch of noncommercial species
- Degradation of critical habitat
- Ecosystem changes from fishing

Ecosystem-Based Management

EBM acknowledges that fishing and other activities take place in complex communities of organisms and habitats. Applying the concepts of EBM to fisheries constitutes a major shift in perspective for most sectors of fisheries management, which tend to focus on a single species or stock and generally assume that the productivity of that stock is a function of its inherent population characteristics. Because the NAFO Convention specifically references fisheries, this report will focus on the application of EBM in fisheries, or ecosystem-based fisheries management (EBFM). The sustainability of catches without compromising the inherent structure and functioning of the marine ecosystem constitutes the main goal of EBFM.

This report identifies four specific objectives that NAFO could use for practical assessment during a shift to EBFM:

- Preventing or reversing overfishing
- Minimizing bycatch
- Identifying and protecting essential habitat
- Maintaining species diversity and key ecological interactions

Alaska's groundfish fishery, regulated by the North Pacific Fishery Management Council, represents a successful national EBFM effort that has resulted in a sustainable fishery after almost 30 years of harvest. The fishery for Antarctic marine resources, regulated by the Convention on the Conservation of Antarctic Marine Living Resources, represents a successful regional fishery management organization. Both fisheries management approaches have a long track record of incorporating ecosystem considerations into management decisions and serve as excellent examples of integrating ecosystem information and a precautionary approach into traditional management efforts.

Application of Ecosystem-Based Fisheries Management in the NAFO Regulatory Area – Case Studies

This report uses three case studies of NAFO-regulated stocks to explore the application of EBFM in the NRA:

- 3NO cod (*Gadus morhua*)
- 2 + 3KLMNO Greenland halibut (*Reinhardtius hippoglossoides*)
- 3LN and 3O redfish (*Sebastes mentella* and *S. fasciatus*)

All of these stocks are vulnerable due to reduced biomass levels but their management introduces unique challenges, as some are actively fished and others are currently under moratoria. For example, actively fished stocks continue to be overfished while moratoria stocks are threatened by bycatch in other fisheries. The case studies describe the problems each stock faces and recommend management measures needed to address the four general objectives of EBFM: preventing and reversing overfishing, minimizing bycatch, identifying and protecting essential habitat, and maintaining species diversity and key ecological interactions.

Recommendations for NAFO Reform

The case studies discuss performance of NAFO management as it relates to the four EBFM objectives. We used the information from the report to propose a set of management recommendations for NAFO to move in the direction of EBFM. We have assessed the recommendations as short-term, those that NAFO could adopt by policy within a year or two, and medium-term, those that would require evaluation and negotiation extending two years or longer. The following table summarizes the recommendations.

Recommendation Categories	Recommendations	Timing
Regulatory policy recommendations	**Ensure adherence to scientific advice** by allowing deviation from advice only in rare, justifiable situations where the consequences are documented and understood.	Short-term
	Make compliance with NAFO measures mandatory by removing the Objection Procedure from the NAFO Convention and requiring all Contracting Parties, as a condition of membership, to pass domestic legislation that ensures compliance with NAFO management measures.	Medium-term
	Strengthen the monitoring and enforcement program by ensuring compliance with regulations, complete and timely catch reporting, and enhanced scientific at-sea monitoring.	Short-term
Recommendations to prevent or reverse overfishing	**Develop and implement recovery and management plans** for all stocks under NAFO management. Plans must include clear, measurable management goals, objectives, and targets aimed at restoring depleted stocks and ensuring that fishing is sustainable over the long term.	Medium-term
	Apply the precautionary approach when setting TACs to hedge against management and scientific uncertainty and ensure that overexploitation does not occur.	Short-term
	Account for all sources of mortality of target stocks when setting TACs by setting an allowable biological catch (ABC) that accounts for commercial catch, retained and discarded bycatch, and other removals, and set commercial TACs such that total removals do not exceed the ABC.	Short-term
	Bring unregulated fisheries under NAFO management to ensure that these stocks are not overexploited.	Short-term
	Establish small fish protocols for all fisheries taking large numbers of juveniles (e.g., 3O redfish) to help manage the impact on these stocks.	Short-term
	Apply the recommendations of the High Seas Task Force to address IUU fishing.	Medium-term
Recommendations to minimize bycatch	**Establish absolute bycatch limits** to reduce excessive bycatch of moratoria stocks.	Short-term
	Implement gear modifications such as sorting grates to help reduce bycatch in all fisheries.	Short-term
	Provide incentives to reduce bycatch by assigning bycatch allotments to Contracting Parties.	Short-term
Recommendations to identify and protect essential habitat	**Identify and protect essential fish habitat** (e.g., spawning and nursery areas) to aid recovery and help ensure that catches are sustainable over the long term.	Medium-term
	Identify and protect sensitive habitats (e.g., cold-water coral concentrations) from damaging fishing activities.	Medium-term
	Minimize the adverse effects of fishing on habitat by evaluating the impact of fishing on different habitat types and implementing appropriate mitigation measures (e.g., closed areas, gear modifications).	Medium-term
Recommendations to maintain species diversity and key trophic relationships	**Model ecological relationships** to develop a better understanding of the trophic interactions in the NRA and surrounding ecosystem.	Medium-term
	Assess the status of species of concern and any potential impact fishing might have on them.	Medium-term

1. Introduction

The Northwest Atlantic Fisheries Organization (NAFO) manages most of the fish stocks (except sedentary species, salmon, and tunas/swordfish) of the Northwest Atlantic that straddle or occur outside Canada's 200-nautical-mile exclusive economic zone (EEZ). The NAFO Regulatory Area (NRA) includes the Nose and Tail of the Grand Banks of Newfoundland and the Flemish Cap (Figure 1).[1,2] NAFO manages 19 stocks comprising 11 species. The majority of these stocks have been severely overfished and 9 are currently under moratoria. Most moratoria stocks do not appear to be rebuilding, and the long-term health of other stocks is threatened. Rosenberg et al. (2005) noted that excessive bycatch mortality is a major impediment to fisheries recovery in the NRA.

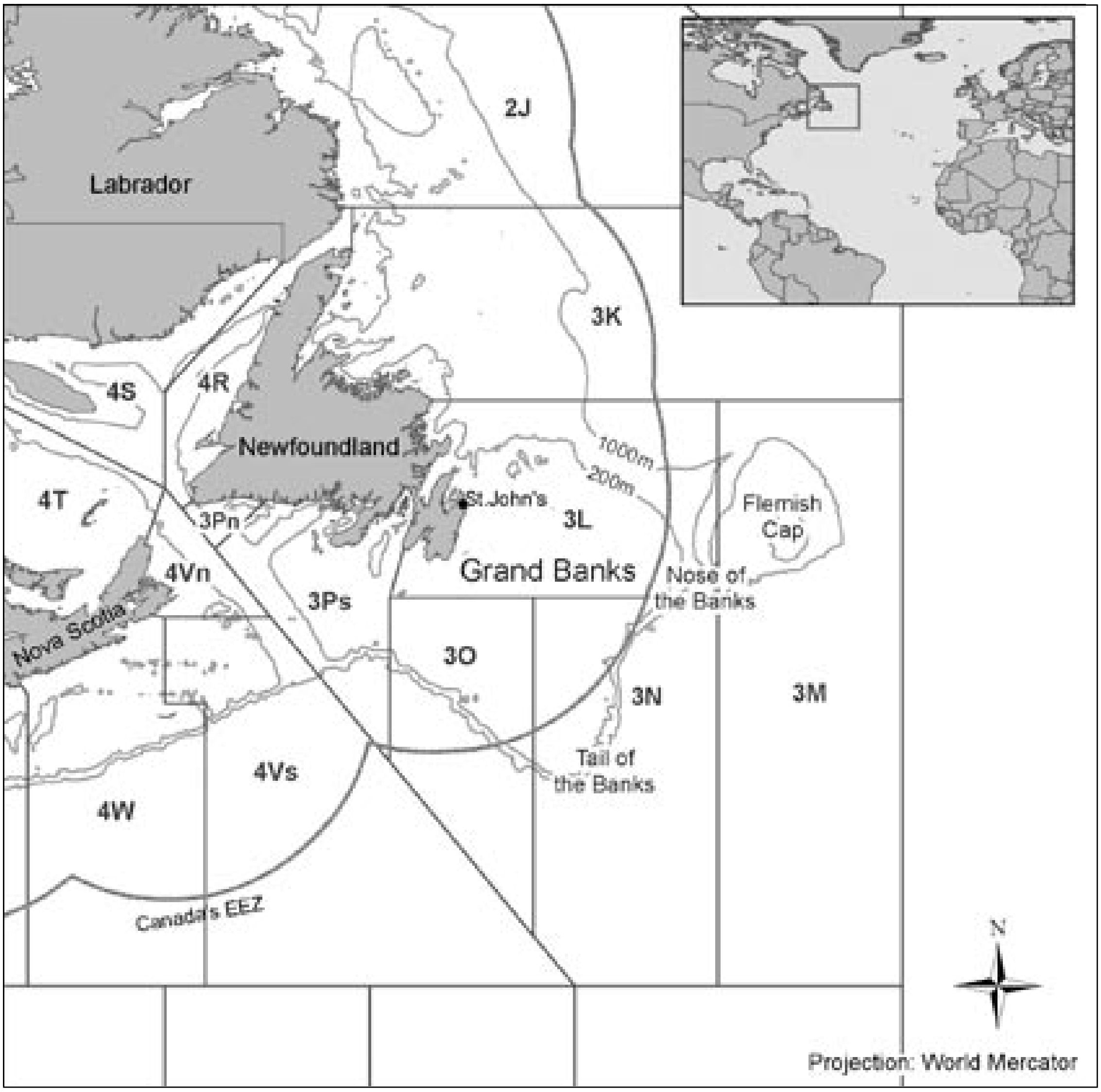

Figure 1. The NAFO Regulatory Area (NRA) includes the Nose and Tail of the Grand Banks of Newfoundland and the Flemish Cap. NAFO divisions and the fish stocks that occur in them are referred to by number/letter combinations, e.g., 3NO Atlantic cod, or 2 + 3KLMNO Greenland halibut (source: WWF-Canada).

[1] The NAFO Regulatory Area (NRA) technically includes all parts of the broader NAFO Convention Area that fall outside the exclusive economic zones of United States, Canada, Saint-Pierre and Miquelon and Greenland (see the NAFO website: http://www.nafo.ca/about/frames/about.html). However, most of the fishing activity in the NRA is concentrated on the Nose and Tail of the Grand Banks and Flemish Cap.

[2] The Grand Banks of Newfoundland include the five banks that flank the southern and eastern coasts of the island. The Grand Bank is the largest of these banks.

NAFO continues to debate management measures each year but has not done a thorough analysis of the problem nor tested the effectiveness of adopted measures. There are inherent problems in the current NAFO management system, which have been identified in previous work, and mounting international pressure has prompted NAFO, at the September 2005 annual meeting, to strike a working group to examine NAFO reform, as outlined in the May 2005 St. John's Declaration. The signatories to the St. John's Declaration agreed, *inter alia*, to implement a decision-making process that (i) relies on the best scientific information available, (ii) incorporates the precautionary approach, and (iii) incorporates ecosystem considerations in fisheries management with due consideration to the work of relevant scientific bodies and initiatives (see the St. John's Declaration: www.dfo-mpo.gc.ca/fgc-cgp/declaration_e.htm). The Canadian and European Union (EU) co-chaired working group will recommend changes to the NAFO Convention that will reform the decision-making process with respect to implementing a precautionary approach that incorporates ecosystem considerations in fisheries management.

International consensus is developing for expanding the focus of fisheries management to include recognition of the importance of the ecosystem in the management process (see section 3). NAFO has developed a Precautionary Approach Framework that, in part, takes ecosystem considerations into account. Only 3LNO yellowtail flounder (*Limanda ferruginea*) and 3M northern shrimp (*Pandalus borealis*), however, are currently regulated under the framework. A commitment to wider ecosystem-based management (EBM) would help rebuild depleted stocks and reduce overfishing in the NRA. The NAFO Fisheries Commission discussed the possible expansion of the Precautionary Approach Framework to other stocks during its September 2005 meeting, recommending that all Contracting Parties consult their respective scientists about prioritizing fish stocks for reference point determination (NAFO, 2005b).

The purpose of this report is to illustrate how an ecosystem-based approach to fisheries management could be implemented in the NRA. While not a comprehensive review of the institutional changes required in NAFO, the report does highlight several regulatory policy issues that will need to be addressed if new management measures are to be implemented effectively. The report is organized into four major sections: the effectiveness of NAFO fisheries management; EBM; application of EBM in the NRA, using case studies; and recommendations for NAFO reform.

2. The Effectiveness of NAFO Fisheries Management

NAFO's overall objective is to contribute, through consultation and cooperation, to the optimum use, rational management, and conservation of the fishery resources of the Convention Area (see the NAFO website: www.nafo.ca/about/frames/about.html). NAFO addresses its objectives through its Fisheries Commission, which establishes Conservation and Enforcement Measures that include a number of management and control regulations, a monitoring scheme, and inspection and surveillance measures. Since 2004, NAFO has published a compliance report. Enforcement of the NAFO regulations is the responsibility of the individual Contracting Parties. The Fisheries Commission receives scientific advice from the Scientific Council, which, on request, reports on the status of fish stocks in the NRA to the Fisheries Commission and coastal states.

NAFO is among several regional fishery management organizations (RFMOs) that have established or are establishing a foundation for EBM. NAFO has adopted a framework for implementing a precautionary approach, with reference points currently used to manage the 3M shrimp and 3LNO yellowtail flounder stocks, the latter of which reportedly is rebuilding. Based on the experience gained through these case studies, the Fisheries Commission will consider broader application to other NAFO stocks. 3LMNO Greenland halibut (*Reinhardtius hippoglossoides*), 3NO white hake (*Urophycis tenuis*), 3O redfish (*Sebastes mentella* and *S. fasciatus*), and 3LNO thorny skate (*Amblyraja radiata*) are currently managed under long-term protection plans, which in essence means that the TAC for each stock is fixed for a period of three years. NAFO also has improved transparency, addressed problems of fishing by nonmembers, and upgraded mechanisms and processes for monitoring compliance by NAFO members.

Ecosystem studies have long been a part of the work of the Scientific Council through its Standing Committee on Fisheries Environment (STACFEN) and more recently the Standing Committee on Fisheries Statistics (STACFIS) in its efforts to apply the precautionary approach to stock assessments and consider multi-species assessments. In 2006, NAFO will hold a symposium to advance knowledge of the Northwest Atlantic ecosystem.

NAFO has enacted a few measures for addressing bycatch and shark conservation. The Fisheries Commission agreed on continuing selective sorting grates for bycatch avoidance and 40-millimetre (mm) mesh size in the shrimp fishery on the Flemish Cap and Division 3L. The Fisheries Commission modified its Automated Hail/Vessel Monitoring System for continuous monitoring of fishing activities in the NRA. NAFO has endorsed the Food and Agriculture Organization of the United Nations (FAO) International Plan of Action for sharks and adopted measures banning finning and the transshipment and landing of shark fins in the NAFO area.

In 2004, NAFO enacted standardized observer reports and electronic submission of reports. NAFO also has created a procedure to blacklist Non-Contracting Party vessels involved in illegal, unreported, and unregulated (IUU) fishing in the Northwest Atlantic and will automatically share information about these IUU fishing activities with other regional fishery bodies and the FAO. NAFO Contracting Parties participated in an EU-hosted workshop for inspectors to harmonize procedures and methods for inspections at sea and in port.

While NAFO has made some progress, it still has a long way to go to achieve effective management measures. The NAFO policies and actions described above demonstrate an awareness of some of the components of effective management. However, NAFO's generally poor success in meeting its objectives, as described below, demonstrates an inability to implement and enforce needed management measures. The severely depleted state and lack of recovery of many of its managed stocks (e.g., in 2005, NAFO scientists recommended continued moratoria for 9 of 19 regulated stocks) is testimony to the need for further action. This section provides a brief overview of the problems that NAFO has experienced in its management approach.

2.1 Lack of Compliance with Management Measures

The restrictive nature of international law, which requires that nations consent to abide by regulatory measures of an international management organization with high seas jurisdiction, limits NAFO to voluntary compliance by Contracting Parties. NAFO does not have the authority to compel its members to comply with its Conservation and Enforcement Measures. Contracting Parties may use the Objection Procedure to opt out of NAFO regulations and object to allocated catch quotas either at the time a regulatory measure is proposed and before it enters into force, or at any time after a year. States can then continue to fish more without penalty. The Fisheries Commission may implement management measures less stringent than those the Scientific Council recommends (e.g., TACs) in an effort to obtain voluntary compliance from Contracting Parties that would otherwise not comply.

2.2 Ineffective Monitoring and Enforcement

Recognizing that the observer program lacked impartiality, timely submission of reports, and a standardized report format, NAFO members agreed at the 2004 annual meeting that observer reports should include catch and effort for each haul, location (longitude and latitude), depth, time of net on the bottom, catch composition, and discards and were to be sent to the NAFO Secretariat in an electronic format. To date, however, only a few countries are submitting reports electronically, and a standardized format for those transmissions has yet to be adopted.

At-sea patrols have been limited until recently, when Canada increased its presence, and Contracting Parties have not taken follow-up action on citations that were issued at sea (Rosenberg et al., 2005). Canada states that increased surveillance of its EEZ, begun in 2004, is having a positive impact: fewer vessels fish in the NRA, and international groundfish fleets have curtailed illegal fishing for moratoria species in the shallower waters of the continental shelf and have largely moved into deeper waters (see Government of Canada, Overfishing and International Fisheries and Oceans Governance: Enforcement: www.dfo-mpo.gc.ca/overfishing-surpeche/enforcement_e.htm). Canada also reported a decline in citations issued from 2003 to 2004, but an increase in 2005 and for the first quarter of 2006 over 2004. However, continued lack of follow-up on citations as identified by Rosenberg et al. (2005) negates the effectiveness of the citations.

2.3 Setting TACs above Scientific Advice and Exceeding TACs

The Fisheries Commission frequently sets TACs at or above the upper range of scientific advice, which has contributed to the decline of many NAFO-regulated stocks. Consistently setting high TACs does not allow a buffer for assessment errors. The Scientific Council provides recommendations on the total catch that should be allowed for a particular stock from directed fisheries, bycatch, and other removals. The Fisheries Commission decides on a TAC and allocates quotas to individual Contracting Parties, which are responsible for ensuring that their fleets do not exceed their quotas. It is not clear whether Contracting Parties take bycatch in other fisheries into account when dividing up their quotas. It appears as though, in most cases, the full quota is assigned to the target fisheries. In such cases, bycatch in other fisheries will cause total removals to exceed the TAC. Perhaps of most concern in the NRA is the redfish (*Sebastes mentella* and *S. fasciatus*) fishery (Rosenberg et al., 2005). The Fisheries Commission repeatedly set the commercial TACs for redfish at the high end of scientific advice (5,000 tonnes [t] for 3M; 20,000 t for 3O), although redfish bycatch in other fisheries respectively amounted to 15 percent to 22 percent of the TAC and was composed almost entirely of juveniles. In 2003, the Scientific Council recommended prohibiting directed fishing on redfish in Subareas 1 and 2 and 3K. The Fisheries Commission decided to allow a directed fishery with no TAC, which resulted in a catch of 32,242 tonnes of this stock.

2.4 Overfishing of Unmanaged and Newly Managed Stocks

Stocks for which no management measures exist or management measures were only recently adopted warrant closer scrutiny and precautionary actions to prevent overfishing. Subareas 2 and 3 roughhead grenadier (*Macrourus berglax*) is of most concern, as no management measures exist for this stock (Rosenberg et al., 2005). Although preliminary analysis indicates that the stock has declined, previous misreporting of roughhead grenadier as roundnose grenadier (*Coryphaenoides rupestris*) has made actual assessment of this stock difficult. In addition, Greenland halibut fisheries are reportedly taking high levels of roughhead grenadier as bycatch. For instance, roughly 45 percent of total catch in 3L consists of roughhead grenadier. A recent examination of roughhead and roundnose grenadier found that both qualify as endangered species under the World Conservation Union criteria (Devine et al., 2006).

The 3NO white hake fishery was unregulated prior to 2005 when NAFO set the first TAC for this stock. Before the 2006 fishing season the Scientific Council indicated that the biomass of 3NO white hake was low and that recruitment has been poor since the 1999 year-class. As a result, the council advised that the current TAC of 8,500 tonnes was not sustainable. The Fisheries Commission decided to maintain the 2006 TAC at 8,500 tonnes despite the concerns raised by the council.

2.5 Fisheries on Juveniles

A number of fisheries in the NRA take large numbers of juvenile fish. Unmarketable juveniles are probably discarded, but anecdotal evidence suggests that a significant amount of undersized and juvenile fish reaches some markets. The number of citations issued for the use of undersized mesh indicates that some vessels are targeting juveniles (see Government of Canada, Overfishing and International Fisheries and Oceans Governance: Citations: www.dfo-mpo.gc.ca/overfishing-surpeche/en_citations_e.htm). High catches of juvenile fish can affect future spawning stock biomass (SSB), which can lead to reduced commercial harvest levels or inhibit the recovery of depleted stocks. NAFO has adopted small fish protocols (if the amount of undersized fish in any one haul exceeds 10% by number, the vessel shall immediately move a minimum of 5 nautical miles from any position of the previous haul) only for Atlantic cod (*Gadus morhua*), American plaice (*Hippoglossoides platessoides*), yellowtail flounder, and Greenland halibut. Several other stocks discussed above have experienced substantial levels of juvenile harvest. These include 3M and 3O redfish, 2 +3KLMNO Greenland halibut, and 3NO white hake.

2.6 Illegal, Unreported, and Unregulated Fishing

Alleged IUU fishing activities by Contracting Parties and Non-Contracting Parties continue to restrict the effectiveness of stock rebuilding measures. NAFO is unable to prevent unregulated fishing in the NRA by Non-Contracting Parties such as Belize, Cyprus, Honduras, Sierra Leone, São Tomé and Principe, Panama, and Dominica. A major challenge to addressing IUU fishing is that Non-Contracting Parties must first agree to be inspected by NAFO inspectors. Oceanic redfish continues to be a prime target for Non-Contracting Parties in Divisions 1F and 2J. The High Seas Task Force, an international consortium of nations, including NAFO members, and nongovernmental organizations, has committed to practical solutions to IUU fishing and has prepared a series of proposals for confronting IUU fishing on the high seas (HSTF, 2006).

It is not known what impact IUU fishing has on moratoria stocks. However, because cod is under moratorium in Division 2J, and redfish and cod are consistently captured together in NAFO-regulated fisheries, it is assumed that some level of cod bycatch is occurring in the unregulated Non-Contracting Party redfish fisheries in this area. Very little information is available about the actual catch and bycatch by Non-Contracting Parties in the NRA, but moratoria species are likely retained and either not reported or misreported as having been taken from another area.

Another problem is the apparent inconsistencies in bycatch and discard rates for similar fisheries carried out by vessels from different Contracting Parties. Bycatch information is not available for all Contracting Parties, including some that have been cited for violations in the NRA (e.g., Estonia, Japan, France, Norway, Poland, Latvia, and Lithuania), so the impact of some fisheries on moratoria species is unknown. As a result, the true extent of the bycatch problem is likely underestimated.

2.7 Bycatch of Moratoria Stocks

Most of the fish stocks that are currently under moratoria continue to be harvested in significant amounts through bycatch in other fisheries in the NRA (Rosenberg et al., 2005). This bycatch is inhibiting the recovery or causing further decline of already depleted stocks. For example, although 3NO cod had an estimated biomass of only 6,100 tonnes in 2003, bycatch in other NAFO-regulated fisheries took as much as 70 percent to 89 percent of this biomass. Bycatch removals of 3NO cod occur primarily from the SSB. Similar bycatch problems occur for 3M cod, 3LNO American plaice, 3LN redfish, and 2J3KL and 3NO witch flounder (*Glyptocephalus cynoglossus*).

2.8 Bycatch of Noncommercial Species

Noncommercial bycatch in NAFO-managed fisheries primarily consists of benthic fishes and invertebrates. For example, wolffishes (*Anarhichas* spp.) are a common bycatch species in bottom-trawl fisheries in the NRA. Excessive bycatch of noncommercial species, while not immediately affecting the market for and availability of commercial stocks, will have longer-term effects that may lead to changes in trophic structure. Benthic fishes and invertebrates are often the prey of commercial species such as cod, and reducing their abundance will force commercial species to search for other sources of food.

2.9 Degradation of Critical Habitat

NAFO monitors physical oceanographic conditions in the NRA and the relationships between certain species and these conditions but it does not have adequate information on the distribution of habitats or the habitat requirements of fish species. Also, NAFO has not assessed the impacts of fishing activities on habitat or evaluated the protection needs for critical habitats, such as fish spawning and nursery grounds. Damage to these areas could inhibit the recovery of depleted stocks. Biogenic habitats, such as cold-water coral forests, are extremely vulnerable to mobile bottom gears because they can take centuries to form (Mortensen et al. 2004). Bottom trawling can also change the abundance and diversity patterns of benthic invertebrates that commercial species depend on for food. Although not well documented, decades of intensive bottom-trawl fishing has surely damaged certain benthic habitat types in the NRA (see *The Report of the ICES Advisory Committee on the Marine Environment* [www.ices.dk/pubs/crr/crr241/CRR241.PDF] for a review of the impacts of mobile bottom gear on benthic habitats).

2.10 Ecosystem Changes Due to Fishing

Sustainable fisheries and the recovery of depleted stocks depend on a healthy ecosystem. Extensive overfishing and depletion of dominant predatory groundfish species, such as Atlantic cod, and declines in prey species, such as capelin (*Mallotus villosus*), have contributed to changes in the ecosystem of the NRA. The consequences of altering an ecosystem can include trophic shifts, loss of biodiversity, and a decrease in species richness. Removal of species that change or influence the biogeochemical makeup of the sediment could negatively affect the biodiversity and the water-sediment processes (Coleman and Williams, 2002). NAFO has established a scientific working group to assess effects on fish of changes in the environment (e.g., climate shifts) but does not have a comparable effort to evaluate the effects of fishing on the ecosystem. Without such an effort, NAFO will not have the basic information needed to initiate recovery activities.

3. Ecosystem-Based Management

This section defines and explores the emerging concept of EBM.[3] The phrase "ecosystem approach" was first coined in the early 1980s but found formal acceptance at the Earth Summit in Rio de Janeiro in 1992, where it became an underpinning concept of the Convention on Biological Diversity. Since then, discussions have occurred in numerous forums on how to define and implement EBM and consensus within scientific and marine management communities, academia, and the fishing industry is growing [e.g., the FAO's Ecosystem Approach to Fisheries (Garcia et al., 2003)].

A recent comprehensive definition of the term EBM for oceans was published jointly by over 200 scientists and policy-makers:

> Ecosystem-based management is an integrated approach to management that considers the entire ecosystem, including humans. The goal of ecosystem-based management is to maintain an ecosystem in a healthy, productive and resilient condition so that it can provide the services humans want and need. Ecosystem-based management differs from current approaches that usually focus on a single species, sector, activity or concern; it considers the cumulative impacts of different sectors (McLeod et al. 2005).

EBM acknowledges that fisheries take place in complex communities of organisms and habitats. Applying the concepts of EBM to fisheries, sometimes termed ecosystem-based fisheries management (EBFM), constitutes a major shift in perspective for most, if not all, sectors of fisheries management. Because the NAFO Convention specifically references fisheries, this report will use the term EBFM throughout.

Most EBM or EBFM definitions include the following key elements, which could serve as guiding principles for the approach in the NRA:

- **The protection and restoration of marine ecosystems is the primary focus.**
  EBFM puts the conservation emphasis on preserving ecosystem structure and function, not just specific components of the ecosystem. Only intact, healthy ecosystems can provide the complete range of benefits that humans want and need over the long term. Removing or damaging some species can dramatically affect others and can disrupt the ability of the system to provide desired services, which range from sustainable food sources to climate regulation to aesthetic values. Healthy ecosystems are those in which environmental quality is high, habitat structure is intact, and a full range of biodiversity is maintained over the long term.

- **The cumulative impacts of different activities are explicitly considered.**
  Humans interfere with ecosystem components through the synergistic effects of exploitation, habitat destruction, nutrient loading, pollution, and other disturbances. For this reason, EBFM must consider the cumulative impact of different sectors. For example, even if each fishery in a large marine ecosystem is reasonably well managed, the cumulative ecosystem impacts of all of the fisheries will likely be greater than the summed effects of individual fisheries. Individual fishery management plans striving to obtain maximum sustainable yield often ignore fishery bycatch or predator-prey interactions. It is entirely possible that a fishery could be considered overfished within the ecosystem plan (i.e., ecosystem overfishing) when it is not overfished in a single-species context. This can occur when a forage species that serves as a prey resource for marine predators is also the target of a fishery, or when overfishing of large predators causes shifts in the food web.

- **The precautionary approach is key to implementing EBFM.**
  Although ecosystems can recover from many kinds of disturbance, they are not infinitely resilient. There is often a threshold beyond which an altered ecosystem may not return to its previous state. The tipping point for these irreversible changes may be impossible to predict. Thus, increased levels of precaution are prudent as ecosystems are pushed further from pre-existing states. Features that enhance the ability of an ecosystem to resist or recover from disturbance include the full natural complement of species, genetic diversity within species, multiple representative samples of each habitat type, and lack of degrading stress from other sources.

[3] Section 3 was completed jointly by MRAG Americas and WWF-Canada.

- **Management is based on clear objectives for conservation and sustainable use.**
EBFM should focus on clear objectives for ecosystem health and function. Multiple indicators and targets are needed to measure progress toward these objectives, the status of ecosystem functioning, service provision, and effectiveness of management efforts. Objectives should also be set for the sustainable use of oceans resources, which are directly linked to ecosystem objectives. For instance, sustaining marine fisheries means restoring and sustaining populations, species, biological communities, and marine ecosystems at high levels of productivity and biological diversity.

- **Management is informed by monitoring and research.**
Effective monitoring is needed to measure progress toward EFBM objectives, and additional research will be necessary to fill important information gaps. EBFM measures must be adapted over time to help address deficiencies or to incorporate new science.

  Monitoring. Ecosystem and catch monitoring is the cornerstone of effective EBFM. Both shore-based and at-sea monitoring of catches (including bycatch and discards) are required in all fisheries. EBFM implements timely and accurate recordkeeping and reporting requirements. Such measures require fishing vessel operators and, if requested, the purchasers to report fishing effort, catch, landings, processing, and transfers. An effective at-sea monitoring system, such as an observer program complemented by technology (e.g., vessel monitoring by satellite) will help assure compliance with quotas (individual, fleet, national), gear restrictions, closed/restricted areas, bycatch limits, and other management measures. Since higher levels of uncertainty require higher levels of precaution, collection of data on biological parameters, ecosystem function, and catch allows analysis that might reduce caution in setting management targets.

  Research. Priority areas for research include (1) the development of mathematical ecosystem models and other analytical approaches for understanding the impacts of fishing and the effectiveness of management measures, (2) identifying and understanding key interactions among species, and (3) classifying marine habitats and assessing their vulnerability to various fishing methods. Research will help reduce the existing uncertainties concerning EBFM.

3.1 Components of Ecosystem-Based Fisheries Management

While conventional fishery management tends to focus on a single species or stock and generally assumes that the productivity of that stock is a function of its inherent population characteristics, EBFM provides a more holistic approach. The sustainability of catches without compromising the inherent structure and functioning of the marine ecosystem constitutes the main goal of EBFM. This section presents four practical objectives for EBFM on which management bodies can focus during a shift to this approach:

- Preventing and reversing overfishing
- Minimizing bycatch
- Identifying and protecting essential habitat
- Maintaining species diversity and key ecological interactions

3.1.1 Preventing and reversing overfishing

Sustainable fishing and stock recovery can occur only when fishing pressure is compatible with stock productivity. Fishing mortality must account for all fishing-induced mortality, including bycatch, discards, and illegal or unreported catch.

To manage target species in the context of the overall state of the ecosystem, single-species targets are still appropriate but will need modification to account for other ecosystem components, primarily through reduction of target fishing mortalities. As uncertainty levels rise, EBFM uses increasingly conservative measures and sets harvest limits at precautionary levels. EBFM adheres to scientific advice and sets TACs above science-based recommendations only rarely and with full evaluation of impacts. Policy decisions and management changes are based on the best available scientific information.

Stefansson and Rosenberg (2005) pointed out the benefits of a properly implemented quota system but found that, when the input information for policy decisions is uncertain, combinations of catch quotas, closed areas, and effort control performed better than any of the measures alone. Uncertainty exists in the determination of TACs and in the ability of management agencies to control catch, effort, and closed areas. Therefore, combining methods provides a greater buffer to uncertainty. Closed areas improve performance of quota management as uncertainty in achieving the quotas increases, if closed areas are large enough to encompass a substantial portion of the fishing area.

Individual vessel owners and operators often have self-interests (maximizing economic benefits) that are different from the interests of society (maximizing societal benefits). Incentives can be used to align individual and societal interests. For example, a Marine Stewardship Council (MSC) certification of fish products promotes sustainable marine fisheries and responsible, environmentally appropriate, socially beneficial and economically viable fishing practices, and demonstrates that the fishery meets rigorous standards of stock status and assessment, ecosystem status, and fishery management.

3.1.2 Minimizing bycatch

All types of fishing gear catch unintended and undesirable species. EBFM attempts to minimize bycatch to limit the overall impact fishing has on the ecosystem. Accurate records or reliable estimates of bycatch and discards are needed to gauge impacts and measure the success of management measures. Bycatch must be limited to ecologically sustainable levels and accounted for.

Bycatch can be effectively minimized by (1) setting strict absolute bycatch limits for all fisheries, (2) accurate monitoring and reporting of all components of the catch (i.e., bycatch and discards count toward the TAC and can result in closure of fisheries that exceed bycatch limits), (3) incentives for bycatch reduction and avoidance, and (4) tools or technical measures, such as gear modifications, to facilitate bycatch reduction.

3.1.3 Identifying and protecting essential habitat

Fishing activities may damage or destroy habitat to the detriment of biological production and species and habitat diversity. To ensure that fish and other organisms have suitable habitat for spawning, feeding, and growth, EBFM must ensure that habitats are protected from adverse effects of fishing.

Effective habitat protection within the context of EBFM first requires the identification and mapping of all habitats that occur in the large marine ecosystem in which fishing occurs. Since certain habitats are more sensitive than others, each habitat type should be assessed to determine its vulnerabilities to fishing and other anthropogenic disturbances, and their biological and ecological significance. Those habitat types that are most vulnerable to fishing and critical to population or ecosystem processes warrant special management attention. EBFM ensures that essential habitats for fish and other sensitive areas, such as cold-water coral forests, are protected from bottom trawling and other potentially destructive fishing practices. Area closures and marine protected areas (MPAs) can be effective management tools to protect essential fish habitat and other sensitive areas.

3.1.4 Maintaining species diversity and key ecological interactions

Fishing activities often result in the incidental mortality of marine mammals, seabirds, and sea turtles in addition to the impacts they have on targeted species and their habitats. EBFM attempts to control the impacts of fisheries on all members of marine communities, particularly endangered and protected species. It also takes into consideration ecological processes that are essential for their recovery. Furthermore, fishing changes the size, age, and reproductive structure of fish populations and so changes predator-prey relationships. EBFM requires identification and preservation of such key interactions.

Single-species management has been successful at reducing incidental catch of protected species in some cases, but EBFM also manages indirect effects such as protecting forage species and essential habitat. For example, the predator-prey relationship between Atlantic cod and northern shrimp is well documented. Over the past decades, as the cod stock has declined, the shrimp stock has increased. Using typical single species management, this increase in the shrimp populations could be explained by environmental factors such as changing ocean temperature, completely ignoring the underlying cause – the decline in the cod population (Worm and Myers, 2003).

3.2 Examples of EBFM Implementation

A number of fisheries management bodies have implemented EBFM in some relevant way. While most examples constitute varying, and often limited, degrees of success in implementation, they represent intermediate steps along the way to more comprehensive EBFM. Here, we focus on two of the most convincing and outstanding examples of EBFM implementation: (1) Alaska's groundfish fishery regulated by the North Pacific Fishery Management Council (NPFMC) represents a successful national effort; and (2) the fishery for Antarctic marine resources regulated by the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) represents a successful RFMO. Both fisheries management approaches have a long track record of incorporating ecosystem considerations into management decisions. Furthermore, they offer excellent examples of the integration of ecosystem information and a precautionary approach into traditional management efforts.

3.2.1 North Pacific Fishery Management Council

The EBFM policies that the NPFMC has developed are successful in the sense that they have:

- Resulted in a sustainable fishery: all groundfish stocks are considered relatively healthy after almost 30 years of sustained harvests that total about 2 million tonnes per year. No fish stocks have been deemed overfished in the NPFMC's management area (the Bering Sea and the Aleutian Islands, encompassing an area of about 2.7 million square kilometres [km^2]).
- Effectively reduced bycatch (e.g., by up to 93% for a certain crab species and by 92% for herring).
- Managed to protect endangered sea mammals (e.g., Steller's sea lion [*Eumetopias jubatus*]).
- Led to sustainable fishing practices, as demonstrated by MSC certification for Alaska salmon (*Oncorhynchus* spp.), Alaska pollock (*Theragra chalcogramma*), Pacific cod (*Gadus macrocephalus*), and sablefish (*Anoplopoma fimbria*).

The NPFMC's precautionary ecosystem-based approach involves (1) conservative catch quotas, (2) limits on bycatch and discards of nontarget species, (3) marine protected areas, (4) measures to protect marine mammals, (5) reliance on scientific research and advice, (6) comprehensive monitoring and enforcement, and (7) public participation. The NPFMC's precautionary management approach is to apply judicious and responsible fisheries management practices, based on sound scientific research and analysis, proactively rather than reactively, to ensure the sustainability of fishery resources and associated ecosystems for the benefit of future, as well as current, generations. The NPFMC has not set harvest levels above the recommendations made by its scientific advisory body.

A more detailed examination of the NPFMC's groundfish management plans, including operational measures for EBFM implementation, is presented in the Appendix I of this report.

3.2.2 Convention on the Conservation of Antarctic Marine Living Resources

CCAMLR was the first RFMO to formally address uncertainty using a precautionary approach in the formulation of fishery management advice, and the first to implement conservation measures designed to reduce catastrophic bycatches of seabirds and other nontarget species.

CCAMLR was negotiated by the Antarctic treaty consultative parties in the late 1970s and entered into force in 1982. Its mandate is to ensure the conservation, including rational use, of Antarctic living marine resources. Convention measures are adopted by CCAMLR by consensus, but implemented and enforced by the 24 members of the convention. CCAMLR's area of influence includes the areas south of the Antarctic Polar Front. Fisheries management within this zone represents an ecosystem approach in the sense that it includes wide-ranging conservation principles. These principles support the objectives of (1) ensuring the maintenance of stable recruitment of target species; (2) maintaining the ecological integrity of the ecosystem, particularly in relation to predators of the target species; and (3) ensuring that the ecosystem effects of fishing are reversible over a fixed period.

The CCAMLR approach to EBFM explicitly considers (1) the impact of fishing on incidental seabird mortality, (2) the effects of trawling on the sea floor, (3) entanglement of marine species in marine debris, (4) the effects of bottom trawling for groundfish and midwater trawling for krill on incidental and nontarget species, and (5) the impact of other fisheries on target stocks by regulating development of new fisheries and emphasizing control and minimization of IUU fishing. CCAMLR's pioneering work on reducing seabird mortality in longline fisheries has contributed to setting the standard for other fisheries agencies (including the FAO) around the world.

Like all international conventions, the ultimate success of CCAMLR in achieving objectives requires voluntary cooperation of many members and recognition of measures by non-members. CCAMLR, however, has a substantial advantage over NAFO in that its measures are mandatory for members. CCAMLR does not impose regulations, but rather negotiates to reach agreement on measures that the members are then obligated to implement and enforce (see the CCAMLR website: www.ccamlr.org/pu/E/e_pubs/am/man-ant/p1.1.htm#Top%20of%20Page). CCAMLR members must require compliance of flag vessels with CCAMLR fishing regulations anywhere in the world. A CCAMLR documentation scheme prohibits landing of fish caught from convention waters in member states unless catch records comply with the documentation scheme.

A more detailed examination of CCAMLR's management plans, including operational measures for EBFM implementation, is presented in Appendix II of this report.

4. Application of Ecosystem-Based Fisheries Management in the NAFO Regulatory Area – Case Studies

To implement EBFM, a wide range of management tools tailored to the individual fisheries must be used. In this section, we explore the case studies of several NAFO-regulated fish stocks: 3NO cod, 2 + 3KLMNO Greenland halibut, and 3LN and 3O redfish. Each stock faces unique challenges and is at various stages of rebuilding. In each case study, we introduce problems and challenges that the fisheries face, and we discuss these in terms of the four EBFM objectives presented in section 3: preventing and reversing overfishing, minimizing bycatch, identifying and protecting essential habitat, and maintaining species diversity and key ecological interactions among species. Recommendations for implementing EBFM measures are provided for each stock.

4.1 Case Study – 3NO Cod

The first case study focuses on 3NO cod, a population of Atlantic cod that occurs on the Southern Grand Bank (Figure 2). This stock was selected because it was once a commercially important stock that has been overexploited, has been under a fishing moratorium since 1994 but has not recovered because of excessive bycatch in other fisheries, is a straddling stock that was targeted by vessels from Canada and other Contracting Parties, and was once a dominant demersal predator in the Southern Grand Bank ecosystem so its recovery could serve as an indicator of restored ecosystem health.

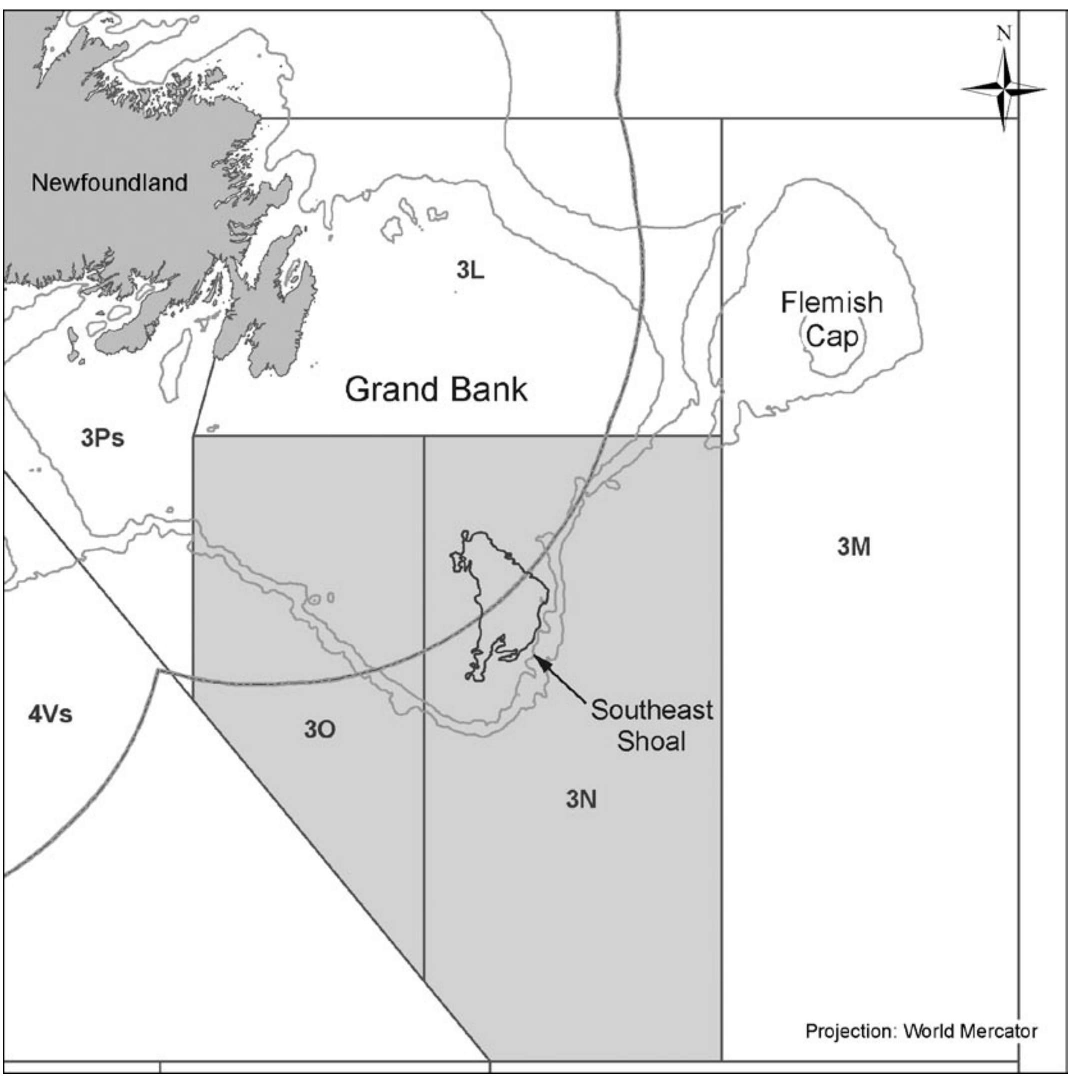

Figure 2. The 3NO cod stock occurs on the southern portion of the Grand Bank (source: WWF-Canada).

Cod is a demersal species found at depths of 10 metres (m) to 150 metres and temperatures of 0° Celsius to 13° Celsius (Collette and Klein-MacPhee, 2002). During the warmer months, the 3NO cod stock is mainly found in the vicinity of the Southeast Shoal but migrates to the slopes of the Grand Bank in the winter (Power et al., 2005). The average lifespan of Atlantic cod is approximately 20 years, and they reproduce at a fairly young age (age at 50% maturity was 4.9 years in 1990, and has since decreased even more) (Power et al., 2005). Recent fishing pressure on the 3NO cod stock, however, has decreased the average age at reproduction by removing most of the older fish (Healey et al., 2003). Spawning typically occurs on smooth sand, rock, pebble, or gravel substrates, in temperatures below 10º Celsius, at depths of 10 metres to 150 metres, and in a wide range of salinities. Cod in 3NO spawn between April and June, with a peak in the last half of May (Templeman, 1962). Cod larvae are found in the water column near the surface before returning to the bottom as juveniles on cobble or gravel substrates. Information about the essential fish habitat for this species is limited. However, Walsh et al. (2001) identified the Southeast Shoal as a cod nursery area.

4.1.1 Problems with 3NO cod

The main goals of EBFM are ecosystem health and sustainable catches. To achieve these goals, EBFM must incorporate precautionary measures that prevent overfishing, reduce excess bycatch, eliminate habitat destruction, and maintain trophic interactions. NAFO's inability to address a range of problems under these categories has resulted in the dramatic decline of the 3NO cod stock. This case study first outlines the problems that led to the decline and those that continue to inhibit the recovery of 3NO cod and then presents a suite of EBFM measures required to restore and effectively manage this stock.

4.1.1.1 Overfishing of 3NO cod

The 3NO cod stock has been under a moratorium since mid-1994. The stock crashed after the SSB (the total weight of all sexually mature fish in the population) was depleted by overfishing due to inappropriately high TACs and constantly exceeding TACs in the 1980s and early 1990s (Power et al., 2005). High catches in the 1960s and 1970s caused the SSB to drop to around 10,000 tonnes in the mid- to late 1970s (Figure 3). The stock appeared to recover as the SSB rose to approximately 90,000 tonnes in the early 1980s. Since the mid-1980s, however, the SSB and catch of 3NO cod has fallen dramatically. Current SSB is estimated to be 5,500 tonnes, or 9 percent of the target spawning stock biomass (SSBlim) (60,000 t) (Figure 3). SSBlim is a predetermined threshold weight of all sexually mature fish in the population. Below this biomass, stock productivity is likely to be seriously impaired.

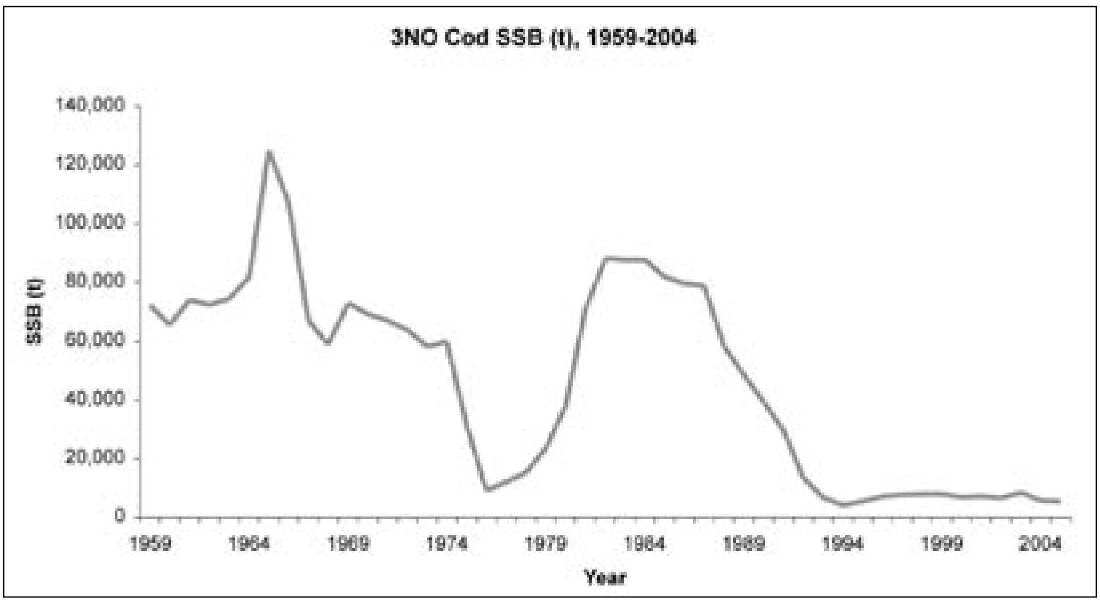

Figure 3. Estimated cod spawning stock biomass (SSB), in tonnes (t), in NAFO Division 3NO, 1959–2004, using annual ogives (cumulative frequency graphs) (source: Power et al., 2005).

In 1973, a TAC was introduced at 103,000 tonnes. Within three years of its establishment, the TAC was cut to less than half of its initial value. Since 1977, TACs have not risen above 40,000 tonnes, although they have fluctuated up and down (Figure 4). For the first five years that TACs were used in management, the total catch never came within 12,000 tonnes of the TAC, despite TACs dropping each year. This inability to reach the allocated quota could have been an early indicator of a declining stock biomass. In addition, between 1982 and 1993 (with the exception of 1992), when TACs ranged from 10,000 tonnes to 40,000 tonnes, the catch exceeded the TAC every year, further contributing to the stock's overfished condition (Figure 4).

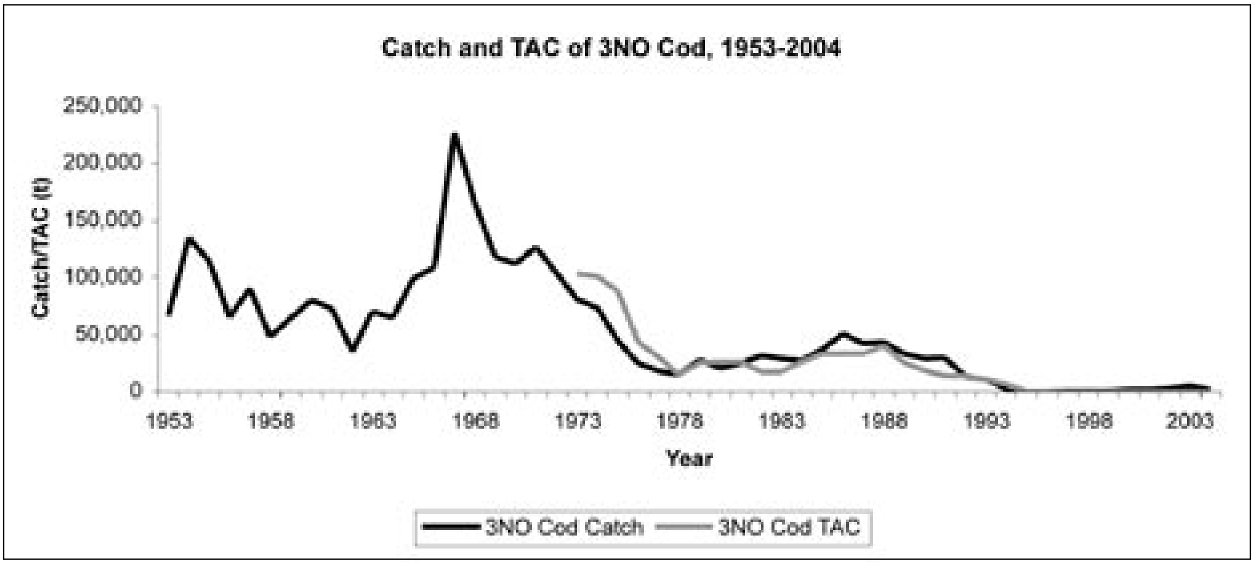

Figure 4. Catch and total allowable catch (TAC) of cod, in tonnes (t), in NAFO Division 3NO, 1953–2004 (source: Power et al., 2005).

NAFO waited too long to close the fishery after allowing the TAC to be exceeded for several years. There was little, if any, enforcement for overages on the TAC between 1982 and 1993. In addition, in-season monitoring was either not used or not heeded. If it had been, the fishery for 3NO cod would have been closed early every year between 1982 and 1993 (except for 1992). Once the annual catch totals were calculated, it was almost impossible to single out any individual country for exceeding the TAC. Even though reported landings are available for each Contracting Party, in-season management is not timely, and the fishing year ends before anyone realizes the TAC was exceeded.

4.1.1.2 Bycatch of 3NO cod

While the closing of the fishery was effective in stopping any authorized directed fishing for 3NO cod, the level of bycatch of this stock in other NAFO-regulated fisheries is a cause for concern. Catches of 3NO cod have actually increased since the moratorium (Figure 5). Between 1995 and 2003, the total annual bycatch of 3NO cod increased from 172 tonnes to 4,870 tonnes. The initial data for 2004 indicate that bycatch of cod has fallen to 934 tonnes, the first year since 1999 that the bycatch was below 1,000 tonnes. The majority of the bycatch is from the 3NO white hake, 3LNO yellowtail flounder, 3NO skate, 3N Greenland halibut, and 3O redfish fisheries, for which Canada, Portugal, Russia, and Spain hold most of the quota. These countries all reported lower bycatch of 3NO cod in 2004 than in 2003. Data are not available, however, from all NAFO Contracting Parties. Presumably, a significant proportion of 3NO cod bycatch is juveniles, but no data were found giving the amount of juvenile cod bycatch, or a ratio of adult to juvenile cod bycatch. In Power et al. (2005), catch at age is given, as are maturity at age values, which would allow calculation of juvenile catch. Despite being under moratorium, the average fishing mortality rate (F) for 3NO cod between 2000 and 2002 was 0.32, which is similar to that when fishing was permitted on this stock (Osborne, 2005; Power et al., 2005). Thus, overfishing is still occurring but in the form of bycatch, including "illegal" directed fishing.

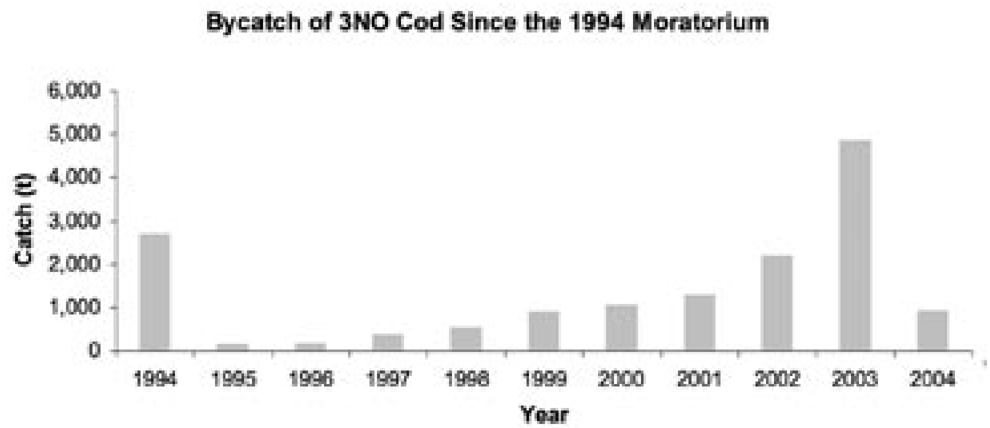

Figure 5. Bycatch of cod, in tonnes (t), in NAFO Division 3NO since the moratorium in February 1994 (source: Power et al., 2005).

The existing bycatch provision in the NAFO Conservation and Enforcement Measures states that "in cases where a ban on fishing is in force or an 'Others' quota has been fully utilized, bycatches of the species concerned may not exceed 1,250 kg or 5%, whichever is the greater." The percentages are calculated by weight for each species of the total catch weight retained onboard (NAFO, 2006a). This bycatch provision is effectively allowing a low level of fishing of the 3NO cod stock, a level that, according to recent scientific evidence, is neither precautionary nor sustainable. If this level of bycatch is allowed to continue, the cod stock is projected to fall to just 2 percent of the target SSB within four years, preventing the cod stock from growing and expanding into its previous trophic role in the ecosystem as a healthy stock (Power et al., 2005). Other models found even worse news. Results from fixed recruitment rate trials at low and recent recruits per SSB (1,000s of fish) and SSB per recruit (kilograms) levels indicate zero probability of rebuilding to above the target population biomass (Blim) by 2020 even when fishing mortality is zero. However, under random recruitment models, the possibility of rebuilding to Blim by 2020 was much greater, but fishing mortality still needs to be reduced by at least 50 percent (Shelton and Morgan, 2005).

4.1.1.3 3NO cod habitat destruction

When the 3NO cod fishery was open, the vast majority of cod were caught using bottom trawls; a smaller portion of the catch was made with set gillnets, set lines, and Danish and Scottish seines. Typical bottom-trawl fishing gear can affect the physical structure and complexity of the bottom habitat, potentially severely affecting the spawning, larval, and juvenile habitats described above. Damage to these habitats, which are crucial during sensitive life history stages, could have played a role in the decline of the 3NO cod stock and may continue to inhibit its recovery. The most well known effect of trawling is the destruction of physical bottom habitat, such as rock and shell formations, and biogenic structures, such as sponge reefs or cold-water coral forests. In addition, trawling can negatively affect community structure and the abundance and diversity of benthic organisms, including fishes and invertebrates that share the bottom habitat with cod (Auster et al., 1996). As the fishery has been closed for 11 years, the actual effect on the bottom habitat and other organisms of trawling for cod is not known. However, there has been trawling for other species such as yellowtail flounder and skates in 3NO. There is also a hydraulic dredge clam fishery operating on the Southeast Shoal. Løkkeborg (2005) described some of the effects of bottom trawling on benthic communities. On sandy bottoms, otter trawls create berms and furrows, and also affect surface relief but not sediment texture. Trawling decreased habitat complexity in this study, but the bottom habitat recovered within 1 year. On sandy/gravel bottoms, a decrease in sediment hardness and a slight increase in surface roughness occurred. These marks disappeared within five months, more quickly than on sandy bottom types.

4.1.1.4 Loss of species diversity and key interactions

Overfishing has altered the Southern Grand Bank ecosystem by drastically reducing the number of cod – a once dominant demersal predator. In addition, the 3NO capelin stock, a critically important prey species for cod and a range of other species, is depressed and is not rebuilding successfully despite a closed fishery and a reduction in predation (May et al., 2005). Many bottom-dwelling organisms are the prey of cod and other fish species; a decrease in the abundance of such organisms could lead to increased predation on juvenile cod by other fish species, reducing recruitment to the mature stock (Auster et al., 1996). For example, the New England cod fishery experienced an increase in predation on groundfish larvae by small pelagic species such as mackerel and herring, and a shift in the dominant fish predator from cod to spiny dogfish (*Squalus acanthias*) during the 1980s (Brodziak and Link, 2002). Worm and Myers (2003) and Frank et al. (2005) also demonstrate trophic cascading effects triggered by cod overfishing in Canadian waters.

4.1.2 EBFM measures for 3NO cod

The 3NO cod stock is severely depleted and continues to decline despite being under a 12-year moratorium. A recovery and management plan is clearly needed to first rebuild and then manage the 3NO cod stock sustainably. Since 3NO cod is a straddling stock, Canada and NAFO should develop and implement a joint recovery plan.

An effective recovery plan must include quantitative recovery targets for biological metrics, such as SSB. The target spawning stock biomasss (SSBlim) for a healthy 3NO cod stock is thought to be at least 60,000 tonnes. It is not clear whether fishing would be allowed to resume once the SSBlim is reached. Once the SSB reaches 30,000 tonnes, the SSBlim will be re-evaluated (Power et al., 2005). The current SSB is 5,500 tonnes, only 9 percent of the SSBlim.

Recent scientific assessments are pessimistic about the rebuilding potential for this stock unless cod bycatch in other fisheries is drastically reduced immediately. Projections indicate that even with zero removals, the SSB is expected to decline even further to 4,900 tonnes by 2010. If fishing (bycatch) continues at the current rate, the SSB could decline to only 1,300 tonnes (Power et al., 2005).

If and when this fishery reopens, it must be managed in a different manner than it was before the moratorium to be consistent with the principles of EBFM. The management plan must incorporate precautionary measures to (1) prevent overfishing, (2) minimize bycatch, (3) protect essential habitat, and (4) maintain species diversity and key trophic interactions. Reducing 3NO cod bycatch in other fisheries should be the initial focus of the plan, as bycatch poses the most immediate threat to this stock. The following sections present a set of management measures that are needed for the recovery and sustainable management of the 3NO cod stock.

4.1.2.1 Measures to address overfishing of 3NO cod

If 3NO cod recovers and the fishery reopens, the following measures should be implemented to prevent overfishing. TACs should be set at the low end of scientific advice as a precautionary measure. Quota overages must be eliminated within each fishing season using timely in-season management. Currently, in-season management, while applied in theory to all NAFO fisheries under TAC management, is not very timely or effective. Vessel trip limits could be useful as well. This would give a better basis for enforcing overfishing. Also, if the sharing of observer data among Contracting Parties and with NAFO were enforced (currently it is not), the prospect of in-season monitoring, both of catch and bycatch, would be much more feasible and would allow for better, more timely enforcement of TACs and bycatch limits. Stefansson and Rosenberg (2005) pointed out the benefits of a properly implemented quota system but found that combinations of catch quotas, closed areas, and effort control performed better – by providing a greater buffer to uncertainty – than any of the measures alone when the input information for policy decisions is uncertain.

4.1.2.2 Measures to minimize bycatch of 3NO cod

Bycatch control is essential to the recovery of the 3NO cod stock and will be a key element in preventing overfishing once a fishery resumes. To aid in the recovery, an absolute catch limit (or allowable biological catch [ABC]) should be set for the stock. If the ABC is exceeded, all fisheries that have significant cod bycatch should be closed.

Once the cod fishery reopens, the catch limit could be apportioned between the directed cod fishery and fisheries that take cod as bycatch (i.e., a bycatch quota could be established for all fisheries with significant cod bycatch). NAFO could manage the ABC for directed catch, for retained bycatch, or a combination. In no case should directed catch, retained bycatch, and discarded bycatch exceed the ABC. Mechanisms to reduce bycatch so that it does not exceed the ABC may be necessary (e.g., closed areas, gear modifications, other fishery closures). If bycatch cannot be reduced to keep total catches below the ABC, prohibiting retention of cod (as opposed to the 1,250 kg or 5% regulation currently in effect) may be required to prevent targeting in the guise of bycatch. For 3NO cod, observers should continue to be required to document all catches in a way sufficient to determine or estimate retained and discarded cod. Innovations in gear technology would also aid in preventing bycatch. Sorting grates, currently used in the Canadian yellowtail flounder fishery to exclude cod from the trawls, should be used by other countries and other fisheries.

4.1.2.3 Measures to protect important habitat for 3NO cod

Essential cod habitats (including those in spawning and nursery areas) should be identified and protected. NAFO currently has no such management measures in place for cod or other stocks. These actions would enhance recovery by protecting habitat, reducing bycatch, and minimizing disturbance during sensitive life history stages. The Southeast Shoal is known to be a 3NO cod nursery area (Walsh et al., 2001). Closing this area to all bottom fishing could aid the recovery of this depleted stock. Canada has used closed areas to protect groundfish habitat within its EEZ. For example, a 2,500-square-nautical-mile closure was established in Hawke Channel to protect spawning and juvenile concentrations of the 2J3KL cod stock (DFO, 2005).

Habitat effects from cod trawl gear should be thoroughly assessed, and appropriate mitigation measures should be implemented if and when the fishery reopens. Even though cod are often caught on bottom types with little vertical relief, there is potential for damage.

4.1.2.4 Measures to maintain species diversity and key interactions

Cod recovery and effective management will depend on a healthy ecosystem. Currently, the ecosystem is in an altered state in which key predators such as cod and important prey such as capelin are both depleted. These depletions cause trophic shifts, such as those observed in New England waters, and the same may have occurred on the Southern Grand Bank. The capelin fishery on the Southern Grand Bank should remain closed to aid in the recovery of this species, which is an integral component of the ecosystem. Predator-prey interactions should be closely studied to determine which fisheries should be a focus of investigation and rebuilding, as we need more research to better understand the intricate trophic interactions involved in the ecosystem.

4.2 Case Study – 2 + 3KLMNO Greenland halibut

Greenland halibut in 2 + 3KLMNO (*Reinhardtius hippoglossoides*) was selected as a case study stock because it is overfished, experiences high levels of mortality on juvenile fish, and is a straddling stock within the NRA and adjacent EEZs (Figure 6). Stock assessments are conducted annually and include data on total biomass, total mortality, bycatch, discards, fishing effort, and several other proxies. A 15-year rebuilding plan was initiated in 2004 after exploitable biomass had reached its lowest observed level and showed no signs of recovery in the near future. The official rebuilding plan, which can be found in chapter 1, article 7, of the NAFO Conservation and Enforcement Measures (see: www.nafo.ca/fisheries/CEM/chapter1.html#%23) specifies the following key points:

- The objective is to attain a level of exploitable biomass of 140,000 tonnes on average for fish age 5 and older, allowing a stable yield over the long term in the Greenland halibut fishery.
- Set TACs through 2007 as follows:

  2004: 20,000 tonnes
  2005: 19,000 tonnes
  2006: 18,500 tonnes
  2007: 16,000 tonnes

- Establish subsequent TACs by taking into account the progress made in the rebuilding of the stock, but set these TACS at levels not more than 15 percent less or greater than the TAC of the previous year.
- Monitor and review, through the Scientific Council, the progress of the program and submit an annual assessment of it to the Fisheries Commission.

The 2004 TAC, however, was still set above the Scientific Council recommendation, and there are serious concerns that the majority of the catch in the past two years is composed of juveniles. Shelton (2005) indicated that the rebuilding plan was unlikely to succeed because it allowed fishing mortality above precautionary rates.

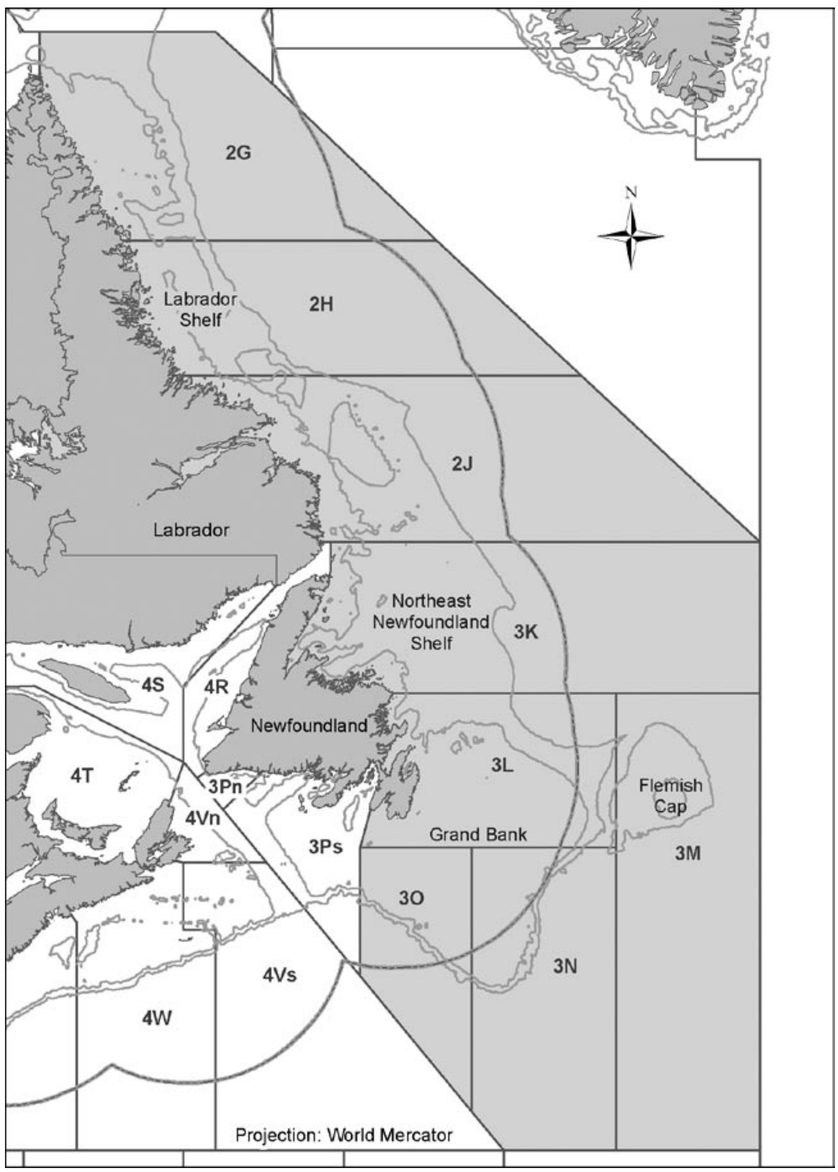

Figure 6. The 2 + 3KLMNO Greenland halibut stock extends from the Labrador Shelf to the Grand Bank (source: WWF-Canada).

Greenland halibut (also known as turbot) is a relatively slow-growing species. Females reach 50 percent maturity at a size of approximately 60 centimetres (cm) (when they are approximately nine years old) and produce 60,000 to 80,000 eggs. Spawning occurs in winter but may be protracted (starting as early as September and continuing until March) (Bulatov, 1983). The spawning grounds of Greenland halibut are believed to be located southwest of Greenland and to cover an extended area from Davis Strait, south of 67 degrees north latitude to south of Flemish Pass off Newfoundland, at depths between 800 metres and 2,000 metres (Boje, 2002). The eggs are benthypelagic (suspended in the water column near the bottom) (D'yakov, 1982). The larvae are planktonic for up to nine months until metamorphosis occurs, usually with a widespread distribution through shallow waters. Juveniles are believed to spend the first three or four years of life on the continental shelf, and then move to the continental slope as adults (Alton et al., 1988; Templeman, 1973). Greenland halibut are demersal to semipelagic. Adults inhabit continental slope waters and make annual spring/fall migrations from deeper to shallower waters.

Greenland Halibut is mostly caught by deep-sea trawling when it is 5 to 12 years of age, weighing between 1 and 4 kilograms. The numbers of male and female are roughly equal, as is their growth rate, until they reach a length of about 45 centimetres at the age of 6 to 7 years. Fish larger than 90 centimetres are all female.

The most significant natural predator of adults is the Greenland shark (*Somniosus microcephalus*), found in great numbers in the same waters and at the same depths as Greenland halibut. Other predators include hooded seals (*Cystophora cristata*), two species of arctic whales, cod, salmon, and other halibut. Because of its slow growth rate, and because many fish are caught before reaching sexual maturity, Greenland halibut is very vulnerable to fishing pressure.

4.2.1 Problems with 2 + 3KLMNO Greenland halibut

The main goals of EBFM are ecosystem health and sustainable catches. To achieve these goals, EBFM must incorporate precautionary measures that prevent overfishing, reduce excess bycatch, eliminate habitat destruction, and maintain trophic interactions. NAFO's inability to address a range of problems under these categories has resulted in the dramatic decline of the 2 + 3KLMNO Greenland halibut stock. This case study first outlines the problems that led to the decline and continue to inhibit the recovery of 2 + 3KLMNO Greenland halibut. Discussion of a suite of EBFM measures required to restore and effectively manage this stock follows.

4.2.1.1 Overfishing of 2 + 3KLMNO Greenland halibut

NAFO manages the 2 + 3KLMNO Greenland halibut as a biological stock complex, which includes Subareas 0 and 1 (NAFO, 2005c). Prior to 1995, Canada set TACs autonomously; since then, the Fisheries Commission has established TACs. Catches increased sharply in 1990 due to a developing fishery in the NRA in Division 3LMNO and continued at high levels during 1991 to 1994 (Figure 7). The catch was only 15,000 tonnes to 20,000 tonnes per year during 1995 to 1998 as a result of lower TACs under management measures the Fisheries Commission introduced. The catch increased since 1998 and by 2001 was estimated to be 38,000 tonnes, the highest since 1994. The estimated catch for 2002 was 34,000 tonnes (Table 1). The 2003 catch could not be estimated precisely but was believed to be within the range of 32,000 tonnes to 38,500 tonnes. The 2004 catch was 25,500 tonnes, exceeding the 2004 rebuilding plan TAC by 27 percent (NAFO, 2005b).

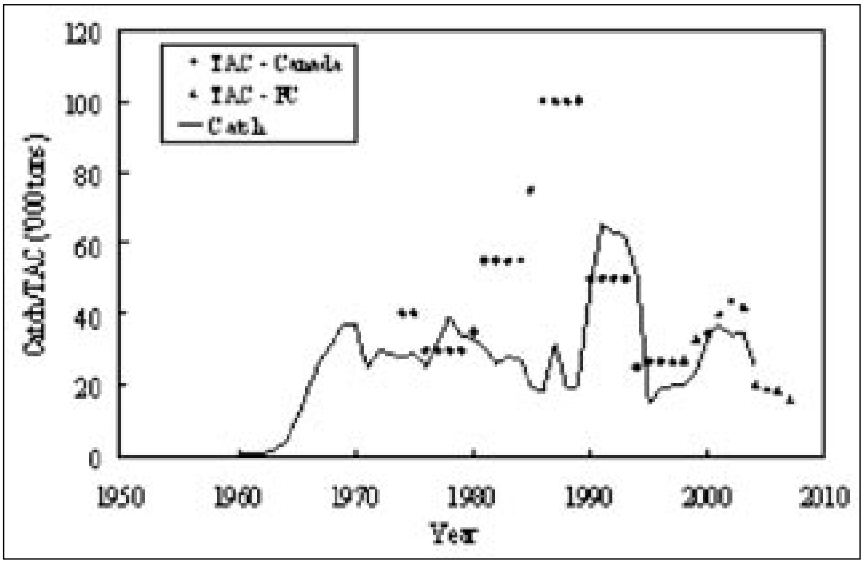

Figure 7. Catch and total allowable catch (TAC) of Greenland halibut in the NAFO Regulatory Area, 1960–2006 (source: NAFO, 2005c). Note that the weight measurement used in this figure is imperial tons, rather than metric tonnes.

Table 1. Catch and total allowable catch (TAC) (recommended and agreed) for Greenland halibut from 2002 to 2005 (source: NAFO, 2005c). STACFIS catch represents an estimate of total fisheries removals while 21A is the total reported catch.

	Catch (**000s tonnes**)		**TAC** (**000s tonnes**)	
Year	STACFIS	21A	Recommended	Agreed
2002	34	29[1]	40	44
2003	32–38.5[2]	27[1]	36	42
2004	25	16[1]	16	20
2005			-	19

[1] Provisional.
[2] STACFIS could not estimate the catch precisely.

The exploitable biomass (age 5+) has been declining in recent years and currently is estimated to be at its lowest observed level. Recruitment subsequent to the 1995 year-class has been below average (NAFO, 2005b). Fishing mortality has increased substantially and is currently estimated as the highest in the time series (NAFO, 2005c). The Scientific Council reiterated its concern that the catches taken from this stock consist mainly of young, immature fish of ages several years less than that at which sexual maturity is achieved (NAFO, 2005c).

The exploitable biomass was reduced to low levels during 1995 to 1997 due to very high fishing mortality. Biomass increased during 1998 to 2000 due to greatly reduced catches, much lower fishing mortality, and improved recruitment. However, increasingly higher catches and fishing mortality since then accompanied by poorer recruitment have caused a subsequent decline. The 2005 estimate of exploitable biomass is the lowest in the series.

Limit reference points could not be determined for this stock. Fmax[4] is computed to be 0.24 and F0.1[5] is 0.14, based on average weights and partial recruitment for the past three years (NAFO, 2005c).

[4] Fmax is the level of fishing mortality (rate of removal by fishing) that produces the greatest yield-per-recruit from the fishery.
[5] F0.1 is the fishing mortality rate at which the increase in yield-per-recruit in weight for an increase in a unit-of-effort is only 10 percent of the yield-per-recruit produced by the first unit of effort on the unexploited stock (i.e., the slope of the yield-per-recruit curve for the F0.1 rate is only one-tenth the slope of the curve at its origin).

Projections were conducted assuming that the catches during 2005 to 2007 do not exceed the rebuilding plan TAC values (19,000 t, 18,500 t, and 16,000 t, respectively for those years). Projection results indicate improvement in the 5+ biomass from the 2005 estimate but suggest a high probability (greater than 85%) that the projected biomass for 2008 will be below the level of 2003, when the Fisheries Commission rebuilding plan was implemented. Projected average fishing mortality indicates a reduction in average F under the rebuilding plan TACs from 2005 to 2007. Projections indicate that average F in 2007 (0.38) will exceed Fmax and that current prospects for stock rebuilding are poor (NAFO, 2005c).

The Scientific Council noted that the 2004 catch of 25,500 tonnes exceeded the 2004 rebuilding TAC by 27 percent. The projected 2008 5+ biomass in the current assessment is 15 percent lower than that predicted in the 2004 assessment. This discrepancy is consistent with the fact that the 2004 catch exceeded the TAC. The Scientific Council noted that if the remaining rebuilding TACs were exceeded, the prospects for rebuilding would be further diminished.

4.2.1.2 Bycatch of 2 + 3KLMNO Greenland halibut

Limited information on 2 + 3KLMNO Greenland halibut bycatch is currently available. The following describes what we know about this stock and the bycatch of other species in the Greenland halibut fishery.

There has been a significant Greenland halibut fishery in the NRA since the mid-1960s. Bycatch of this species in other fisheries is recorded and displayed in the NAFO database 21B, which contains monthly catch and effort information by year, country, gear, tonnage, main species, and divison. Estimates of removals at age of Greenland halibut in the Canadian fishery for northern shrimp in NAFO Subarea 2 and Divisions 3KL during 1996 to 2003 indicate that during this period less than 5 percent of an average year-class was taken as bycatch. This suggests a potential loss in yield to the Greenland halibut fishery of about 900 tonnes to 1,400 tonnes annually, given recent fishing patterns (Bowering and Orr, 2004).

Bycatch is not specifically mentioned in the 15-year rebuilding plan, which calls for the Scientific Council to monitor and review the progress of the program and submit an annual assessment of it to the Fisheries Commission. However, as with all NAFO stocks, TACs that the Scientific Council advises are meant to include all removals (directed and bycatch).

Greenland halibut fisheries catch significant numbers of moratoria species such as cod, American plaice, and witch flounder, many of which appear to be juveniles in Division 3LNO. Portugal, Spain, and Russia list these three species as representing the largest portion of their bycatch, particularly in Division 3LMNO. Total bycatch for this fishery ranges between 12.8 percent and 62.3 percent in some months. American plaice, witch flounder, and redfish are part of the bycatch in some of these months. In addition, Canadian Greenland halibut fishers reported taking cod with gillnets in Divisions 2J3KL, 2GH, 3M, and 3NO, and witch flounder in Divisions 2J3KL and 3NO in the Canadian Greenland halibut otter trawl fisheries. Canada also reported capturing American plaice in otter trawls in Subarea 2 and Division 3KLMNO (34 t of which came from Subarea 2). The stock size of American plaice in Subarea 2 and Division 3K was reported to be just 3 percent to 5 percent of 1980s levels.

Seabirds are caught incidentally in various commercial longline fisheries, including the Greenland halibut fishery. The species of seabird most frequently taken in the North Atlantic is the northern fulmar (*Fulmarus glacialis*) (see the FAO's International Plan of Action for Reducing Incidental Catch of Seabirds in Longline Fisheries: www.fao.org/figis/servlet/static?dom=org&xml=ipoa_seabirds.xml).

4.2.1.3 2 + 3KLMNO Greenland halibut habitat destruction

The main 2 + 3KLMNO Greenland halibut fishing areas are in deep waters (350–1,600 m) off Newfoundland and the Flemish Cap. The vast majority of Greenland halibut are caught using deep-sea bottom trawls; a smaller portion of the catch is made with set gillnets and bottom longlines. Typical bottom-trawl fishing gear can affect the physical structure and complexity of the bottom habitat. The most well known effect of trawling is the destruction of physical bottom habitat, such as rock and shell formations and cold-water coral forests. Preliminary analysis of coral bycatch patterns in Newfoundland and Labrador waters suggests that the Greenland halibut fishery has the highest rate of coral bycatch (Wareham and Edinger, unpublished data). In addition, other organisms, including fishes and invertebrates, typically share the bottom habitat with Greenland halibut, and they can be caught by trawling for this species (Auster et al.,1996).

4.2.1.4 Loss of species diversity and key interactions

Little is known of the trophic interactions of Greenland halibut, although Scott and Scott (1988) state that major prey species include capelin, Atlantic cod, polar cod (*Boreogadus saida*), young Greenland halibut, roundnose grenadier, barracudinas (*Paralepididae* spp.), redfishes, sand lance (*Ammodytes* spp.), crustaceans, especially northern shrimp, and cephalopods (squid). Predation on certain species can also lead to higher bycatch of Greenland halibut. Bowering and Orr (2004) demonstrated that 900 tonnes to 1,400 tonnes of Greenland halibut were lost annually due to bycatch in the northern shrimp fishery. Furthermore, prey species, such as capelin, have declined substantially in abundance; a decrease in their abundance would lead indirectly to increased predation on Greenland halibut juveniles by other fish species, reducing recruitment to the mature stock (Auster et al., 1996). At least one species of seal and two species of arctic whales are known to feed on Greenland halibut and will also be affected by variations in the stock size. While marine mammals have the capacity to alter their diet depending on prey availability, cumulative decreases in stock sizes across multiple fisheries would affect them negatively (Kaschner et al., 2001).

4.2.2 EBFM measures for 2 + 3KLMNO Greenland halibut

NAFO recognizes that the relationships between fish and their environment remain very difficult to quantify and model. STACFEN's role is to analyze the effects of the environment on the managed fish stocks. This does not include the effects of fishing pressure on fish stocks, but rather environmental factors such as nutrient availability, water temperature, salinity, currents, and pollution. Current management, however, does not meet the EBFM standard of maintaining the health of the marine ecosystem and sustainability of catches. To achieve these goals, EBFM incorporates consideration of and precautionary measures for overfishing, bycatch, habitat, and trophic interactions. Despite NAFO's attempt to rebuild this fish stock by setting lower TACs, current management of Greenland halibut is inconsistent with effective single-species management and does not come close to recognizing the additional requirements of EBFM.

4.2.2.1 Measures to address overfishing of 2 + 3KLMNO Greenland halibut

Greenland halibut is currently under a 15-year rebuilding plan that the Fisheries Commission initiated in 2004. The stock is overfished, and the 2004 TAC (20,000 t) was exceeded by 27 percent. Since the rebuilding plan calls for an adjustment of the TAC when that of a past year is exceeded, the TAC for 2005 was reduced to 14,079 tonnes from the planned 19,000 tonnes. No information could be found to suggest that the TACs set in the rebuilding plan accounted for bycatch of Greenland halibut in other fisheries.

The objective of the rebuilding plan is to attain a level of exploitable biomass (age 5+ fish) of 140,000 tonnes on average, allowing a stable yield over the long term. The 2005 5+ biomass is the lowest ever recorded and was estimated to be between 60,000 tonnes and 65,000 tonnes.

The TAC specified in the rebuilding plan was exceeded in 2004. Furthermore, the TACs that the NAFO Scientific Council originally recommended were not adopted, and the Fisheries Commission allocated higher TACs. For the stock to potentially recover to a level that would allow for a sustainable yield, the catches have to remain at or below an ABC recommended by the Scientific Council that specifies maximum removals (directed fishing, bycatch mortality, IUU, etc.). Also, if observer data sharing among Contracting Parties and with NAFO were enforced (currently it is not), the prospect of in-season monitoring, both of catch and bycatch, would be much more feasible.

4.2.2.2 Measures to minimize bycatch of 2 + 3KLMNO Greenland halibut

The NAFO Scientific Council is concerned that the catches taken from this stock consist mainly of young, immature fish of ages several years less than that at which they achieve sexual maturity. Decreasing bycatch and mortality of juvenile Greenland halibut could be achieved through gear modifications (e.g., larger mesh size, bycatch reduction devices, larger hooks, nursery-ground closures, and limited tow times). Bycatch control is a key element in preventing overfishing of Greenland halibut. An ABC (in weight) for Greenland halibut should be established and enforced to prevent overfishing. The ABC could be apportioned between the directed Greenland halibut fishery and fisheries that take Greenland halibut as bycatch. NAFO could manage the ABC for directed catch, for retained bycatch, or a combination. In no case should directed catch, retained bycatch, and discarded bycatch exceed the ABC. Observers should be required to document all catches in a way sufficient to determine or estimate retained and discarded Greenland halibut. If discarding occurs, every effort should be made to return these species to the ocean alive.

4.2.2.3 Measures to protect important habitat for 2 + 3KLMNO Greenland halibut

Habitat effects from Greenland halibut trawl gear should be thoroughly assessed. Bottom trawling can potentially damage deep-water corals and sponges, dramatically altering key habitats. The latter could occur in the form of disturbing juvenile nursery grounds and affecting halibut food sources. Overall, more research is needed to determine the structure of deep-sea Greenland halibut habitat and the exact consequences of trawling over specific areas. Developing a better understanding of the impacts of Greenland halibut fishing on cold-water corals and exploring the importance of corals as habitat for this species should be research priorities. NAFO does not specifically incorporate essential fish habitat in its management measures; essential Greenland halibut habitats (including spawning and nursery areas) should be identified and protected from adverse effects of fishing. This could be done using geographic information system (GIS) technology to map the benthic habitats of the NRA. The Canadian Department of Fisheries and Oceans developed such a map in 2003 to investigate the relationships between Davis Strait bottom sediments and Greenland halibut (Sheridan et al., 2003).

4.2.2.4 Measures to maintain species diversity and key interactions

Predator-prey interactions should be studied closely to determine which fisheries should be a focus of investigation. Bycatch of juvenile Greenland halibut and many other fishes and invertebrates, results from deep-sea trawling. Modified gear, area closures, and limited tow times could result in less degradation to the benthic environment.

4.3 Case Study – 3LN and 3O Redfish

The redfish stocks in Divisions 3LN and 3O are the focus of the third case study. Two species of redfish inhabit Divisions 3LN and 3O, the deep-sea redfish (*Sebastes mentella*) and the Acadian redfish (*Sebastes fasciatus*) (Figure 8). These stocks are considered extremely vulnerable because they consist primarily of juveniles, and the SSB and total biomass have been severely depressed. 3LN and 3O redfish are also of special interest because they are managed separately despite evidence that they may constitute a single stock. Valentin et al. (2005), using genetic and morphometric analyses, did not find evidence of separation for either species between the two areas.

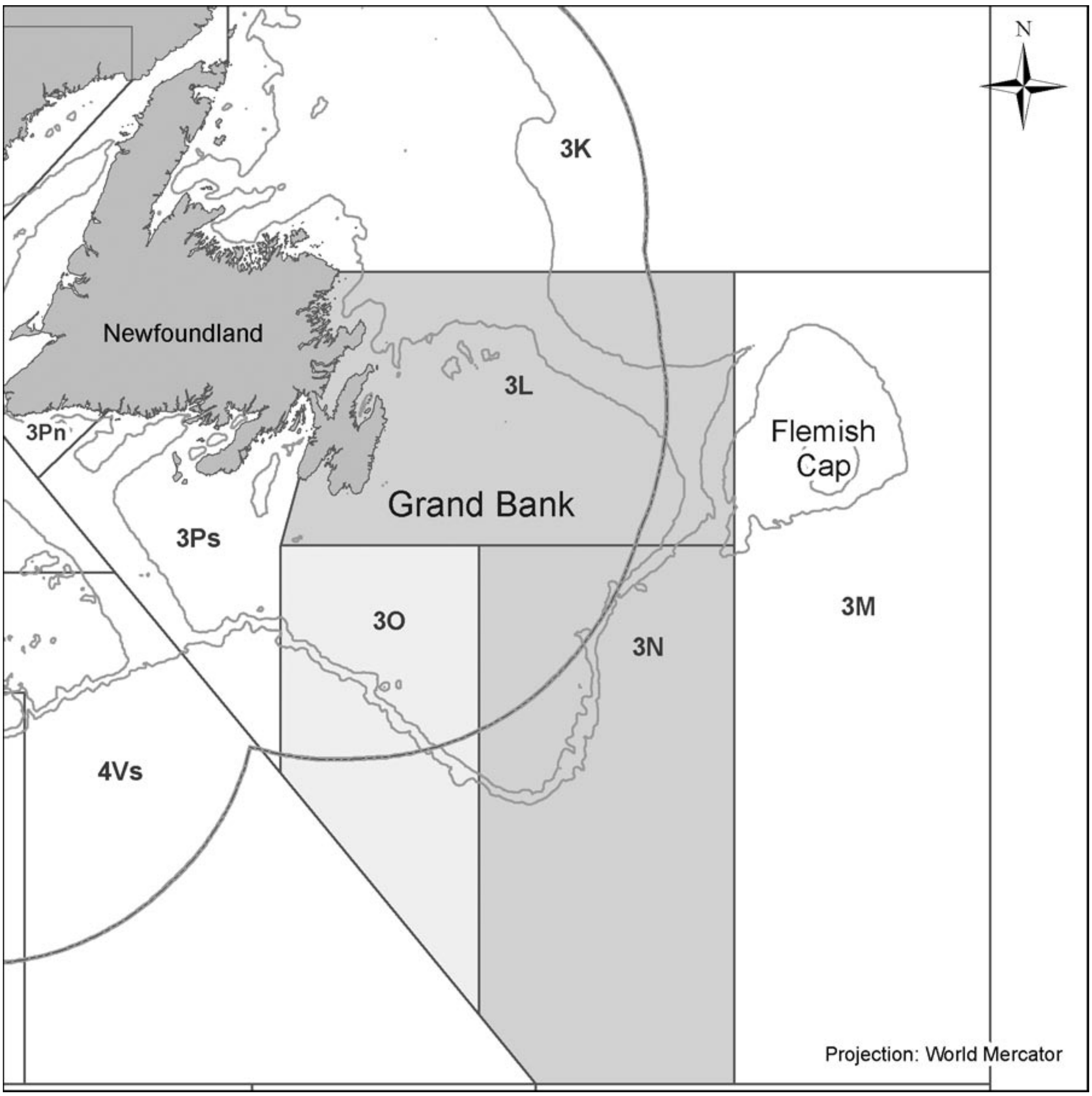

Figure 8. The 3LN and 3O redfish stocks occur adjacent to one another on the Grand Bank (source: WWF-Canada).

Redfish are a slow-growing, long-lived species with a fairly low natural mortality. The maximum recorded age is 58 years. Their most frequent natural predators are cod and white hake (Collette and Klein-MacPhee, 2002). In Division 3O, mass maturation (50%) occurs at age 5, at lengths between 20 and 21 centimetres. Complete maturation occurs between the ages of 9 and 10, and at lengths between 28 and 29 centimetres. According to catch data, the majority of the catch is between 22 and 25 centimetres long, so at least a portion of the catch is immature (Vaskov, 2005). The low natural mortality of these species and the potential for catching juvenile fish make this stock vulnerable to overfishing, especially if errors occur in the stock assessments.

In Division 3LN, the deep-sea redfish, *S. mentella*, is thought to comprise almost 100 percent of the catch (Ávila de Melo et al., 2005). Redfish are demersal fish that inhabit rocky, hard, or muddy grounds at depths to 600 metres; however, the deep-sea redfish is often found in deeper aggregations (below 300 m) than the Acadian redfish (above 400 m). In addition, the redfish habitat has been linked to cold-water corals. Redfish prefer temperatures between 0° Celsius and 13° Celsius (Collette and Klein-MacPhee, 2002). Information about essential fish habitat for this species is sparse. Nothing is known about breeding behaviour or spawning grounds, but copulation probably occurs between February and April for the NAFO stocks, and larval extrusion is estimated to occur in early June. Redfish in the Gulf of St. Lawrence display annual migration patterns as they inhabit deeper waters in the summer and autumn months but move into shallower waters for winter and spring. Juveniles of the species always prefer the shallower depth strata (Collette and Klein-MacPhee, 2002).

4.3.1 Problems with 3LN and 3O redfish

The main goals of EBFM are ecosystem health and sustainable catches. To achieve these goals, EBFM must incorporate precautionary measures that prevent overfishing, reduce excess bycatch, eliminate habitat destruction, and maintain trophic interactions. In addition, effective EBFM requires managing a stock throughout its range. The high probability that 3LN and 3O redfish constitute a single stock, rather than two individual stocks, suggests combining them for management purposes, and concomitant reassessment and re-estimation of how combined biological and ecological information would affect management decisions. NAFO's inability to address a range of problems under these categories has resulted in the dramatic decline of the 3LN and 3O redfish stocks. Although the 3O redfish stock is still open for fishing, evidence suggests that it is being overfished, and the current fishing mortality and stock size are unknown. This case study first outlines the problems that led to the decline and continue to inhibit the recovery of 3LN and 3O redfish. Discussion of a suite of EBFM measures required to restore and effectively manage these stocks follows.

4.3.1.1 Overfishing of 3LN and 3O redfish

3LN redfish

The 3LN redfish stock is managed by NAFO but has been closed since 1998 due to severe overfishing. A TAC of 28,000 tonnes was introduced for 3LN redfish in 1974 but was lowered to 16,000 tonnes within three years. In 1980, the TAC was raised to 25,000 tonnes, where it stayed until 1991 when it was lowered to 14,000 tonnes and then 11,000 tonnes for 1996 and 1997 (Figure 9). Between 1959 and 1974, catches varied from 10,000 tonnes to 45,000 tonnes. The highest historical catches occurred in 1987 at 79,000 tonnes. After 1987, catches declined steadily until the moratorium went into effect. Between 1986 and 1993, the catches consistently exceeded the TAC. However, for the four years before the moratorium went into effect, the industry landed substantially less than the quota amount, an indicator that the stock may have been overfished (Figure 9) (Ávila de Melo et al., 2005; Power, 2003a). Other explanations for not reaching the quota, other than low abundance, may have included low market demand or low market price, rendering fishing for that species no longer economical. There are no set target indicators for stock size, biomass, or fishing mortality. Indices of abundance are evaluated for this purpose, but without other indicators, determining the progress the stock is making toward recovery is difficult.

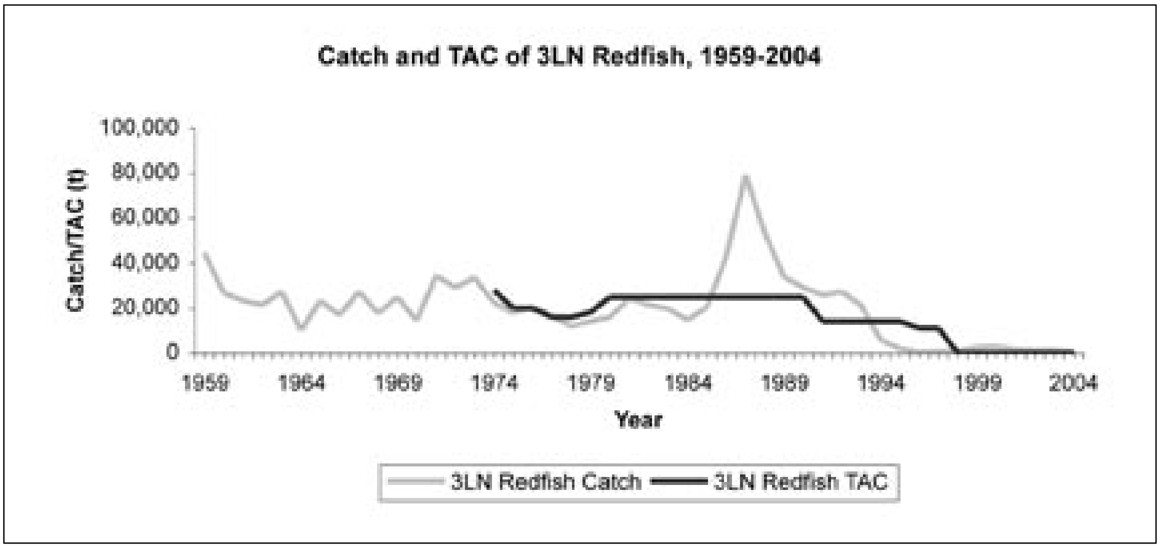

Figure 9. Catch and total allowable catch (TAC) of redfish, in tonnes (t), in NAFO Division 3LN, 1959–2004 (source: STACFIS estimates from Ávila de Melo et al., 2005 and Power, 2003a).

Total stock abundance and biomass of 3LN redfish have increased between 1991 and 2004, but there has been considerable inter-annual variability. To detect changes in the stock that can be masked by the high inter-annual variability of the surveys, biomass and abundance indices were averaged for three periods (Figure 10). Post 1991 abundance data are not comparable to data prior to 1991, as the survey methods were different (Morin et al., 2004).

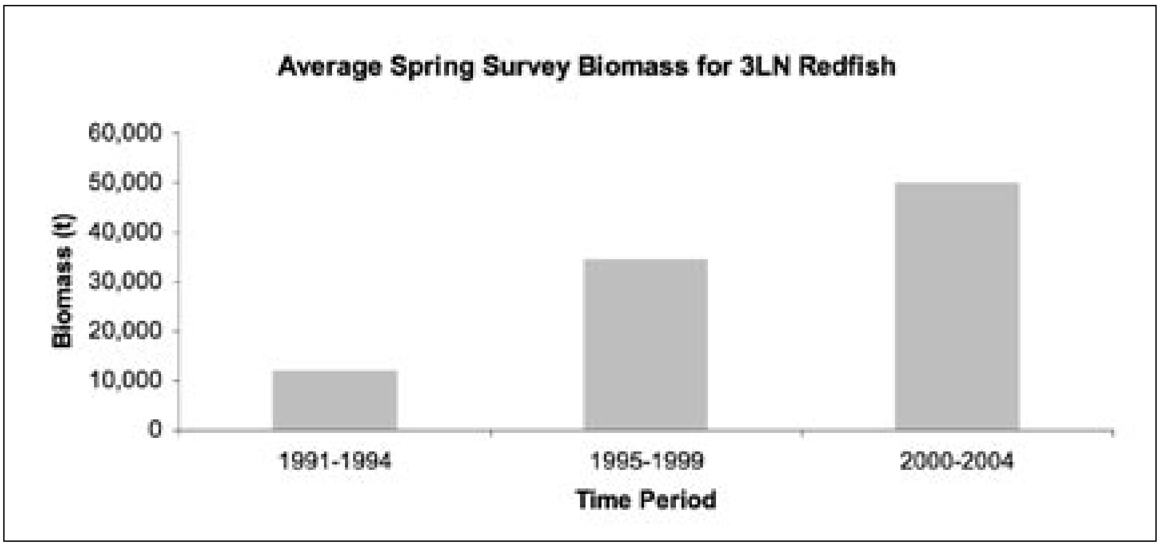

Figure 10. Average spring survey biomass for redfish in NAFO Division 3LN, 1991–2004 (source: Ávila de Melo et al., 2005).

3O redfish

Fishing is currently allowed on the 3O redfish stock. Current fishing mortality and absolute stock size are unknown, which should dictate more cautionary management until they can be determined. The catch data in the assessments have been adjusted upward to account for unreported catches, resulting in substantial uncertainty in actual catch and in the resulting status of the stock.

The 3O redfish fishery in the NRA was unregulated until 2005, when NAFO began assigning a TAC for the entire division. Prior to 2005, Canada set the TACs for this stock. However, the Canadian TAC applied only to the portion of Division 3O that fell within the Canadian EEZ, which is approximately half of the total area of the division, but more than 90 percent of the habitable redfish area (Power, 2000).

Canada first set a TAC of 16,000 tonnes for this stock in 1974, increased it to 20,000 tonnes in 1979, decreased it to 14,000 tonnes in 1988, and then even further to 10,000 tonnes in 1994, where it remained until 2005 when NAFO took over management (Power, 2003b; Power, 2005). Canadian catches never exceeded the TAC but, between 1974 and 2004, the total catch for all Contracting Parties was greater than the TAC in 11 of the 31 years (Figure 11). The fact that significant redfish catches have occurred in the relatively small NRA component of Division 3O suggests that a division-wide TAC should have been set sooner to better regulate fisheries removals. In 2005, when NAFO began assigning 3O redfish TACs, it doubled the TAC set by Canada in 2004, from 10,000 tonnes to 20,000 tonnes. There is no scientific justification for setting the TAC at this level.

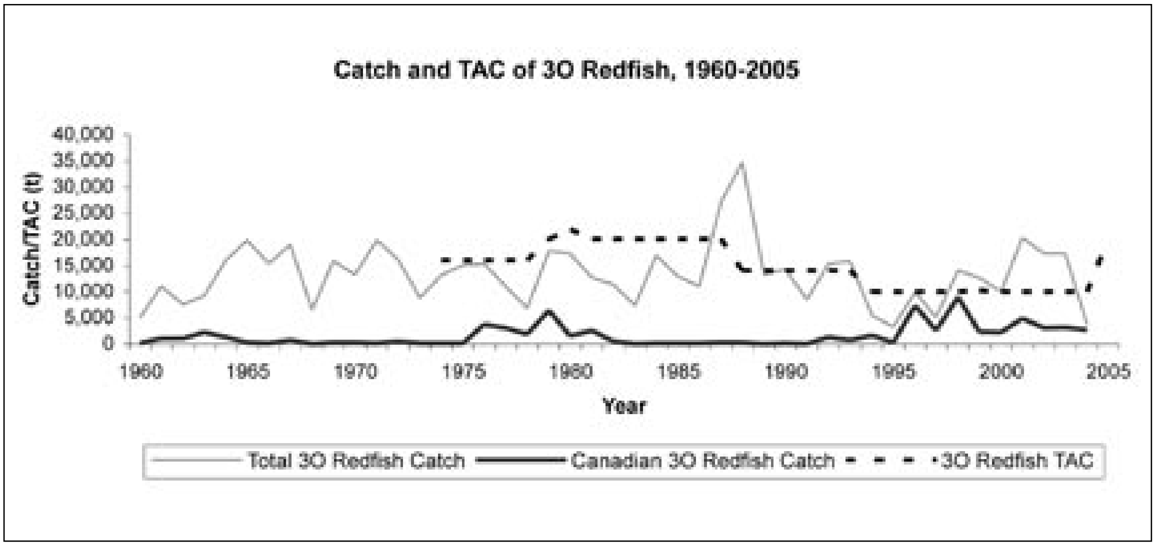

Figure 11. Catch and total allowable catch (TAC) of 3O redfish, in tonnes (t), 1960–2005 (source: Power, 2005). Prior to 2005, Canada set the TACs but they applied only to the portion of the catch inside the Canadian exclusive economic zone.

Total stock biomass for 3O redfish appears lower in recent years (Figure 12); however, data obtained prior to 1991 are not comparable as different survey methods were used. In addition, the size distribution of the catch from the surveys is not similar to the size distribution fishers reported, so the survey data may not actually represent total stock abundance (Morin et al., 2004). This is true of most surveys that use gear designed to capture more than just the commercial sizes of a particular species.

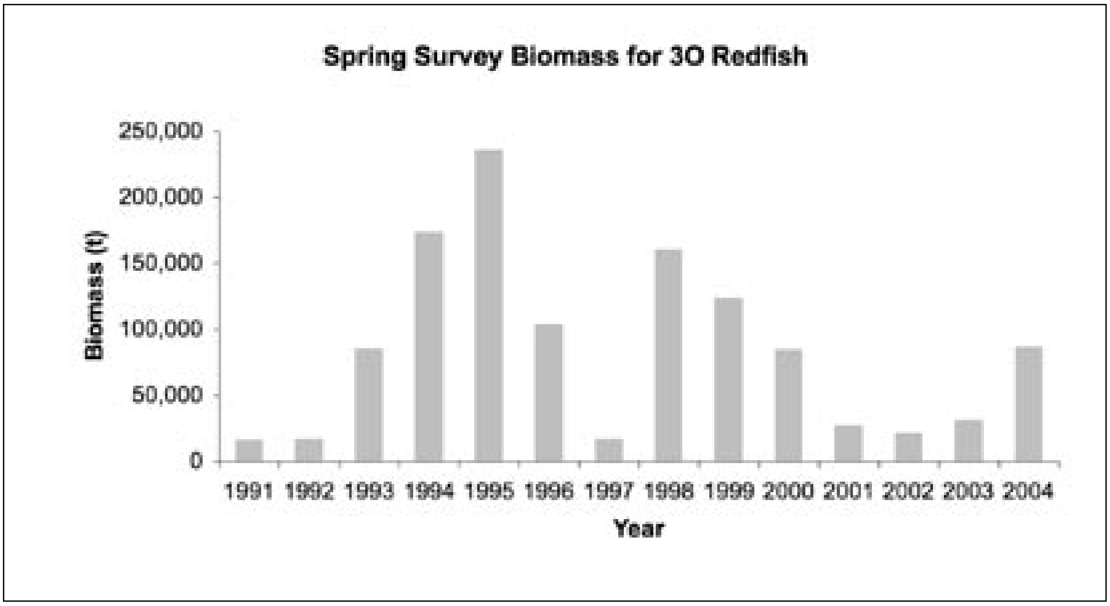

Figure 12. Spring survey biomass for redfish in NAFO Division 3O, 1991–2004 (source: Power, 2005). Surveys prior to spring 1996 used an Engel trawl. Estimates were converted into Campelen trawl equivalents based on comparative fishing trials .

4.3.1.2 Bycatch of 3LN and 3O redfish

3LN redfish

While closing the 3LN redfish fishery was effective in stopping any authorized directed fishing for this stock, there is still enough redfish bycatch in other fisheries to cause concern. Recent bycatch of 3LN redfish is particularly high relative to the low pre-moratorium catches in 1996 and 1997 (451 t and 630 t, respectively). Since the moratorium, estimated bycatch of 3LN redfish has ranged from 900 tonnes to 2,600 tonnes (Figure 13) (Ávila de Melo et al., 2005; NAFO, 2006a). Despite this, fishing mortality attributed to the bycatch is assumed to be low, given the previously noted upward trend in stock biomass. The majority of the bycatch in this division comes from the Greenland halibut and groundfish fisheries by Russia, Spain, Portugal, and Japan (NAFO, 2006a).

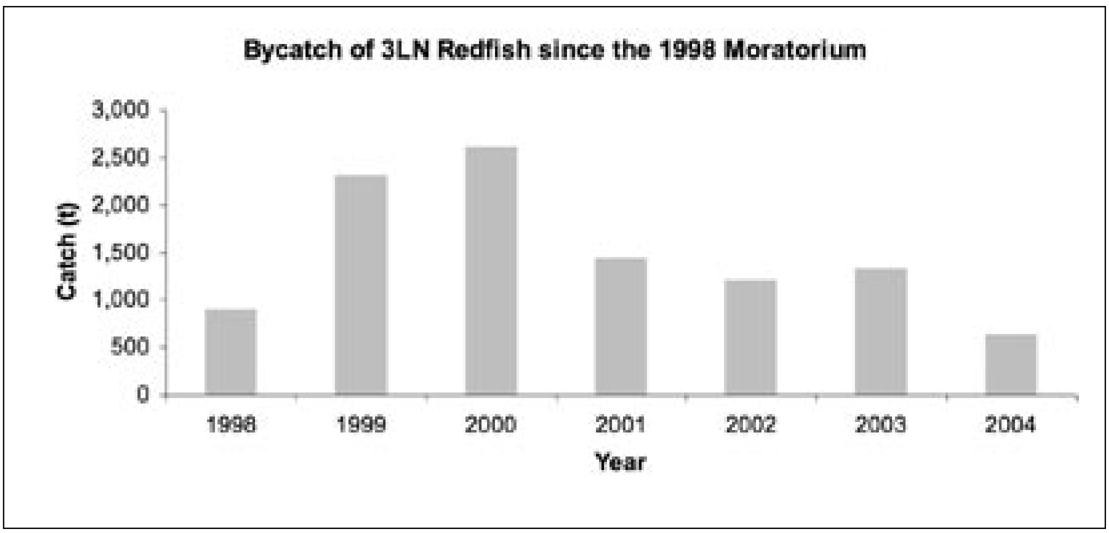

Figure 13. Bycatch of 3LN redfish, in tonnes (t), since the moratorium in 1998 (source: Ávila de Melo et al., 2005).

The existing bycatch provision in the NAFO Conservation and Enforcement Measures states that "in cases where a ban on fishing is in force or an 'Others' quota has been fully utilised, bycatches of the species concerned may not exceed 1,250 kg or 5%, whichever is the greater." The percentages are calculated as the percentage, by weight, for each species of the total catch retained onboard (NAFO, 2006b).

Bycatch of juvenile redfish by the shrimp fisheries is also a concern. According to Orr et al. (2004), low weights of redfish, Atlantic cod, and American plaice were taken in the 2004 Canadian 3L shrimp fishery, but juvenile redfish habitat and areas of highest shrimp concentrations overlap. As a result, the small amount of redfish bycatch is almost entirely composed of juvenile fish, which could have a large impact on the reproductive health of the stock. To counteract this bycatch, the use of a sorting grid to reduce bycatches of fish is mandatory for all shrimp vessels fishing in NAFO Divisions 3L and 3M (Orr et al., 2004). Rosenberg et al. (2005), however, reported that the 2003 bycatch of redfish in the 3M shrimp fishery represented 83 percent of the total redfish catch in numbers, most of which were juveniles.

3O redfish

In the 3O redfish fishery, bycatch of juvenile redfish from the target fishery is the biggest concern. Between 2000 and 2003, the reported catches of redfish were 12,790 tonnes, 22,574 tonnes, 19,452 tonnes, and 21,486 tonnes, respectively for those years, well over the set TAC of 10,000 tonnes (NAFO, 2006a). The amounts over the TAC are technically landed bycatch. By not imposing a minimum size for both fish and meshes, NAFO may actually be promoting the catch of juveniles. Fishers will use smaller meshes if allowed to do so because they are more effective, but smaller mesh sizes also catch a larger proportion of undersized and immature fish that have not yet reproduced.

4.3.1.3 3LN and 3O redfish habitat destruction

There do not appear to be any studies of the effects of redfish fishing gear on habitat in the NRA. This topic deserves assessment in both Divisions 3LN and 3O. Redfish have a close association with the benthic habitat, for both feeding and protection from predators. Because of this, the deep-water bottom-trawl gear that is used to fish for redfish must pass very close to and usually in contact with the bottom. The bottom type that redfish inhabit is rocky, and interaction with cold-water corals is suspected. Severe habitat damage caused by fishing gear could inhibit redfish recovery, and the destruction of habitat could mean a loss of nursery areas. Further investigation would be necessary to determine measures that should be implemented to decrease negative effects on habitat.

4.3.1.4 Loss of species diversity and key interactions

Even though the Division 3LN redfish stock is currently closed to fishing, trophic effects from when fishing was allowed could still be an issue. Fishing for 3O redfish could cause similar trophic effects. As redfish depend on other bottom-dwelling invertebrates and fish species for food, the act of fishing for them will affect the trophic role that redfish play in the ecosystem. As it scrapes along the bottom, trawl gear removes, damages, or kills important prey organisms, such as juvenile fish and invertebrates. This leads to a reduction in species complexity and potentially causes more predation on juvenile redfish, as well as a shift in trophic roles.

4.3.2 EBFM measures for 3LN and 3O redfish

A management plan is clearly needed to first rebuild and then manage the 3LN and 3O redfish stocks sustainably. There does not appear to be a rebuilding plan in effect for the 3LN redfish stock even though the fishery is closed. Stock abundance appears to be increasing over recent years, but information on which to establish reference points with respect to the precautionary approach is insufficient (Ávila de Melo et al., 2005). NAFO appears satisfied that current management measures are adequate to rebuild the stock, as it has not implemented further measures to reduce bycatch.

The 3O redfish stock has not been designated in need of a rebuilding plan, although biomass is decreasing. The fishery has exceeded TACs since 2000 and, in response, TACs have been increased over the past two years (Ávila de Melo et al., 2005). In addition, recruitment has been poor since the 1988 year-class, and catches are composed of immature fish (Power, 2005). There are no stock reference points, and the actual stock abundance is not known and cannot be estimated. Bycatch data are limited. NAFO has not addressed the risk to redfish stocks from status quo management, or proposed management measures to reduce the risk.

If and when the 3LN redfish fishery reopens, it must be managed in a different manner than it was prior to the moratorium to be consistent with the principles of EBFM. As well, some key changes could be made to the management regime for 3O redfish to bring that stock more in line with EBFM. Primarily, the management plan for both stocks must incorporate consideration of and precautionary measures for overfishing, bycatch, habitat, and trophic interactions.

4.3.2.1 Measures to address overfishing of 3LN and 3O redfish

Recovery and management plans should be created to specifically address the redfish stocks in Divisions 3LN and 3O. The first step toward preventing overfishing would be to determine reference levels for fishing mortality and biomass for both stocks, and definite measures of stock abundance and population status. Currently, scientific evidence is insufficient to make these determinations, so efforts should be undertaken to establish them. For both stocks, quota overages must be addressed within each fishing season. An ABC (in weight) of redfish should be determined that would prevent overfishing and allow continued rebuilding as necessary. For 3O redfish, the TACs are already split up among seven different entities, but the largest TAC recipient is the EU, making it difficult to determine individual catches and TAC violations by countries of the EU. Vessel trip limits could be useful as well; they would give a better basis for enforcing overfishing. If observer data sharing among Contracting Parties and NAFO were enforced (currently it is not), the prospect of in-season monitoring, both of catch and bycatch, would be much more feasible.

4.3.2.2 Measures to minimize bycatch of 3LN and 3O redfish

Bycatch control is essential to the recovery of the 3LN redfish stock and will be a key element in preventing overfishing of both stocks once fishing resumes. The main problem with the 3O redfish stock is bycatch of juvenile or immature fish in the directed fishery. To better manage that bycatch, it would be prudent to impose a minimum size limit, a minimum mesh size, or a combination of both. In addition, bycatch of redfish should be monitored and regulated in other fisheries, such as the shrimp trawl fishery, which overlaps with the redfish stock. To aid in the recovery of the 3LN stock, an ABC for the stock could be set. Once the fishery reopens, the catch limit could be apportioned between the directed redfish fishery and fisheries that take redfish as bycatch. This should be done immediately for the 3O stock.

In both stocks, NAFO could manage the ABC for directed catch, for retained bycatch, or a combination. In no case should the total of the directed catch, retained bycatch, and discarded bycatch exceed the ABC. Mechanisms to reduce bycatch so that it does not exceed the ABC may be necessary (e.g., closed areas, gear modifications). If bycatch cannot be reduced to keep total catches below the ABC, prohibiting retention of redfish bycatch (as opposed to the 1,250 kg or 5% regulation currently in effect) may be required to prevent targeting in the guise of bycatch. Observers should continue to be required to document all catches in a way sufficient to determine or estimate retained and discarded redfish. If discarding occurs, every effort should be made to return these species to the ocean alive.

4.3.2.3 Measures to protect important habitat for 3LN and 3O redfish

Habitat effects from redfish trawl gear should be thoroughly assessed. In addition, NAFO's current management does not address the protection of redfish feeding, spawning, and nursery areas. To aid in the creation of such protective management, essential redfish habitat should be identified. These actions would enhance recovery by protecting habitat, reducing bycatch, and minimizing disturbance during sensitive life history stages.

In addition, as redfish habitat is associated with cold-water corals, the potential for damage from trawl gear is great. Severe habitat and trophic damage could halt the progress of an EBFM plan. Overall, more research is needed to determine the structure of deep-sea redfish habitat and the exact consequences of trawling over specific areas. As well, cold-water corals and other important redfish habitats should be identified and protected.

4.3.2.4 Measures to maintain species diversity and key interactions

Redfish recovery and continued health will depend on a healthy ecosystem. As little is known about the trophic structure for the two redfish stocks, predator-prey interactions should be investigated before any trophic effects of fishing for these stocks can be determined. Researchers and observers should monitor these interactions closely to determine which fisheries should be a focus of investigation and rebuilding. Redfish catches should also be monitored to determine the extent of interactions with protected species such as mammals, turtles, and seabirds. If there are a large number of interactions, actions should be taken to reduce them.

5. Recommendations for NAFO Reform

In this section we use the information from sections 2, 3, and 4 to propose a set of management recommendations to move NAFO in the direction of EBFM. We have assessed the recommendations as short-term, those that NAFO could adopt by policy within a year or two, and medium-term, those that would require evaluation and negotiation extending two years or longer. Table 2 provides a summary of recommendations for NAFO reform, incorporating EBFM. Specific recommendations for the case studies are included in section 4.

Table 2. Recommendations for NAFO reform, incorporating ecosystem-based fisheries management

Recommendation Categories	Recommendations	Timing
Regulatory policy recommendations	**Ensure adherence to scientific advice** by allowing deviation from advice only in rare, justifiable situations where the consequences are documented and understood.	Short-term
	Make compliance with NAFO measures mandatory by removing the Objection Procedure from the NAFO Convention and requiring all Contracting Parties, as a condition of membership, to pass domestic legislation that ensures compliance with NAFO management measures.	Medium-term
	Strengthen the monitoring and enforcement program by ensuring compliance with regulations, complete and timely catch reporting, and enhanced scientific at-sea monitoring.	Short-term
Recommendations to prevent or reverse overfishing	**Develop and implement recovery and management plans** for all stocks under NAFO management. Plans must include clear, measurable management goals, objectives, and targets aimed at restoring depleted stocks and ensuring that fishing is sustainable over the long term.	Medium-term
	Apply the precautionary approach when setting TACs to hedge against management and scientific uncertainty and ensure that overexploitation does not occur.	Short-term
	Account for all sources of mortality of target stocks when setting TACs by setting an allowable biological catch (ABC) that accounts for commercial catch, retained and discarded bycatch, and other removals, and set commercial TACs such that total removals do not exceed the ABC.	Short-term
	Bring unregulated fisheries under NAFO management to ensure that these stocks are not overexploited.	Short-term
	Establish small fish protocols for all fisheries taking large numbers of juveniles (e.g., 3O redfish) to help manage the impact on these stocks.	Short-term
	Apply the recommendations of the High Seas Task Force to address IUU fishing.	Medium-term
Recommendations to minimize bycatch	**Establish absolute bycatch limits** to reduce excessive bycatch of moratoria stocks.	Short-term
	Implement gear modifications such as sorting grates to help reduce bycatch in all fisheries.	Short-term
	Provide incentives to reduce bycatch by assigning bycatch allotments to Contracting Parties.	Short-term
Recommendations to identify and protect essential habitat	**Identify and protect essential fish habitat** (e.g., spawning and nursery areas) to aid recovery and help ensure that catches are sustainable over the long term.	Medium-term
	Identify and protect sensitive habitats (e.g., cold-water coral concentrations) from damaging fishing activities.	Medium-term
	Minimize the adverse effects of fishing on habitat by evaluating the impact of fishing on different habitat types and implementing appropriate mitigation measures (e.g., closed areas, gear modifications).	Medium-term
Recommendations to maintain species diversity and key trophic relationships	**Model ecological relationships** to develop a better understanding of the trophic interactions in the NRA and surrounding ecosystem.	Medium-term
	Assess the status of species of concern and any potential impact fishing might have on them.	Medium-term

For practical purposes we have organized the recommendations into two categories: (1) regulatory policy recommendations and (2) recommendations that specifically address the four EBFM objectives:

- Preventing or reversing overfishing
- Minimizing bycatch
- Identifying and protecting essential habitat
- Maintaining species diversity and key trophic relationships

5.1 Regulatory Policy Recommendations

5.1.1 Ensure adherence to scientific advice

The Fisheries Commission should not deviate from scientific advice except rarely, with clear justification and documentation of consequences.

The Fisheries Commission currently receives sound advice on TACs from its Scientific Council. Decisions in support of stronger adherence to the best scientific advice will have major implications for setting TACs at conservative levels. The positive examples for EBFM – the NPFMC in Alaska, and CCAMLR (see section 3) – demonstrate the close attention being paid to the advice that strong and respected scientific bodies provide. The NPFMC, for example, has not set ABCs at higher levels than its scientific advisory body recommended.

In some cases, social and economic factors may require some deviation from scientific advice. In these rare situations, the managing body should provide justification for the deviation, explain the expected impacts on the resource, and determine whether adjustments to harvest levels are required in subsequent years.

NAFO must continue to expand the focus of the advice provided by the Scientific Council beyond TACs to address important research gaps needed to inform EBFM. For instance, identifying essential habitats for commercial fish stocks and developing a better understanding of trophic interactions in the ecosystem should be high research priorities.

5.1.2 Make compliance with NAFO measures mandatory

NAFO measures cannot take the place of national laws, but they must become legally binding on Contracting Parties. To achieve this, NAFO should develop a framework to be respected by all parties, some of which may need to adopt domestic legislation to ensure that NAFO measures are implemented at the national/EU level.

A decision to implement mandatory compliance would demonstrate NAFO's political will to implement EBFM. The most advanced application of EBFM – through the NPFMC in Alaska and CCAMLR in the Southern Ocean (see section 3) – requires mandatory compliance with their respective management measures on a national and RFMO level. A decision to require mandatory compliance may increase the risk that some nations will choose to leave or not join NAFO. Furthermore, comprehensive and effective management measures may become harder to negotiate among Contracting Parties. However, a fully effective regulation that does not have all desirable elements provides more conservation value than a comprehensive regulation that is ignored. Although NAFO may not have the capacity to jump instantly into EBFM, it has the opportunity to recognize the need for mandatory compliance within the time frame of the St. John's Declaration.

Under the NAFO Convention, Contracting Parties can use the Objection Procedure to opt out of management measures they do not support. For example, a Contracting Party that is not satisfied with its quota, as allocated by the Fisheries Commission, can use the Objection Procedure to ignore the allocation and set its own catch limit without penalty. The existence of this clause undermines conservation measures implemented by NAFO. Removing the Objection Procedure from the NAFO Convention would eliminate a legal means of overfishing. NAFO should develop and adopt a dispute-resolution mechanism that allows for the timely resolution of disagreements among Contracting Parties regarding TACs, allocations, and other management measures.

5.1.3 Strengthen the monitoring and enforcement program

NAFO must improve its monitoring and enforcement program by ensuring compliance with regulations, complete and timely catch reporting, and enhanced scientific at-sea monitoring.

Canada expanded aerial surveillance and at-sea patrols in the NRA during 2004, an action that has had a positive impact: fewer vessels fish in the NRA, and international groundfish fleets have curtailed illegal fishing for moratoria species on the shallower waters of the continental shelf and have largely moved into deeper waters. NAFO should establish comparable coverage to further improve compliance in the NRA. NAFO member parties should also conduct follow-up to citations issued at sea to provide consequences for illegal activities.

A complete and timely annual catch reporting must account for all sources of fishery-induced mortality, including landed catch, discarded catch, reliable estimates of IUU catch, and mortality from lost and discarded gear. When known sources of mortality, such as IUU catches, cannot be estimated accurately, a non-zero estimate based on available information (proxies from other fisheries, anecdotal reports) provides for precautionary assessment and may lead to research to obtain actual data. NAFO should establish a due date for all catch reporting that will allow review and incorporation into stock assessment.

NAFO should initiate a comprehensive review of its observer program and other at-sea monitoring. Effective implementation of an at-sea scientific monitoring program requires that managers and users determine in an unambiguous manner (1) what the data are to be used to estimate, (2) at what level of resolution (e.g., time and space) estimates are desired, and (3) what criteria should be used to assess performance of an overall at-sea monitoring program. In most cases, an observer program will form the core monitoring role. Electronic monitoring can supplement or replace on-board observers: closed circuit television enhances compliance, sensors on fishing gear or engines provide information on fishing activity, and vessel monitoring systems provide information on location.

5.2 Recommendations to Prevent or Reverse Overfishing

5.2.1 Develop implement recovery and management plans

NAFO should develop comprehensive recovery and management plans for all stocks for which it is responsible. Plans must include explicit management goals, objectives, and targets aimed at restoring depleted stocks and ensuring that fishing is sustainable over the long term. NAFO should establish a senior-level policy and scientific group to develop recovery and management plans.

NAFO has not developed comprehensive recovery plans for any moratoria stocks. Comprehensive recovery plans must include recovery goals, targets, and timelines, and outline the specific management measures that will be implemented. Limiting total removals to a conservative and scientifically rigorous ABC would allow rebuilding. Uncertainty in determination or control of the ABC requires combinations of catch quotas, closed areas, and effort control; together these measures performed better than the individual measures as uncertainty increased (Stefansson and Rosenberg, 2005). In the context of EBFM, management measures should collectively contribute to the four objectives of preventing overfishing, minimizing bycatch, protecting essential habitat, and maintaining trophic interactions. Similar management plans should be developed for actively fished stocks to ensure that fishing is sustainable over the long term.

The 3NO cod stock is in clear need of a recovery plan because it is severely depressed and showing no signs of recovery despite a 12-year moratorium. The plan should focus on rebuilding SSB. Population and SSB estimates available from 1959 to 2005 allow calculation of baselines for biomass and abundance, and establishment of reference points. The Scientific Council has identified a target for SSB of 60,000 tonnes, while the current SSB is estimated to be only 5,500 tonnes (approximately 9% of the Blim). NAFO should evaluate gear restrictions and closed areas (both spatial and temporal) for use in cod rebuilding. Gear restrictions, such as bycatch reduction device requirements, could aid in limiting the bycatch of cod, and other gear restrictions could reduce damage to essential cod habitat. Area restrictions could be used to protect essential cod habitat such as feeding, spawning, and nursery areas.

5.2.2 Apply the precautionary approach when setting TACs

NAFO must set conservative TACs to account for scientific and management uncertainty. This is especially true for newly managed species for which information on stock abundance and status often is lacking.

Stock assessments may contain insufficient information to provide an accurate representation of stock status. Control and monitoring of fishing activities may not be adequate to ensure that total removals remain within harvest guidelines or that accurate records of removals are available. The impact of fishing on the ecosystem is rarely known in any comprehensive way. Given the resulting uncertainties, precautionary TACs provide a buffer against overfishing at the stock and ecosystem levels. Fisheries for which information is limited, such as those for newly managed stocks, require higher levels of precaution than well-studied stocks.

As an example, little is known about the 3O redfish stock, and it would benefit from more precautionary catch limits. A lack of analytical assessments results in poor information for actual stock size, recruitment patterns, or stock dynamics. NAFO management of 3O redfish established a TAC that approximately doubled the TAC Canada set for its EEZ, even though 90 percent of redfish habitat occurs in the EEZ. The Scientific Council has expressed a concern that poor recruitment has occurred since the 1988 year-class. Mixing may occur between the 3O stock and the overfished 3LN stock. Thus, the harvesting of 3O redfish could be affecting the 3LN stock, which has been under moratorium since 1998. If 3LN and 3O are actually the same stock, then management should be changed to reflect this immediately: TACs should be lowered, and the possibility of closing the 3O fishery should be investigated.

5.2.3 Account for all sources of mortality of target stocks when setting TACs

The Fisheries Commission should set an ABC that accounts for commercial catch, retained and discarded bycatch, and other removals, and set commercial TACs such that total removals do not exceed the ABC. This will help ensure that TACs are not exceeded and commercial stocks are not overfished.

When the Scientific Council provides advice to the Fisheries Commission regarding fisheries removals for a particular stock, it takes into account directed catch, bycatch in other fisheries, and other sources of fishing mortality. The Fisheries Commission sets a TAC and allocates quotas to different Contracting Parties, which then divide their quotas among their respective fleets. It is not clear whether the TACs are meant to include bycatch in other fisheries. If not, bycatch will result in total mortalities that are higher than the TAC. This can be extremely problematic when TACs are already high. Contracting Parties must closely monitor the catches and bycatches of their fleets to ensure that total catches do not exceed the quotas assigned by the Fisheries Commission.

As an example, the Fisheries Commission set the 2004 Greenland halibut TAC at the upper end of the range recommended by the Scientific Council. The TAC was exceeded by 27 percent but we could find no estimates of Greenland halibut bycatch, so could not determine the extent to which bycatch in other fisheries contributed to the TAC being exceeded.

5.2.4 Bring unregulated fisheries under NAFO management

Unregulated fisheries operating in the NRA should be brought under NAFO management to ensure that stocks are not overexploited.

Currently, NAFO does not actively manage several commercially exploited fish stocks in the NRA. Examples include roughhead and roundnose grenadier, both of which are considered severely depleted (Devine et al., 2006). Precautionary TACs and other necessary management actions should be implemented for these and other unregulated fisheries.

5.2.5 Establish small fish protocols for all fisheries taking large numbers of juveniles

The small fish protocol, which requires that a vessel shall immediately move a minimum 5 nautical miles from any position of the previous haul if the amount of undersized fish in any one haul exceeds 10 percent by number, should be expanded to other fisheries.

Application of the small fish protocol to other species, such as redfish and white hake, could reduce or prevent fisheries on juveniles of these stocks. Since the mortality of juveniles may have a much different effect on stock status than adult mortality, an evaluation must distinguish between impacts of adult versus juvenile catches.

5.2.6 Apply the High Seas Task Force recommendations to address IUU fishing

NAFO should apply the measures proposed by the High Seas Task Force to expose and deter IUU fishing and improve enforcement against those responsible for it (HSTF, 2006).

The active involvement of NAFO and its Contracting Parties in the efforts of the High Seas Task Force will help reduce IUU fishing.

5.3 Recommendations to Minimize Bycatch

5.3.1 Establish absolute bycatch limits

NAFO should set appropriate limits for bycatch that, if exceeded, trigger mandatory and enforceable management responses, such as closures of the directed fishery, gear prohibitions, and area closures.

Excessive bycatch of moratoria stocks is inhibiting the recovery of once abundant stocks, such as 3NO cod, leaving the ecosystem in an altered state. NAFO currently tries to minimize bycatch of moratoria stocks using a bycatch limit of 1,250 kilograms or 5 percent of catch for each fishing trip. Evaluation is needed of the effectiveness of this measure, both from the standpoint of the proportion of vessels honouring the limit and whether the limit adequately reduces bycatch. The current approach essentially allows a low level of fishing on depleted stocks and does not put an absolute limit on bycatch removals. Bycatch limits should also be established for actively fished stocks to reduce the chances of exceeding ABCs.

NAFO should establish a senior policy and scientific group to set explicit goals and objectives for bycatch reduction, and evaluate fishery closures, gear prohibitions, and area closures as measures to achieve the goals and objectives.

5.3.2 Implement gear modifications to help reduce bycatch

NAFO should require all fishing vessels to use the most practicable available gear modification technology to reduce bycatch of moratoria species and other species of concern.

NAFO adopted some gear modification measures (e.g., minimum mesh sizes, sorting grates in shrimp fisheries), but continued excessive bycatch in many fisheries suggests that additional measures are needed. The Canadian 3LNO yellowtail flounder fishery has had some success with the use of sorting grates to reduce bycatch of 3NO cod. This and other technologies should be identified and expanded to other fisheries in the NRA.

5.3.3 Provide incentives to reduce bycatch

NAFO should assign bycatch allotments to NAFO Contracting Parties.

During periods of foreign fishing in U.S. waters, the NPFMC set a total allowable bycatch and assigned bycatch allotments – monitored by an effective observer program – to participating nations. Fishing ceased for a nation when it reached its TAC or bycatch allotment, and this approach led to historically low bycatch quantities. The nations often assigned quotas to individual fishers or groups of fishers. Setting an overall bycatch mortality limit less than current levels and assigning bycatch allotments to NAFO member nations could lead to positive internal measures to reduce bycatch.

Individual fishers have an incentive to maximize short-term production, even if methods to do so have longer-term negative impacts on the fishery as a whole. High discards often result because fishers do not take the extra effort to minimize bycatch (e.g., do not move out of high bycatch areas, fail to use or tune gear to minimize bycatch) because to do so would increase their costs and put them at a competitive disadvantage under a system in which fishers race to harvest a quota. Aligning fishers' short-term self-interests with society's longer-term interests would provide fishers with incentives to make extra efforts. Dedicated access programs, in which individual fishers or groups of fishers have specific allocations of TAC for species, have reduced bycatch in other regions (e.g., the NPFMC region management using individual fishing quotas and co-op quotas). Setting a maximum amount of bycatch within an ABC, allocating the bycatch among nations (national bycatch quota), and allocating a national bycatch limit to individual vessels (individual bycatch quota) would provide individual and national incentives to minimize bycatch.

5.4 Recommendations to Identify and Protect Essential Habitat

5.4.1 Identify and protect essential fish habitat

NAFO should take actions to identify and protect essential fish habitat (waters and substrates necessary for fish spawning, feeding, growth to maturity, etc.).

Understanding the relationship between the habitat and life history of fish is crucial to describing habitat essential to fish production. In many cases, insufficient information exists to describe and identify essential fish habitat adequately. In such cases, descriptions should be based on the best available information from proxies or generalizations while research is underway to obtain better knowledge. The lack of complete knowledge of essential fish habitat should not preclude action to protect areas that are known to be important.

NAFO should initiate a research program to identify essential fish habitats, such as spawning, nursery, and feeding areas, in the NRA and assess the effects of fishing on these areas. The research should identify and map habitats throughout the NRA; determine the sensitivity of particular habitats to fishing activity; determine the extent of the fishing activity; and combine sensitivity and extent of the fishing activity into a measure of fishing impacts on the habitats, preferably by geographic location. This will help identify priority areas for protection or other mitigation measures.

At least one important habitat for commercial fish stocks has been identified in the NRA. Walsh et al. (2001) found the Southeast Shoal to be an important nursery area for 3NO cod, 3LNO American plaice, and 3LNO yellowtail flounder. NAFO should assess the importance of the Southeast Shoal to these and other stocks and consider whether protection for at least a portion of the area would aid the recovery of cod and American plaice and help sustain catches of yellowtail flounder. Closed areas have been used to protect essential fish habitat in other jurisdictions (e.g., the NPFMC), but these measures are most effective when accompanied by a reduction in fishing effort and gear restrictions (Stefansson and Rosenberg, 2005).

5.4.2 Identify and protect sensitive habitats

NAFO should identify and protect sensitive and unique habitats in the NRA.

The research program to identify essential fish habitat (see section 5.4.1) should also identify especially sensitive or unique habitats in the NRA to focus conservation priorities on specific areas that play a particularly important role in the life cycles of fish species or perform ecological services. Areas such as concentrations of cold-water gorgonian corals provide habitat for other species but are extremely sensitive to mobile bottom fishing because they can take centuries to form. Cold-water coral concentrations in Canadian, U.S., and European waters have been protected through the establishment of area closures and MPAs. NAFO should immediately protect any significant cold-water coral areas and other comparable environments identified in the NRA.

5.4.3 Minimize the adverse effects of fishing on habitat

NAFO should evaluate and implement measures to minimize adverse effects of fishing on habitat.

NAFO should establish a senior policy and scientific group to set explicit goals and objectives for minimizing the impacts of fishing gear on habitat, and evaluate gear modifications, gear prohibitions, and area closures as measures to achieve the goals and objectives. Combinations of measures may provide more precautionary control than any single measure, as Stefansson and Rosenberg (2005) showed for fishing mortality. Research on the extent and sensitivity of different habitat types (see section 5.4.2) would form the basis for precautionary management with respect to habitat. Within specific areas, (1) configuring bottom trawls without protective gear (chafing gear, roller gear) would encourage fishers to avoid rough bottom that would damage or destroy nets, (2) rotating harvest among subareas would allow habitat to recover, and (3) prohibiting bottom-tending gear would eliminate most impacts.

5.5 Recommendations to Maintain Species Diversity and Key Trophic Relationships

5.5.1 Model ecological relationships

NAFO should establish a special scientific group to review existing models that address ecological relationships and to select and run models appropriate for the NRA and surrounding ecosystem.

Mathematic and conceptual modelling provides a systematic way of evaluating ecosystem effects of fishing with respect to predator-prey relationships, ecosystem energy flow, and various measures of diversity. Based on historical status and trend information for a variety of ecosystem components, the modelling approach can provide advice on possible future trends in the ecosystem under various fishing scenarios. Models may provide guidance on possible aggregate effects of fishing that are not captured under single-species assessments.

5.5.2 Assess the status of species of concern

NAFO should identify and assess species of concern in the NAFO area.

NAFO and many of its Contracting Parties currently participate in national and international forums to assess protected species (e.g., national plans of action for seabirds, International Whaling Commission). NAFO should include all marine mammals, seabirds, and other species of concern in assessment activities (population status and trends, threats from fishing activities, threats from nonfishing activities) to provide a comprehensive data set for use with the models (see section 5.5.1) and to help protect endangered species.

Spotted wolffish (*Anarhichas minor*) and northern wolffish (*Anarhichas denticulatus*) are listed as threatened under Canada's Species at Risk Act. The primary threat to these species is bycatch in groundfish bottom-trawl fisheries, and both species are common in the NRA. The impact of NAFO-regulated fisheries on these species should be explored and appropriate mitigation measures identified.

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Appendix I: Fishery Management in Alaska Accounts for the Ecosystem Context

With respect to ecosystem-based fisheries management (EBFM), a detailed examination of the groundfish management plans of the North Pacific Fishery Management Council (NPFMC) reveals the following operational measures.[6]

Measures Relating to Overfishing

- **Conservative total allowable catches.** As uncertainty levels rise, the NPFMC uses increasingly conservative measures and sets acceptable biological limits at conservative levels. For example, at the beginning of the fishing year, after the total allowable catch (TAC) is determined for each species or group, an unspecified reserve is set aside to correct operational problems in the fisheries, to adjust species TACs according to stock conditions, and for further apportionments.
- **Catch closures.** The regional director may close an area wholly or in part to directed fishing for a species whose remaining TAC is needed as bycatch in other directed fisheries. If directed fishing is prohibited, the species may be retained in amounts less than those that would constitute directed fishing. If a TAC is fully reached, the regional director will publish a notice declaring that species prohibited and stating that it must be discarded. If continued fishing on other species may constitute a threat of overfishing on a species whose TAC is exhausted, the regional director has the authority to stop the other directed fisheries or require gear adjustments.

Measures Relating to Bycatch

- **Conservative bycatch reduction measures.** The NPFMC has adopted measures such that bycatch and discards count toward the TAC and can shut down fisheries that exceed bycatch caps.
- **Bycatch caps.** Limits on the bycatch of so-called prohibited species (crab, herring, halibut, and salmon) have been established to reduce the impacts on these species by traditional fisheries. When bycatch limits are reached, fisheries responsible for the bycatch are closed for the rest of the season or are prohibited from fishing in areas for which bycatch rates are historically high. As a result of this action, the bycatch of prohibited species in the Bering Sea and Aleutian Islands groundfish trawl fisheries declined (in % change) over an eight-year period (1994 to 2002) by 12 percent for Pacific halibut (*Hippoglossus stenolepis*), 61 percent for red king crab (*Paralithodes camtschaticus*), 6 percent for Tanner crab (*Chionoecetes bairdi*), 93 percent for Opilio crab (*Chionoecetes opilio*), 92 percent for herring, 14 percent for chinook salmon (*Oncorhynchus tshawytscha*), and 17 percent for other salmon. In 2003, the bycatch limits of the Bering Sea and Aleutian Island groundfish trawl fisheries included 3,675 tonnes of halibut, 1,526 tonnes of herring, 97,000 red king crab, 3,950,000 Tanner crab, 4,350,000 Opilio crab, 29,000 chinook salmon, and 42,000 other salmon. These bycatch limits equate to less than 1 percent of the halibut, crab, herring, and chum salmon (*Oncorhynchus keta*) populations. Bycatch of chinook salmon is slightly larger, between 1 percent and 2 percent.
- **Area closures.** The NPFMC has closed several areas to trawling to reduce the bycatch of crabs, halibut, chinook salmon, chum salmon, and herring. Changes are being made to the Bering Sea salmon bycatch area closures because they have been unable to control the record levels of salmon bycatch observed in the past three years. Even though the high bycatch can be attributed directly to the massive increase in hatchery fish that Japan and other nations are pumping into the North Pacific, bycatch is still of serious concern.
- **Rationalizing.** Rationalizing means creating some type of dedicated access program (such as cooperatives and individual fishing quotas [IFQs]) that eliminate the "race for fish," thereby allowing fishers to change their behaviour and fish more selectively for fish of marketable species and sizes. The Alaska scallop, Bering Sea pollock and crab, Alaska halibut and sablefish (*Anoplopoma fimbria*) fisheries operate as rational fisheries. The Gulf of Alaska rockfish fisheries will operate as rational fisheries in 2007. The NPFMC is currently working to develop a program to rationalize the remaining fisheries with relatively high bycatch and discard rates (Bering Sea flatfish trawl fisheries), including fisheries targeting rockfish and Atka mackerel (*Pleurogrammus monopterygius*) in the Aleutian Islands.

[6] Appendix I provided by Bettina Saier.

- **Real-time bycatch reporting and associated "hotspot" closures for pollock.** The Bering Sea pollock fishery has implemented its own system of real-time bycatch reporting and associated hotspot closures to address salmon bycatch. For example, cooperatives implement area closures so that salmon bycatch can be minimized. Cooperatives are provided with a "Dirty 20 List" that identifies the vessels with the highest bycatch rates in the fishery. This allows participants in the fishery to effectively manage themselves and provides incentives for individual vessels in the fishery to minimize bycatch.
- **Gear restrictions.** Gear restrictions have been implemented to reduce bycatch. Biodegradable panels are required for pot gear to minimize bycatch associated with so-called ghost fishing of lost gear. Tunnel openings for pot gear are limited in size to reduce incidental catch of halibut and crabs. Gillnets for groundfish have been prohibited to prevent ghost fishing and bycatch of nontarget species. In 1999, the use of bottom-trawl gear was prohibited for vessels targeting pollock in the Bering Sea to reduce crab, halibut, and other nontarget bycatch and benthic disturbance.
- **Discard reduction.** To reduce discards, the NPFMC adopted an improved retention and utilization program for all groundfish target fisheries. Beginning in 1998, 100 percent retention of pollock and Pacific cod (*Gadus macrocephalus*) was required, regardless of how or where it was caught. Only fish not fit for human consumption can be discarded legally. This measure has reduced overall discard of groundfish. In 1997, about 22,100 tonnes (8.6% of the catch) of cod and 94,800 tonnes (8.2% of the catch) of pollock were discarded. In 1998, discards amounted to only 4,300 tonnes (2.2% of the catch) of cod and 16,200 tonnes (1.6% of the catch) of pollock. A regulation requiring full retention of all demersal shelf rockfish species such as yelloweye rockfish (*Sebastes ruberrimus*) was adopted in 1999. Rock sole (*Lepidopsetta bilineata*) and yellowfin sole (*Limanda aspera*) retention was adopted in 2003.
- **Mandatory observer program.** Bycatch is monitored through a comprehensive and mandatory observer program, which requires 100 percent observer coverage on vessels over 49 metres. Observer requirements for smaller vessels are less restrictive. When a bycatch limit is attained, on the basis of fleetwide extrapolation of observer data, all vessels are prohibited from participating in the fishery for the remainder of the season.

Measures Relating to Habitat Destruction

- **Conservation of essential fish habitat.** The NPFMC took significant action to identify and conserve essential fish habitat (EFH) from potential adverse effects of fishing. EFH is defined as those waters and substrates necessary for fish spawning, breeding, feeding, or growth to maturity.
- **Marine protected areas and coral protection.** To address concerns about the impacts of bottom trawling on benthic habitat (particularly on coral communities) in the Aleutian Islands, the NPFMC took action to prohibit all bottom trawling, except in small discrete "open" areas. Over 95 percent of the Aleutian Islands management area will be closed to bottom trawling (277,100 square nautical miles [nm^2]) and about 4 percent (12,423 nm^2) will remain open. Additionally, six areas with especially high density of coral and sponge habitat will be closed to all bottom contact fishing gear (longlines, pots, trawls, etc.). These "coral garden" areas, which total 110 square nautical miles, are thus essentially considered marine reserves. To improve monitoring and enforcement of the Aleutian Island closures, a vessel monitoring system (VMS) will be required for all fishing vessels. In addition, a comprehensive plan for research and monitoring will be developed to improve scientific information about this area, and improve and evaluate effectiveness of these fishery management measures.
- **Protection of crab habitat.** Extensive no-trawl zones were established to protect habitat for crabs and other species.

Measures Relating to the Loss of Species Diversity and Key Interactions

- **Protection of Steller's sea lion (*Eumetopias jubatus*).** To protect endangered sea mammals such as the Steller's sea lion, no trawling is allowed year-round within 10 nautical miles and 20 nautical miles of some sea lion rookeries. Furthermore, the number of seasonal and year-round trawl exclusion zones was expanded for pollock around important sea lion rookeries and haulouts. The rules also implemented measures to disperse pollock fishing effort, both temporally and spatially, and closed the Aleutian Islands to pollock trawling. Further restrictions were placed on the Aleutian Islands fishery for Atka mackerel, an important Steller's sea lion prey species in some areas.

Other Measures

- **Ecosystem status indicators.** On an annual basis, ecosystem status indicators such as climate and oceanographic information, and status and trends for habitats, marine mammals, and seabirds are taken into consideration when making management decisions about setting single-species quotas. This is achieved through an annual Ecosystem Considerations chapter of the Stock Assessment Fishery Evaluation process that so-called plan teams use to set single-species quotas.

- **Ecosystem Committee.** An Ecosystem Committee with the mandate to explore ecosystem approaches to management was established to assist the NPFMC in pursuing such approaches.

- **Recordkeeping and reporting requirements.** Recordkeeping and reporting requirements have been implemented to keep track of fishing effort, landings, processing, and transfers and to ensure timely and effective management of bycatch and individual groundfish stocks. Catch records must be kept for (commercially important) "target species" and so-called other species (those of little economic value).

- **The NPFMC.** The NPFMC has 11 voting members representing state and federal fisheries agencies, industry, fishing communities, and academia. Six are from Alaska, 3 are from Washington, 1 is from Oregon, and 1 is from National Oceanic and Atmospheric Administration Fisheries. The NPFMC's four nonvoting members represent the U.S. Coast Guard, the U.S. Fish and Wildlife Service, the U.S. Department of State, and the Pacific States Marine Fisheries Commission.

- **Advisory Panel Scientific Statistical Committee.** The NPFMC receives advice at each meeting from a 22-member Advisory Panel (representing user groups, environmentalists, recreational fishers, and consumer groups), and from a 12-member Scientific and Statistical Committee (SSC).

- **Scientific review.** The SSC, consisting of biologists, economists, and social scientists from academia and federal and state agencies, meets five times per year. It reviews all analytical documents prepared for each management change. In addition to providing comments to analysts, the SSC makes recommendations to the NPFMC on the adequacy of analytical documents relative to the best available scientific information. The SSC also reviews development of models and other analytical approaches for understanding impacts of fishery measures. Furthermore, the SSC provides recommendations on priority areas for research.

- **Public participation.** Each NPFMC decision is made by recorded vote in a public forum after public comment. Final decisions then go to the Secretary of Commerce for a second review, public comment, and final approval. Decisions must conform with the National Environmental Policy Act, Endangered Species Act, Marine Mammal Protection Act, Regulatory Flexibility Act, and other applicable law, including several executive orders.

- **Observer program.** At the core of the North Pacific monitoring system is a comprehensive on-board observer program, primarily funded by industry (annual cost to the fishing industry is more than $11 million US). Except for small vessels less than 60 feet and halibut vessels, all vessels fishing for groundfish in federal waters are required to carry observers, at their own expense, for at least a portion of their fishing time. The largest vessels, those over 125 feet, are generally required to carry observers 100 percent of the time, and multiple observers are required on catcher/processors and in certain fisheries. Observers collect biological and catch and discard information, which complements the revised recordkeeping and reporting requirements. In order for the industry to afford such a program, the fisheries must be profitable. One of the paradoxes of current fisheries management, including that of the Northwest Atlantic Fisheries Organization, is that, in the past, many fisheries were allowed to expand to the point of unprofitability, thereby dramatically constraining options for improved catch monitoring in the process.

- **Stock rebuilding progress.** The NPFMC has rebuilding plans for the few stocks that are at low biomass levels. Specifically, rebuilding plans are in place for four Bering Sea crab stocks (Tanner crab, snow crab, Pribilof Islands and St. Matthew blue king crab [*Paralithodes platypus*]). In all of these cases, stock size fell below threshold levels not because of overfishing, but because environmental conditions had resulted in sequential years of poor recruitment. The rebuilding plans are very aggressive in that they reduce catch limits or close the fishery entirely until the stock increases to sustainable levels.

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Appendix II: CCAMLR's Fishery Management to Implement EBFM

The ecosystem approach of the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) includes the operational measures described below.[7]

Measures Relating to Overfishing

- **Conservative catch limits for target species.** All regulated fisheries in areas under CCAMLR jurisdiction are subject to precautionary catch limits. The precautionary approach to the management of the krill fishery provides a method by which uncertainty in parameter estimates such as high temporal population fluctuations can be explicitly included in the estimate of harvest rate. The framework is flexible and can accommodate adjustment of management objectives and reformulation of the criteria used to ensure that the objectives are met.

- **Conservative catch limits for new fisheries and new fishing techniques.** New fisheries are often exploited (even overexploited) well before the necessary information to manage them properly is available or even collected. CCAMLR recognizes that fisheries need to be managed from the time they start and has therefore developed conservation measures to be followed before any new fishery commences. There is a requirement at the new fishery stage to collect information on the target, as well as dependent species, and the catch or effort (or both) may be limited. In the second year, both CCAMLR's conservative approach and data collection requirements allow for a full assessment of the fishery and stock(s) to be developed. A data collection plan must be followed and a research and fishery operation plan produced. CCAMLR's Scientific Committee reviews all such plans each year.

- **Catch documentation scheme.** CCAMLR adopted a catch documentation scheme (CDS) for Patagonian toothfish (*Dissostichus eleginoides*) in 2000. The scheme is designed to determine whether toothfish are caught in compliance with conservation measures by tracking landings and trade flows (corroborated by a mandatory vessel monitoring system). Regulated high seas fishing in conformity with CDS protocol includes all necessary documentation pertaining to landings, imports, and transshipment of toothfish. The presumption exists that if documentation is not completed, fishing is illegal, unregulated, and unreported fishing.

Measures Relating to Bycatch

- **Bycatch limits.** CCAMLR's management approach involves linking total allowable catches (TACs) for target species to allowable bycatch. A fishery may thus be closed when it reaches the TAC level for the bycatch of a particular species, even if the TAC for the target species has not been reached.

- **Fishing closures.** CCAMLR has directly prohibited fishing when the risk to bycatch species is thought to be too great, as was the case with the mackerel icefish (*Champsocephalus gunnari*) fishery around the South Orkney Islands. Fishing for this particular species has been confined to the use of midwater trawls only, as the potential for bycatch is lower.

- **Observer program.** Since the fine-mesh nets used in midwater trawling for krill catch fish larvae and juveniles, scientific observers on board krill trawlers collect data on such bycatch. CCAMLR members are now intensifying their collection of information so that CCAMLR can be in a better position to assess more precisely where and when fish are most vulnerable to bycatch by the krill fishery and to identify an appropriate course of action.

- **Seabird bycatch reduction measures.** Longliners fishing for Patagonian toothfish set some 5,000 to 15,000 baited hooks during each set. These act as lures for albatrosses and white-chinned petrels (*Procellaria aequinoctialis*); thousands of birds drown when they are hooked or entangled when trying to take the bait. In 1989, CCAMLR took its first steps to minimize this "incidental mortality." Vessels deploying longlines in the Convention Area now use various methods to reduce this bycatch. For example, longlines are set at night, offal is not thrown overboard during setting, and streamer lines (or "scare" devices) are deployed to minimize potentially damaging interactions between foraging seabirds and longlines. The opening of the toothfish season has also been moved to a time when fewer birds are likely to be in the Convention Area or close to fishing vessels. As one of their designated functions, scientific observers serving on board all members' longline

[7] Appendix II provided by Bettina Saier

vessels in the Convention Area monitor and record any deaths of seabirds during longlining. A notable success has been the observation that setting at night has reduced albatross deaths by about 80 percent over the past three years.

Measures Relating to Habitat Destruction

- **Ban on bottom trawling.** Although the impacts of heavy trawling gear on the fragile and slow-growing communities of the Southern Ocean have not been assessed, CCAMLR has banned bottom trawling for mackerel icefish around South Georgia, as well as for a number of demersal fish that are taken only by bottom trawling.

Measures Relating to the Loss of Species Diversity and Key Interactions

- **Protection of marine mammals and seabirds.** In 1990, CCAMLR's Scientific Committee reported that fishnet fragments and plastic packaging bands were having a negative impact on Antarctic fur seal (*Arctocephalus gazella*) populations on South Georgia. CCAMLR promptly intensified its campaign to promote compliance with the International Convention for the Prevention of Pollution from Ships (MARPOL) and disseminated substantial information on the potential ecological damage likely to be associated with marine debris in the Convention Area. A key facet of this initiative was to improve awareness of the issue among vessel operators. It was also recommended that if fishers had to jettison debris, care should be taken to eliminate plastic waste and to ensure that the potential for any impact by the debris associated with fishing is minimized (e.g., by ensuring that any plastic packaging material capable of forming loops is cut).
- **Protection of key predator-prey interactions.** To meet the requirements of krill predators (both pelagic and land-breeding), CCAMLR also endeavours to monitor the potential effect that krill harvesting may have on species that either eat krill or are eaten by krill predators. Krill catch limits are consequently set to keep krill biomass at a higher level than would be the case for single-species harvesting considerations.
- **Ecosystem monitoring program.** The CCAMLR ecosystem monitoring program monitors selected predators in a few areas.

Other Measures

- **Scientific advice.** CCAMLR must base decisions on the best scientific evidence available.
- **Scientific Committee.** CCAMLR receives advice from its Scientific Committee.
- **Data collection.** CCAMLR collects data on fishery catch and effort. Scientific observers collect data on fish bycatch, incidental mortality of seabirds, and marine mammals. Biological information and biomass estimates are obtained during fishery-independent scientific surveys.
- **Observer system.** CCAMLR has 100 percent observer coverage of all fisheries (with the exception of krill) by independent, regional scientific observers. Data collected are submitted directly to a CCAMLR database.
- **Vessel monitoring system.** Each vessel licensed by CCAMLR members to fish in the Convention Area is required to have a vessel monitoring system (VMS) monitored by a flag state. Parties submit VMS data to CCAMLR as they are collected via the flag state, or on a voluntary basis directly to the CCAMLR Secretariat from the vessels engaged in all toothfish fisheries.
- **Enforcement.** Enforcement of CCAMLR measures is undertaken through a system of observation and inspection adopted in 1998. This is a nationally operated scheme with CCAMLR-designated inspectors. Where members designate inspectors, results of inspection are reported to CCAMLR. As of 2003, port inspection of all toothfish vessels is mandatory.

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WWF's mission is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature, by:

- conserving the world's biological diversity;
- ensuring that the use of renewable natural resources is sustainable; and
- promoting the reduction of pollution and wasteful consumption.

WWF was established in 1961, operates in more than 100 countries and raises some $500 million per year worldwide. WWF-Canada was established as a national office in the WWF network in 1967.

WWF-Canada, like other offices in the network, concentrates on long-term partnerships with governments, businesses and other NGOs, local communities and Aboriginal peoples. This inclusive approach helps us to influence specific policies through targeted legislation, market forces and voluntary commitments.

Working with the rest of the WWF network, WWF-Canada focuses its conservation efforts by identifying solutions to the challenges associated with endangered species, toxic pollution, climate change, oceans and coasts, freshwater and forests.

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